GEOLOGICAL SURVEY OF NEW JERSEY

ANNUAL REPORT

OF THE

STATE GEOLOGIST

FOR THE YEAR

1891

TRENTON NEW JERSEY
THE JOHN L. MURPHY PUBLISHING COMPANY PRINTERS
1892

CONTENTS.

ILLUSTRATIONS.

ERRATA AND ADDENDA.

PAGE 7.—Line 2 from bottom, insert "constituent" after "that."

" 45.—Line 10 from top, last word, read "decreased" for "increased."

" 46.—Line 17 from top, read "scoring" for "scouring."

" 46.—Line 1 from bottom, read "scoring" for "scouring."

" 47.—Line 10 from top, read "from" for "in."

" 50.—Line 7 from bottom, strike out parenthesis marks.

" 59.—Line 19 from bottom, read "decrease" for "increase."

" 68.—Line 10 from bottom, read "valleys" for "valley."

" 75.—Line 8 from top, "where a shallow lake" for "when shallow lakes."

" 77.—Line 8 from bottom, read "subglacially" for "subglacial by."

" 82.—Line 6 from bottom, read "a superglacial origin" for "such an origin."

" 86.—Line 16 from top, insert "many of" before "the peculiar."

" 86.—Line 15 from bottom, read "was" for "is."

" 88.—Line 1 from bottom, at close of last sentence, add "this phenomenon was probably restricted to the marginal part of the ice."

" 97.—Lines 1 and 2 from top, strike out the words "whose banks might retard the flow."

" 97.—Line 5 from bottom, read "current" for "currents."

" 102.—Line 9 from bottom, read "this" for "their."

" 143.—Line 9 from bottom, read "there" for "then."

" 145 *et seq.*—Sudbury water-shed. With the aid of the tables of flow covering years from 1875 to 1890, published in the Twenty-second Annual Report of the State Board of Health of Massachusetts, a much fuller discussion of this water-shed will be made for the complete report.

" 150.—Line 14 from top, for "division" read "diversion."

" 190.—All of the water-power at Boonton is owned by the estate of J. Couper Lord; the names given as owners are those of the lessees.

" 249.—Line 14 from bottom, insert "Franklin Furnace" after "Buckwheat opening."

BOARD OF MANAGERS.

His Excellency LEON ABBETT, Governor and *ex-officio* President of the Board........................Trenton.

I. CONGRESSIONAL DISTRICT.

JOHN CLEMENT..Haddonfield.
CLEMENT H. SINNICKSON..............................Salem.

II. CONGRESSIONAL DISTRICT.

EMMOR ROBERTS..Moorestown.
HENRY S. LITTLE..Trenton.

III. CONGRESSIONAL DISTRICT.

WILLIAM H. HENDRICKSON..............................Middletown.
HENRY AITKEN..Elizabeth.

IV. CONGRESSIONAL DISTRICT.

SELDEN T. SCRANTON*..................................Oxford Furnace.
THOMAS LAWRENCE..Hamburg.

V. CONGRESSIONAL DISTRICT.

AUGUSTUS W. CUTLER..Morristown.
GEORGE RICHARDS..Dover.

VI. CONGRESSIONAL DISTRICT.

WILLIAM M. FORCE†..Newark.
THOMAS T. KINNEY..Newark.

VII. CONGRESSIONAL DISTRICT.

LEBBEUS B. WARD..Jersey City.
SAMUEL B. DOD..Hoboken.

* Died November 20th, 1891. † Died November 23d, 1891.

GEOLOGICAL SURVEY STAFF.

STATE GEOLOGIST.

JOHN C. SMOCK..Trenton.

ASSISTANT-IN-CHARGE OF OFFICE.

IRVING S. UPSON....................................New Brunswick.

GEOLOGIST IN CHARGE OF PLEISTOCENE GEOLOGY.

ROLLIN D. SALISBURY...................................Madison, Wis.

ASSISTANT GEOLOGIST.

C. W. COMAN...Trenton.

CONSULTING ENGINEER AND TOPOGRAPHER.

C. C. VERMEULE..New York City.

To His Excellency Hon. Leon Abbett, Governor of the State of New Jersey and ex-officio President of the Board of Managers of the Geological Survey of New Jersey:

SIR—I beg leave to present herewith the Annual Report of the Geological Survey for the year 1891.

Respectfully submitted,

JOHN C. SMOCK,
State Geologist.

TRENTON, N. J., December 22d, 1891.

REPORT.

The work of the Geological Survey has been carried forward during the year 1891 (1) in the study of the surface or Pleistocene formations of the northern part of the State; (2) in an examination of the oak-land and pine-land belts of the southern part of the State; (3) in the continued study of the stream-flows and the water-sheds, for the report on water-supply and water-power, and (4), in co-operation with the United States Geological Survey, in the study of the crystalline rocks of the Highlands of northern New Jersey.

Some notes on the active iron mines and on the artesian wells have been collected.

STUDY OF THE SURFACE OR PLEISTOCENE FORMATIONS.

The production of a geological map of the State was one of the leading objects of the present Survey, as indicated in the last annual report. Particular stress was put on the need and desirability of a map which should exhibit by appropriate colors or symbols the various surface formations, as distinguished from the underlying rock formations, commonly shown on geological maps, and to the exclusion of the former class. The work of preparing such a map has been begun by the State in conformity to the plan agreed upon with the United States Geological Survey, whereby the latter undertakes the study of the crystalline rocks, and the State is to map the surface formations. According to this plan of co-operation the National Survey has about three-sevenths of the State to map geologically, irrespective of the surface formations. The State work will cover the whole, excepting the comparatively small areas of outcropping older formations which may be exhibited by the maps of the United States Survey. The result of their work will be important and helpful in the study of these newer and overlying surface formations. Some difficulties will be thus eliminated in advance of the State work. Prof. Rollin D. Salisbury, of the United States Geological Survey, has been put in charge of the study of the surface or Pleistocene formations, and of the work of mapping them. His experience in the study of glacial phenomena and wide observations will, no doubt, be of much service in differentiating the various elements entering into the complex nature of the *drift* in New Jersey. He began his work in a reconnoissance across the northern-central part of the State, and in tracing the southward extension of the glacial drift beyond the belt known as the "terminal moraine" of the Survey reports. The existence of a glacial drift south of this line was announced in the first published notice or description of the moraine by the Survey.* In a report on the "Surface Geology," made in 1880, this more scattered southern drift was again referred to, and localities of occurrence were cited.† The designation of "preglacial drift" was given it in accord with a belief that it was older than the terminal moraine. The possible southern line or limit, from the Raritan to the Delaware, along the valleys of Lawrence brook and the Assanpink creek, was also stated in that report.‡ The relation of these deposits and scattered bowlders to the terminal moraine had been left unstudied. Prof. Salisbury's observations corroborate the hypothesis that the glacial drift extends south of the moraine of our maps, and marks an earlier stage in the ice epoch. The subject of glaciers in general, their origin, formation, movement and effects, has been discussed by him in an instructive, interesting and clear way, which is commended to the reader familiar with

*Ann. Rep. of the State Geologist, for 1877, p. 19.
†Ann. Rep. of the State Geologist, for 1880, pp. 81-87.
‡See page 81.

glacial phenomena but ignorant of its origin. Reference is made to the great North American ice-sheet, and to the work it did. The application of these facts of wide, continental range, and of the laws governing the movement of a great ice-sheet, is made to New Jersey, and some details relating thereto are given. The various forms of drift are classified and described with references to localities in the State in illustration of these forms. The action of waters flowing from the ice, in transporting further and in sorting the burden of the glacier, as well as in re-working glacier drift and in modifying older deposits, is stated briefly. It is hoped that this fresh presentation of the subject in its general relations and in this clear and concise way will suggest more observation of the drift deposits, and lead to the discovery of facts as a contribution to science in its study of this phase of the earth's later history.

Of more interest and importance are the further studies, in detail, made by him in the survey of Essex, Union and Middlesex counties. They show the complex constitution of the drift in that part of the State. Its resolution into the elements of ice-deposits, deposits in flowing waters, deposits in the glacial lakelets of the epoch, and those made by the re-working of ice-laid materials, tells an interesting story in the history not so far beyond the coming of man or the historic period. The mapping has necessarily to follow closely the geological classification and show these several kinds of surface materials. A great difficulty is met with in mapping on account of the lack of sections or excavations showing the nature of the material. The whole ground has to be traversed and in some places gone over in review to get correct observations and to reach a proper conclusion as to its real nature or particular class of deposits to which it belongs. The importance of such an accurate map of the surface to the farmer, or to the capitalist seeking farming lands, to the builder in locating where drainage is good and dry, to the landscape artist in search of forms of beauty and lines that may produce the desired effect, to the engineer looking for water-supply and a desirable water-shed whence it may be had, is such as to justify the time and care necessary to produce it. Prof. Salisbury's report as here given shows the amount of work done. It has been thought best to defer the publication of the map until a whole sheet of the atlas has been gone over. Early in the coming field season, the territory of sheet No. 6 will have been thus traversed and that sheet will be ready for printing.

GEOLOGICAL WORK IN THE SOUTHERN PART OF THE STATE.

C. W. Coman, Assistant Geologist, has given nearly all of the year to the work in the southern part of the State. The latter part of 1890 and the first half of the current year were devoted to a reconnoissance survey of Cape May county, preparatory to detailed work and the production of an accurate map of the surface-beds which crop out within the limits of the county, and the adjacent parts of Atlantic and Cumberland, covered by sheet No. 17 of the Topographical Atlas. The narrow range in the variation of the surface beds of clays, sands and gravel, their irregularity in outcrop, and the nearly level nature of the whole surface make it difficult to represent them by any scheme of classification whose division lines are drawn sharply. The absence of good sections showing the succession of the beds, except in the artesian-well borings at Sea Isle City and Cape May City, makes the study of the geological structure more difficult than elsewhere in the State, or where the order of succession can be seen. The outcrops, as noted in their characteristic features, must be compared with the surface-beds in the adjacent parts of the State, and with outcrops whose geological horizon is known. This correlation work is necessary before the geological map of the county can be made. The data accumulated by this reconnoissance is, therefore, withheld from publication until the whole southern part of the State has been traversed, and a scheme of classification made to include these outcrops in Cape May. The question is a geological one, and the delay does not affect the economic results flowing from the publication of such studies. In fact, the map published in the report of the late Dr. Cook on the geology of the county shows on a large scale and in detail the clearings, forests, tide-marshes and sea-beaches.

In view of the necessity for a more detailed study of the geologic structure than the limited field season would permit, the work in Cape May was suspended, and Mr. Coman was transferred to the division of economic geology. He devoted the latter part of the summer and the autumn to an examination of the oak-land and pine-land belts of the southern part of the State, and their agricultural capabilities. A prominent object in this survey was to find the location and approximate areas of uncultivated lands southeast of the greensand-marl belt, which are adapted to agricultural improvement, or, in other words, which can be cleared and farmed with profit. This part of the State has been so long and so generally misrepresented as a region of barren wastes, "pines," "sands," and by other disparaging names, that it is difficult to correct the common opinion as to its agricultural capabilities.*

"The wants of our first settlers required that they should clear and till land that would produce crops at once, and without manure; and such were the only lands cultivated in the early settlement of our State. All lands which did not possess this degree of available fertility were considered to be barren and worthless. A large area in New Jersey, especially in the southeast parts, came under this condemnation, and was held in disrepute until very recently. * * * It is one of the discoveries of modern farming that such lands can profitably be tilled." †

Another reason for the lack of agricultural development has been the comparative inaccessibility of the region, excepting the narrow shore belt. Without railroads and with sand paths as roads, large areas had no rapid means of communication with the outer world. The construction of several lines of railway from the cities to the sea-shore within the last decade, has made nearly all parts of South Jersey easily accessible.

*Ann. Rep. of State Geologist, for the year 1867, p. 11.
†Ann. Rep. of State Geologist, for the year 1871, p. 23.

The large size of the tracts of woodland held for the supply of wood and charcoal to the iron works and glass-houses of the district, retarded clearing and prevented settlements. The decline of the iron works, and the concentration of the glass-manufacturing industry at a few points, have left nearly all of these large tracts valueless except for farming purposes or for the production of firewood for local demands. The increasing danger of fire threatens the destruction of their value as wood-producers.

Attention has been directed to these lands in the annual reports of the Survey, and particularly in that for 1878. In the report for that year a map was given which showed the location and extent of these so-called oak-land and pine-land belts. The results were considered as approximate only, and preliminary to a full and detailed survey. The development since that report was published has been rapid, particularly in Cumberland and Atlantic counties, near the railway lines. The importance of the subject has made it necessary and desirable to publish again notes on this region, which may help on its development, and in advance of the issue of the detailed maps of the surface geology.

The geological map of the State, as now proposed, will show the various tracts of available lands for agriculture as well as forestry, and will give their boundaries in detail corresponding to that of the topographic sheets. The demand for information about our unimproved lands by incoming and by prospective settlers, and the value of such precise data in developing the natural wealth of the State, suggested an advance publication of reliable facts bearing upon the location, extent, character and comparative advantages of these South Jersey lands. The work of Mr. Coman has been to traverse the territory and to examine the soil and note its forest growth and its possible capabilities. The map and report of 1878 have been valuable guides in this survey, and constitute, in part, the basis for his scheme of arrangement and treatment of the subject. As will be noted in his statement, the work shows results which tend to modify greatly those of 1878. A more careful study shows that the area of pine lands or pine barrens is less than it was represented to be at that time. It is difficult, however, to exhibit on a map the extent of these several oak-land and pine-land belts, because they merge into one another by almost imperceptible gradations, and are not well defined, excepting where streams form the boundaries. No attempt has been made to show them on the State map which accompanies this annual report. The detailed descriptions given by Mr. Coman will enable the reader to locate them on this map, and their relation to the political divisions, and the railways and navigable water-ways to them. The map shows the large area of tide-marsh and the swamp lands of the interior, the former of which is not included in the descriptions of the several belts. The names which were used in 1878 have been retained so far as they are applicable and descriptive in location.

The soils of this part of the State may be described as sandy, and the percentage of sand is greater than in the more clayey soils of the central and northern counties of the State. The grains of sand are generally coarse and grade into fine gravel in many cases. Gravelly soils also are common. They consist generally of quartzose pebbles of yellowish and red shades of color, well rounded and from the size of small peas to masses as large as one's fist, with a very few silicified fossiliferous fragments and some chert, and the whole held together by a clayey admixture. A distinguishing mark of the gravelly soils of the region is the clay, in contrast with the more sandy gravels of the northern part of the State. The former are not as porous, and are more retentive soils than the latter. The "clay" soils of South Jersey are more sandy than clay soils generally, and would be classified as "sandy" in a general scheme of classification of soils.

The small amount of vegetable matter in the soils of the pine-land belts, generally, is owing to the frequent forest fires, which have consumed that in the superficial layer and left bare, glistening, white sands only. In the oak-land belts, where leaf-mould has been accumulating undisturbed by fires, the soil contains a larger percentage of organic matter. A recently-made analysis of the white sandy soil typical of the poorer pine lands shows two-tenths of one per cent. of organic matter, whereas the yellow subsoil contained nearly four-tenths of one per cent., or twice as much. Analysis shows also the deficiency in phosphoric acid and in lime as compared with naturally fertile soils. Some have scarcely enough of these constituents necessary for a single crop of wheat. The scanty and stunted growth of timber on the Burlington Plains and on other pine-land belts is evidence of the poverty of the land. There is, however, a wide range in composition between the soils of the oak lands and those of the poorer pine barrens. On the former the growth of wood shows, as well as chemical analyses, the greater capabilities of production. The clearings are further evidence of their adaptation to farming. The soils of the oak lands are not naturally so rich as to be suited to continuous cropping or pasturage without the addition of fertilizers of some kind. They are better adapted to the raising of vegetables, melons, sweet potatoes and small fruits than to cereals and grass, and a lack of attention to this peculiar adaptation has in many cases resulted in failure and brought discredit upon the country. The success at Hammonton, Egg Harbor City, Vineland and other places is noteworthy and suggestive of imitation over wide areas of land now uncultivated.* The ease with which these lands can be cleared and tilled, the nearness to the great cities and the mildness of the climate as compared with the long winter seasons of the New England States, New York and the far Northwest, are other advantages of South Jersey. So much has been published on the soils and the farming of that part of the State that it is unnecessary to do more than add references to these publications.*

The Survey of the past season gives the following summarized statement of oak lands, pine lands and cleared upland:

---

*For notes on soils of South Jersey, see Ann. Rep. of State Geologist, for 1879, p. 113; Ann. Rep. of State Geologist, for 1886, pp. 90–94; First Ann. Rep. State Board of Agriculture, 1884, pp. 23, 24.

1. Oak lands...1,300,309 acres.
2. Pine lands... 486,000 acres.
3. Cleared upland.................................... 438,298 acres.

Assuming that nearly or all of the clearings are in the oak-land belts, there would remain over 800,000 acres in forest which are available for farms. Inasmuch as some of the clearings are in the pine-land belts, it is safe to estimate the available area at 900,000 acres. Should all of the oak lands be put in farms, the forested areas would still amount to 20 per cent. of the total upland. The distribution of these available oak lands and the pine lands in the several counties is shown on page 140 of this report.

"These uncleared lands constitute the largest body of undeveloped wealth in the State, and they offer a most inviting field for those who wish to get cheap farms and homes for themselves, and at the same time retain the advantages which come from proximity to the great business centers of the country."*

The cutting off the timber on the oak lands and putting them all into farms would, however, be disadvantageous to the country, on account of the great stretches which, thus bared of all wind-breaks, would be exposed to the full force of on-sweeping winds, and be more liable to suffer from both drought and cold. For a fruit-raising region, it is highly important that these possible drawbacks be avoided and some belts of wood be retained. The pine-land belts are not so situated as to afford this distribution of their shelter. They will be left to wood-growing largely, and in tracts of large size. Their value is now diminishing, in view of the low price of the wood which they produce, and the insecurity of the standing timber because of the danger from fires. State protection is opposed to our policy and impracticable, hence it is suggested that the best and most efficient way to deal with these pine lands is to encourage their distribution among a greater number of owners, and the opening of farms and clearings, which may serve as barriers to fires, and also enlist the services of more owners interested in the protection of the wood. In

*Ann. Rep. State Geologist, for 1871, pp. 28, 29.

this way it is believed that ravages of great spreading fires can be much lessened and the timber on larger areas reach maturity, or at least an age to make it of more value than the fire-scarred poles which now make so unsightly a view over many miles of South Jersey. Besides, the increased farm population on the cleared oak lands would make a large force of natural protectors, where now both oak and pine lands are swept over by fire with few to offer successful resistance to it. In this way it is believed that the products of the 400,000 or more acres of pine lands may be made to amount to as much as is now obtained from the whole timbered area. The enhanced value which must attach to the pine lands, thus protected, warrants the cost of clearing the oak lands as an economic measure, and a part also of a prudent forestry management. It is to this end that Mr. Coman's survey has been directed as initiatory and specific.

WATER-SUPPLY AND WATER-POWER.

WATER-SUPPLY.—The sources of available supply of wholesome water for domestic consumption have been referred to in the "Geology of New Jersey," published in 1868, and in several of the annual reports since published. The importance of the subject has been proven by the widespread demand for these reports, and for information relative to the location of these sources of supply. The rapid growth of population in the cities of the State also shows the importance of accurate knowledge of the districts and streams which can yield a supply of good water adequate to their needs. The supply from deep-bored or artesian wells is a subject of inquiry in some places, and the data then sought have reference to the possible existence of subterranean reservoirs or water-bearing horizons and their depth below the surface of the ground. These inquiries come from cities and towns seeking a public supply, and from individuals and manufacturing establishments interested in getting either more water or better quality than that of the common dug well or that of cisterns storing rain-water. The improved sanitary arrangements of houses both in country and in city cause a demand for an increasing supply of wholesome water.

It has been one of the leading objects of the Geological Survey to contribute that kind of information which may be helpful to the people of the State in the development of its natural resources in water. A short reference to some of its work in this direction is here given to show what has been done and the relation of the data put in print to the present needs of our population. One of the earliest references to water-supply is in the "Geology of New Jersey," published in 1868, in the chapter on "Water,"* in which the chemical analyses were given, showing the composition of well-waters in old-settled parts of cities, of waters from the Delaware, Passaic and Raritan rivers, and from artesian wells. The results of these examinations at that time were such as to show that the comparison between these well-waters and "the pure waters from streams is the best argument that can be made for the superior wholesomeness of the latter."

The subject was introduced in the annual report of the State Geologist for 1874, with the following sentence: "Another of our natural products that is coming to be of great value, is pure and wholesome water."† In that report the areas of the several drainage basins in the Passaic water-shed were given, and their capacity for storage and supply. The Delaware river and the streams of the southern part of the State were also referred to in their relation to the needs of cities near them. In the annual report for 1875 the subject was again discussed, with references to analyses of polluted waters, and the possible dangers in the use of waters of doubtful purity. The question of a supply for "Newark, Jersey City and the other towns and villages in the thickly-settled part of the State near New York City" was again discussed, and the necessity for another source than the Passaic was pointed out as urgent.‡ The subject was studied in greater detail in 1876, at the

* Geology of New Jersey, Newark, 1868, pp. 701–708.

† Ann. Rep. of the State Geologist, for 1874, p. 60.

‡ Ann. Rep. of the State Geologist, for 1875, p. 31.

request of a committee of the Mayors of Newark, Jersey City, Hoboken, Bayonne, Orange, Bloomfield and Montclair, preferred by the Governor as President of the Board of Managers of the Geological Survey. Following this direction, Geo. W. Howell, of Morristown, was employed by the State Geologist to make a survey of the lakes and natural reservoirs of the Highlands. Full statistics of the drainage areas and of the storage reservoir sites and analyses of the Passaic waters were given in the report for that year.* Plans for supplying the several cities were indicated in broad outline. A map of the Passaic river system accompanied that report. The frequent references to it, the copious extracts from it, and the demands for it show its value and the interest in the subject of water-supply. The importance of a new supply for Newark and Jersey City was set forth briefly in the annual report for 1878, and that of the Upper Passaic was shown to be adequate to the needs of a large population.† The report for 1881 had a short section devoted to the subject.‡ In 1882 the topographic survey of the State had progressed so far as to afford precise information about the limits, slopes, character and areas of the several drainage basins of the northern part of the State, and it was published in the report for that year, supplemented by a reprint of descriptive notes on the lakes and natural reservoirs contained in the report for 1876.§ Statistics of rainfall, of drainage-basin areas, analyses of Passaic waters, and plans for supplying the larger cities and towns were given. In 1887 it was stated that "The topographic maps, 4 and 7, of the Passaic water-shed, with its area and elevation, contain the information which is sought by those inquiring into the particulars desired in a plan for a water-supply for these cities, and a study of them will show the numerous and well-adapted localities which are available for the storage and supply of water."¶ In the last annual report

* Ann. Rep. of the State Geologist, for 1876, pp. 13-50.

† Ann. Rep. of the State Geologist, for 1880, pp. 93-97.

‡ Ann. Rep. of the State Geologist, for 1881, pp. 73, 74.

§ Ann. Rep., 1882, pp. 96-132.

¶ Ann. Rep., 1887, p. 25.

made by the late Dr. Cook, are these words: "At Little Falls all this water is in one stream, at an elevation of 158 feet above mean tide. * * * * By going a few miles further up the stream most of the water could be collected at an elevation of 250 feet, or high enough to supply all of these cities by gravity. The quality of this water is unquestionable in purity. It is mostly gathered from a country which is mountainous, mostly in forest and likely to remain so for a long time to come. As a substitute for the filthy water supplied to almost half of the people of the State it is of incalculable value, and there should be no delay in securing its health-giving benefits."* A clear presentation of the whole case and a strong argument, and representing the result of years of patient and painstaking labor summed up almost in a single sentence. These references to the Geological Survey reports show what has been done by the State in giving information of value upon this question of water-supply. Under the wise and far-sighted direction of Dr. Cook the subject was kept prominently before the people.

It would seem as if the State had done nearly all that was necessary, so far as surveys of the territory capable of furnishing a public water-supply were concerned. The study of the surface formations in the northern part of the State, which has been begun recently, promises to give a more nearly correct knowledge of the nature of the surface and of its forested covering, and its cleared areas—and hence a more detailed survey with geological maps, showing the surface deposits and their relations to the several streams which flow from them. At this point the problem of water-supply to the several cities is so related to engineering, business management and inter-city and municipal control, that the Geological Survey of the State finds here a proper limit to its investigations. It continues, however, to be one of great public interest and importance, affecting as it does about half of the population of the State. And the question of an abundant supply of wholesome water in place of

* Ann. Rep. of the State Geologist, for 1889, p. 72.

what is now unsatisfactory in quality, is one of sanitary importance. In view of what has been referred to, as bearing on this subject, it may be stated here that little more can be done than to emphasize the arguments of these reports and show the increasing urgency of attention to it, because of the rapid increase in our population and the prospective cities which are destined to occupy the northeastern part of the State. The Upper Passaic valley with its several streams is the natural source whence these cities and towns are to be supplied with good water. The geologic structure and the geographic positions indicate it. The red sandstone plain through which the lower Passaic flows, from Paterson to the sea, is so situated that it is to be covered by towns and cities and by market-gardens, which cluster around centers of dense populations. Once an agricultural district, it has lost much of its older character, and is to-day in process of transformation, and new towns are springing up between the rapidly-approaching lines of the older cities. Jersey City, Newark, Paterson and Elizabeth will be so close within a decade that the railway traveler may not recognize their confines as he whirls across that part of the State. Bordering this plain on the northwest there is an upland valley, almost completely shut in by ranges of hills, in which are many beautiful sites for suburban homes and for quiet villages, attractive to the smaller class of people, who may live further from the toil of the city. Pompton, Little Falls, Montville, Hanover, Caldwell, Chatham, Madison and Morristown are in this valley. The density of population which it is highly probable will mark this upper valley of the *Middle Passaic* within a few years is opposed to it as good gathering-ground for a city water-supply, and it is excluded from consideration on this account. The extensive tracts of wet meadows (which will no doubt be reclaimed as rich agricultural, and particularly as pasturage lands) are an undesirable feature in collecting water from it. Flanking this valley on the north and west are the Highlands, a hill country, which rises from 400 to 800 feet above it. A land of wooded hills, studded here and there with natural ponds and beautiful lakes, it is the ideal territory on which to collect and store water for city use. Some of its advantages may be stated. 1. Its geological structure is such that there are many springs flowing out along the hillsides and in its valleys which are of excellent water, and some of them are noted for their tonic effects. The granitic, gneissic and quartzose rocks, which make up the structure of the Highlands, afford better water than is obtainable from rock formations of adjacent territory and of later geological age. The purity of waters of granitic rock districts is almost a proverbial truth. 2. The large part of this Highlands district which is in forest is remarkable in a country so old settled and so near New York. Sixty-seven per cent. of the area of the Passaic valley above Paterson is in forest. For its tributaries, the following are the respective figures of percentages: *

Pompton river	69	per cent. in forest.
Ramapo river	72	" " " "
Wanaque river	83	" " " "
Pequannock river	78	" " " "
Rockaway river	80	" " " "
Whippany river	36	" " " "
Passaic (above Chatham)	23	" " " "

Similar figures obtain for the water-sheds of other streams on the Highlands west and south of the Passaic system. This forest area offers little chance for pollution from agricultural operations or from dense population. It is not at all likely that the rainfall on this hill country will be affected injuriously, as is possible on one which is deforested. In fact, the amount of precipitation thereon is slightly greater than on one bare of forest. The conformations of the country with their wooded surfaces are conditions favorable to the increase of precipitated moisture. No doubt the rainfall is more uniformly distributed through the several calendar months and the seasons than it is in the red sandstone plain to the

* Topography of New Jersey, Final Report, Vol. I., pp. 190, 191.

southeast, or, in other words, the droughts are less severe. The statistics, so far as obtainable, seem to show that this favorable condition exists. The hilly surface conduces to a more rapid loss by surface drainage and to floods in its streams, but this drainage is in part counteracted by the wooded condition of the surface. The well-known absorptive tendency of forest mould, which holds back the flow, as a sponge, is here largely active. The forests also tend to prevent loss by evaporation from the surface, and the concentration of saline matters characteristic of surface-waters in times of drought in a cleared country and on bare ground. The action of the forests is therefore favorable to the quality as well as conducive to quantity of steady flow. 3. The nature of the surface is such as to be almost prohibitory of agricultural development. The extent in forest and the comparatively small percentage of the total area in farms or under cultivation, is explained by the numerous rock outcrops and the stony soil, where the ledges do not appear on the surface. There is no other equal area in our Eastern States comparable with it excepting those on the same range in New York and Pennsylvania and New England. The Bearfort and Green Pond and Copperas mountains are as rough and rocky as the Sierra Nevada or the Rocky mountains of our Western States. Their cultivation in farms would seem to be an impossibility. Even for timber they are almost forbidding because of difficulties of access. The gneissic rock areas are less rocky in general, but the mantle of glacial drift, which covers a large part of the gneissic strata, is almost as forbidding to prospective cultivation as the rock outcrops or solid ledges. The small fields with their wide stone rows for fencing show the abundance of stone picked off the surface, and closer inspection shows that in many cases the soil is still filled with stone. This abundance of cobbles and bowlders makes tillage difficult, expensive and undesirable, and, as a result, the farms are being devoted more to pasturage than they were formerly. A part of the territory is reverting to the forested condition. The ease of tilling lands elsewhere draws away the farmers from the toilsome labor of farming such stony soils. The profits from the rapid growth of some kinds of wood, notably the chestnut, on these stony hills, also operates against their devotion to farming and to their clearing. This unsuitability to agriculture makes the territory more desirable as a source whence to draw a public water-supply. 4. A remarkable advantage in these Highlands is in the number of streams and in their geographic position. The geologic conformation which has determined their lines of drainage and their water-sheds, is such that there are five principal or leading basins emptying into the Passaic as they come out of the Highlands and debouch on the Red Sandstone or the Upper Valley, as here termed. The comparatively small size of these streams is unfavorable to the concentration of large city populations about any mill-sites on them. The growth of the town is offset by the decrease in the rural districts. 5. The small population on the Highlands conduces to the excellence of the water and minimizes the dangers arising from possible pollution through man's agency. According to the census of 1890 there are 75,000 inhabitants on the Passaic water-shed, above Paterson, or about 3,000 increase in fifteen years, but the greater part of the increase has been in the towns of the Middle Passaic and not in the Highlands.*

There are some indirect advantages in making that part of the State a gathering-ground whence to draw an abundant supply of water which may be presented at this time. The preservation of the forests, particularly on the steep mountain sides, and the enlargement of the area in growing wood, might be of much value as a factor in climate. Opportunities and desirable locations would be given for the beginning of successful experiments in forestry, which might serve as valuable examples to foresters and to land-owners of the whole State. The judicious management of these protected woodlands would yield a larger return in the form of forestry products than that which is now

* Croes & Howell; Report on Additional Water-Supply of Newark, 1869, pp. 15–17.

obtained from these tracts of wood or from the farms on these stony soils. The natural beauties of the Highlands offer advantages in the location of natural parks and game preserves, which are deserving of the attention of the crowded dwellers in the suburban districts and in the great metropolis across the Hudson. The success of Tuxedo Park, in the adjacent part of the Highlands, in New York, is suggestive in this relation. There is room for a group of such parks, easily accessible by railway lines from the cities and yet so situated as to inclose secluded glens and bits of scenery as wild and as unimproved as any country in our middle Eastern States. Greenwood lake, Lake Hopatcong, Budd's lake, Green pond, Splitrock pond, Macopin pond and Wawayanda lake are among the larger and more widely-known sheets of water in this region. There are many smaller natural lakes and lakelets which are set in picturesque landscapes and attractive to the lover of scenery.

City and country may in this way become mutually helpful, although the characteristic development of each one may be more intense, and in lines peculiarly its own.

WATER-POWER.—The increasing scarcity of wood along the lines of transportation, the cost of coal, and the urgent need of attention to greater economy in some kinds of manufacturing work, are producing a notable tendency toward a more general and more efficient use of the power which is to be had in the many streams of the State. The more thorough utilization of the water-power heretofore allowed to run idly away, or left in large part unused, is an important element in the development of the resources of the State. A view of the relief map shows that the streams of the Highlands fall rapidly and afford many sites for power. The streams flowing out of the Highlands and across the northern-central, or *piedmont* division of the State, gather in volume as they cross the latter, and on them there are notable water-powers, as at Paterson, Dundee and other points. In the southern or coastal-plain division of the State there are many streams, some of which as the Mullica, Great Egg Harbor, Maurice, Cohansey and Rancocas rivers, are large in volume, but generally the descent of the streams in this part of the State is so slight that there are fewer mill-sites than in the northern part of the State. Their more equable flow is compensatory to some extent, affording a more steady power throughout the whole year than that in the hill-country streams. This equable flow has been discussed fully in the report of Mr. Vermeule. The Delaware river, on our western border, is an inter-state river, and flows out of the Highlands across the *piedmont* and coastal-plain belts to the sea. It furnishes power at a few sites in the State, but the aggregate thus utilized is a small part of what could be had at any one of several sites, if the whole stream were put at work. An extract from the first annual report of the late Dr. Cook is here pertinent. After referring to the advantages for location of manufacturing towns in New Jersey, he says: "Take the Delaware river as a source of power for driving machinery. Its volume of water is immense even in the driest weather—greater by far than the Merrimac at Lowell. Its fall from Port Jervis to Trenton is not less than four hundred feet. * * * The power which is here lying idle would, if improved, be sufficient to drive the machinery of a Lowell every ten miles, would furnish profitable investment for millions of capital, and create a large and constant home market for our farm * and market-garden products." After the lapse of 28 years, this note on the Delaware river has lost none of its force; although it may be said that there are other interests which affect the case and retard development, and difficulties arising from inter-state relations which are in the way.

The use of water-power in the State has declined apparently within the last half century, because of the change in the location of the iron-making industry. The forges and furnaces which were located on nearly all of the streams have disappeared, and in some places they have not been replaced by other industries, but remain as abandoned mill-sites.

---

*Annual Report of Prof. Geo. H. Cook, State Geologist, for the year 1864, Trenton, 1865, p. 20.

The importance of accurate information on this subject, and the need of it, is evident from the numerous inquiries which are made concerning sites, capacity and availability of water-power. On account of its practical importance, the subject of water-supply and water-power has been made a separate study, and it has been decided to give the results of this work in one volume of the series known as the Final Report of the State Geologist. The necessary surveys and studies and the preparation of the volume have been in charge of C. C. Vermeule. They were begun in 1890. The census of the water-powers in the northern part of the State, and the data obtained from the measurement of stream-flows, with a discussion of the relation of these flows to the amount and distribution of the rainfall, evaporation, ground storage, floods and droughts, and storage in surface reservoirs, were given in the annual report of the State Geologist for that year. The work has been carried forward throughout the year. The canvass of mill-sites where water-power is used, has been completed.

The data obtained from the period of observation on the flow of streams and its relation to rainfall is discussed in this report. The marked difference between the streams of the northern and southern parts of the State is worthy of attention, and has a practical bearing upon the important subjects of water-supply and water-power. The two-year period of observation, which will be available for use in the spring of 1892 for the final report, approximates closely to the normal or standard which is had from a longer observing period. Climatic, geologic and topographic features enter into the discussion of the problem of flow, and the peculiarities of the streams in these measures reflect the influences of these features of their water-sheds. The loss by greater evaporation in the winter months in the case of the streams in the southern part of the State, the heavier spring flows of those of the northern and mountainous districts, and the more equable flow of the former for the year, are noteworthy facts shown in the discussion of these records in Mr. Vermeule's report.

The canvass of water-power has been completed, and the sites of power thus utilized and those undeveloped are given in this report. The power by industries, the increase of utilized power, its value and importance to the development of the natural resources of the State, are topics there discussed. The aggregate value of the water-powers and their improvements is put at $20,000,000. The further statement that in the southern part of the State there is an aggregate of 6,000 horse-power unused in stream falls, is full of suggestive hints to capitalists and workers in search of this kind of material help. The importance of development at all of these unused sites to the symmetrical growth of population, and favorable to better social conditions of the workers, is worthy of the attention of all of our people. The highest degree of utilization of the water-power is an economy in our stores of fuel as well as a saving of power now running away and lost. The accessible lines of railway near or parallel to nearly all of the larger streams of the State afford easy transportation to the large cities on the borders. There is not a place within the State on any of these streams which is not less than 100 miles of both Philadelphia and New York by existing railroads. Navigable waters are at several of the larger stream-falls, and water-power sites—New Brunswick, Trenton, Bridgeton, Millville and Mays Landing—are at such meeting-points of tidal and river waters and at fall lines.

The list of water-powers for the State is given, with kind of work done, fall, horse-power utilized and ownership, that of the streams of the northern part of the State being reprinted from the last annual report. The list for the southern part of the State is complementary in some degree to the notes on the undeveloped and cleared lands of that part of the State, which also are given in this report. It shows that the development of the stream-powers has gone on faster than the clearing of the forest and the cultivation of the soil. The latter is in great part untouched, except as it is robbed of its wood by cutting or ravaged by fire. From the location of the power-sites on the streams near tide-water and in the shore belt and near the better and more available farm lands there is an indication of their development as likely to help forward that of the land also. The light and more sandy soils and pine lands farther in the interior and about the head-waters of these streams, where there is little water-power, are indicative of forest conditions as best suited to them. These interior and more distant lands from navigable waters are needed in forest in order to a preservation of that equable flow which now marks these streams of the southern part of the State, and makes them valuable for water-power on their lower reaches.

The full report on water-supply and water-power is in course of preparation and is to be published in 1892 as Volume III. of the Final Report.

ARTESIAN WELLS.

Water-supply from artesian and deep wells is attracting more attention each succeeding year, and many inquiries are addressed to the Geological Survey for information on the nature of the strata, position of water-bearing beds or subterranean reservoirs, quality of water to be had and volumes of flow, at localities in all parts of the State. Some notes on new wells, of which the Survey has had notice, are given in this report, but no attempt to present a complete statement of the wells put down during the year has been made.

In response to my request, Lewis Woolman, of Overbrook, Pa., has continued his investigations of water-bearing horizons in the southern part of the State, and has prepared a short paper thereon, with a few notes on wells in Philadelphia and Milford, Delaware.

This subject is of so great practical importance, and the discoveries made in boring are so valuable helps in the study of geological structure, that a full report on our artesian wells is suggested as a proper subject for the Geological Survey, and steps are being taken to obtain complete records of well borings and suites of specimens to illustrate the same. The co-operation of the firms engaged in sinking wells in the State is earnestly asked to facilitate the work.

DRAINAGE.

The Geological Survey is authorized and empowered by law to make surveys and plans for drainage of tracts of land "subject to overflow from freshets, or which are in a low, marshy, boggy or wet condition," on the application of at least five owners of separate lots of land included in such wet tracts.*

Under the provisions of the laws on drainage, the Survey has been enabled to prepare a plan for the improvement of the drainage by the Pequest river through the Great Meadows, in Warren county. The results there are such as to commend drainage for the improvement of other tracts in the State similarly situated. Of course all drainage plans of this nature imply the necessity of constant watchfulness and care that there may not be any impairment through obstructions in the stream or unlawful interference with a free channel or water-way. And the maintenance of the benefits accruing to any tract through drainage improvements seems to demand the oversight of some common superintendence continued after the work of drainage has been done.

The improvement of the channel of the Passaic river at Little Falls, with the object of draining more efficiently the waters which in times of flood cover a large part of the level lowlands in that valley, has been in charge of the commissioners of the Passaic drainage, appointed in pursuance of an act of the Legislature, and the plan of drainage is that proposed by the Geological Survey and authorized by this Board. The work in the channel below the falls is nearly all done. There remains to deepen the cut near the dam and the removal of the bar at Two Bridges. The report of Geo. W. Howell, one of the commissioners, refers to the necessity of some changes which are desirable in continuing the work. (See page 233.)

* This act does not extend to lands flowed by tide. (See Ann. Rep. for 1888, pp. 49-60.)

UNITED STATES GEOLOGICAL SURVEY WORK IN NEW JERSEY.

The U. S. Geological Survey, in fulfillment of its promise to co-operate with the State Survey, has begun the study of the crystalline rocks of the Highlands of northern New Jersey, and the preparation of the geological map of the areas occupied by these rocks. By direction of Hon. J. W. Powell, the work was put in charge of Prof. R. Pumpelly. The field work has been under the more immediate charge of Dr. J. E. Wolff. The difficulties in the way of the classification of the various rocks found in the district, and a correct differentiation of the horizons represented has made it necessary to do some preliminary work in a general survey of the whole district. The correlation of these rocks with the crystalline schists of New England and New York and the gneissoid rocks of Pennsylvania is studied to advantage in connection with comparative examinations and surveys of these extra-limital outcrops, and more easily by the U. S. Survey, whose wider range of observation is better able to grasp all of the facts. The experience and practical direction which Prof. Pumpelly can give to this department leads to the confident expectation that the results will be of great geological importance and of substantial economic value to the State. The relation of these crystalline rocks and the iron, zinc and other metallic ores, and minerals which occur associated with them, is intimate. The discovery of the laws of their occurrence must be of service in the search for new mineral localities and new ore deposits. In the iron-mining districts it will be of great importance to ascertain what are the relations between the ores and the various rocks in order to discover new ore-ranges or trace the continuation of ore-shoots beyond the limits of mines now actively worked or nearly exhausted. The recent abandonment of two of the large and historic iron mines of the State, and the apparent exhaustion of others in the near future, show the want of practical help—from geologic science—and accurate knowledge of the facts of occurrence which can be put to service by the miner and prospector.

The work of the season has been in part to determine the areas occupied by various rock outcrops, and to prepare a detailed map of these areas. The northern part of the Jenny Jump mountain range, Warren county, the Alamuche mountain and the outcrops in Byram and Andover townships, in Sussex county, and an area in the vicinity of Mount Hope and Hibernia, in Morris county, have been mapped in detail. The full geological maps cannot, however, be published until the general survey of the district has been completed, and the classification scheme determined. All of this work is preparatory to a complete geological map of the State on the scale of the topographic survey atlas sheets.

PUBLICATIONS.

In consequence of the incompletion of the rooms for the Geological Survey in the State House, the distribution of its publications has been continued at the New Brunswick office, under the direction of Irving S. Upson, the assistant in charge.

The demand for the volumes of the annual and final reports of the State Geologist, as well as for the maps of the topographic atlas increases from year to year, and demands daily attention. No additional volume of the final report series has been published, and the limited edition of the first volume, upon the topography, magnetism and climate of the State, is nearly exhausted, as are also most of the annual reports previous to 1883.

The large edition of the clay report of 1878, for which there is continuous demand, was burned in the State House fire of 1885, and has not been reprinted. The Geological Survey has no copies of this report for distribution.

It is the wish of the Geological Survey to complete, as far as possible, imperfect sets of its publications in the public libraries of New Jersey and adjacent cities, and Mr. Upson will give correspondence relative thereto immediate attention.

It is very gratifying to note the interest manifested in the Survey by the increasing number of requests for its publications from intelligent citizens throughout the State.

OFFICE WORK.

The office work is largely correspondence and distribution of publications. The correspondence has an ever-widening range, as the demand for information grows with the acquaintance with the operations of the Survey. Inquiries from citizens of the State are numerous, and refer to all kinds of material sought for in mining, quarrying and even in farming and manufacturing, to some extent. They are answered as fully as possible by letter or by publications on the subject of inquiry. The subject of water-supply is prominent. Cities, towns, factory-owners and individuals seek information on it. The letters from capitalists outside of the State, who are looking for opportunities within our limits, are an important feature of the correspondence. The State has so great advantages in location that citizens of other States and of foreign nations are studying closely all of our reports, and noting chances for investment in our lands and mineral products. And the Survey appears to be the bureau to which such letters are addressed. While it is possible to answer these inquiries officially without imparting much information and in a comparatively short time, the careful attention given to them in the conscientious discharge of one's duty requires much more time. It is believed that the State gains by this attention to details in answering even individual letters from those outside of it.

The distribution of publications embraces (1) that to the public schools of the State, paid for out of the School Fund; (2) the distribution of annual reports and other publications to individuals, and (3) the sale of maps of the Atlas of New Jersey. This work was done from the office at New Brunswick, through a part of the year. It is being transferred to Trenton as rapidly as is possible, in view of our restricted room at present. The sale of maps continues to be large. Their usefulness is attested by this demand for them. The annual reports are also in brisk demand, and the editions of all of the earlier reports are exhausted. The demand for the volume on topography and climate, of the final report, has so far reduced the size of the edition that great care is exercised in the distribution. During the year, Volume II., Part II., has been distributed to all of the public schools, thus completing that work to date. The Atlas of New Jersey had been supplied to them in previous years. The time given to the distribution is productive of valuable results. The dissemination of information is recognized as important, as its collection and the prompt and widespread distribution of what is collected is appreciated by the people.

REMOVAL.

The collections of geological specimens, ores, minerals, clays, marls, soils and other material for the illustration of the geologic structure and economic resources of the State, heretofore deposited at Rutgers College, New Brunswick, have been removed to the State House, Trenton. They are stored temporarily in the basement, and awaiting the construction of cases for the new museum-room in the old library part of the building.

The storage of maps and reports also is now at Trenton, excepting a small part of the later editions of the Atlas of New Jersey, which are distributed by sales from Mr. Upson's office at New Brunswick.

In consequence of this removal the laboratory fixtures and chemicals are in part packed away in cases, and the Survey is not equipped with a chemical laboratory, and is not prepared to make assays or do analytical work. At present the necessary chemical work has to be done at a private laboratory, and is paid for out of the appropriation. Many specimens which are sent in by citizens of the State and many applications for chemical examinations have to be returned untested and unanswered because of the want of a laboratory. Facilities for doing such work are needed and are hoped for in connection with the equipment of the State museum in the State House. The ability to answer all inquiries in reference to the composition and value of ores, minerals, marls, clays, soils, &c., occurring in the State will tend to the increase in the number of such inquiries which may come to the office, and thereby be the means of distributing valuable information promptly, and popularize the work of the Survey among the people of the State.

STAFF OF THE SURVEY.

The working force of the Survey has been changed by the resignation of Frank L. Nason, Assistant Geologist, and by the engagement of Rollin D. Salisbury as geologist in charge of the studies of the surface or Pleistocene formations. Mr. Nason left at the beginning of the field season, to accept an important position on the staff of the Geological Survey of Missouri. The special work in which he had been employed is now being done by the United States Geological Survey, in co-operation with the State Survey, and is under the direction of Prof. Raphael Pumpelly.

Prof. Salisbury, of the University of Wisconsin, and formerly in the service of the United States Geological Survey, was engaged early in June. He was in the field about two months, and was assisted by Charles E. Peet, a student in geology.

Charles W. Coman, Assistant Geologist, spent nearly the whole of the year in the southern part of the State, excepting three weeks in the summer which were given to a reconnoissance along the Delaware river in studying the river terraces of that valley.

Irving S. Upson, so long the efficient clerk of the late Dr. Cook, has been retained as the financial clerk, and has had charge of the distribution of the publications from the office at New Brunswick.

C. C. Vermeule, Consulting Engineer and former Topographer of the Survey, has continued his work in preparing a report on water-supply and water-power. He has also given some time to the proof-reading and the revision of the editions of the sheets of the State Topographic Atlas.

The United States Geological Survey, in its work in New Jersey, has had Dr. J. E. Wolff, of Harvard University, in charge of the field studies of the crystalline schists of the Highlands of the northern part of the State, under the general direction of Prof. Pumpelly. He has had several assistants with him.

Geo. C. Bullock, Alfred A. Cannon and Burton S. Philbrook have given a part of their time to the work of distribution, under Mr. Upson, at the office at New Brunswick.

Hatfield Smith is retained as general assistant. He has given a part of his time to the work of removal to Trenton.

UNITED STATES GEOLOGICAL SURVEY WORK IN NEW JERSEY.

DEPARTMENT OF THE INTERIOR.
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C., December 17th, 1891.

Dr. J. C. Smock, State Geologist, Trenton, N. J.:

SIR—In accordance with the arrangement between the State Survey of New Jersey and the U. S. Geological Survey, for co-operative work, the U. S. Survey has carried on work upon the crystalline schists as follows:

The work was placed under the general charge of Prof. R. Pumpelly and under the immediate direction of Dr. J. E. Wolff. Prof. Pumpelly has been for many years in charge of a division having for its field the crystalline rocks of New England, and Dr. Wolff has been one of his principal assistants. The special assignment of this work was made for the purpose of giving to the investigation in New Jersey the advantage of the experience acquired in New England in the study of similar rocks.

Dr. Wolff has been assisted for various periods by Mr. R. S. Tarr, Mr. L. G. Westgate, Dr. August F. Foerste and Mr. H. J. Richmond.

The work has been directed to the accomplishment of two general results—first, the discovery of the true classification of the formations making up the crystalline area, and, second, the delineation on the map of the boundaries of these formations. As the classification is essential to the mapping, the first of these works might logically be completed before beginning the second, but it was thought best to do as much as possible of the preliminary work of classification in such manner as to furnish final data for areal delineation. Three of the assistants were therefore employed in the delineation on maps of the lithologic elements found in the districts assigned to them, marking their boundaries upon the map in advance of the determination of their classification and sequence, while Dr. Wolff himself was occupied with the general examination of the formations of the district and of the continuation of the belt into the State of New York. Dr. Foerste was sent from point to point to search for fossils to be used in the identification of metamorphic rock, and thus aid in the classification of the formations.

The areas covered by the local detailed work indicated on the accompanying map, are small, but they do not properly represent the general progress of the work. As clearer ideas are obtained in regard to the classification of the formations, the areal work will come to consist of the tracing of a comparatively small number of boundaries and will advance much more rapidly.

Yours, with respect,

J. W. POWELL,

Director.

UNITED STATES COAST AND GEODETIC SURVEY OF NEW JERSEY, 1891.

BY EDWARD A. BOWSER.

In the month of April an observing tower 64 feet high was built at Colsons; and in June and the first half of July a reconnoissance was made for opening vistas through the tree-tops from Colsons to Taylors, Bridgeton, Burden and Lippincott.

On July 15th this reconnoissance was completed, and the measurements of the horizontal angles at Colsons were begun. While these measurements progressed, the vistas were cut through the tree-tops on the lines from Colsons to Bridgeton and Taylor. Many of the trees on the latter line were very large and from 90 to 125 feet high.

A careful search was made for the monuments at Lippincott, Burden and Pine Mount stations, but they could not be found. Signals were therefore erected at Lippincott and Burden as near the old stations as we could tell, and observed upon from Colsons.

Granite monuments were set in hydraulic cement, at each of the stations Colsons, Bridgeton, Taylor, Kellogg, and Russia, to mark the center of the station. On September 5th the observations at Colsons were completed, and the instruments were moved to New Brunswick.

In December the latitudes and longitudes of a number of points were computed, including Colsons, Vineland Catholic Seminary, Clayton Church and Whiglane.

The next stations to be occupied are Taylor, Lippincott and Bridgeton, requiring observing towers about 48, 16 and 64 feet high respectively, and probably a long vista will have to be opened through the tree-tops on the line Bridgeton-Burden.

If this work is continued this summer, it is desirable to build the observing tower at Taylor during April or June, so as to be prepared to begin measuring angles at Taylor on July 1st. We should then determine Lippincott during the summer of 1892. If there is an allotment of $400 for the present fiscal year, for New Jersey, the observing tower at Taylor can be built, and a part of the reconnoissance can be made before June 30th.

PLATE I.—STONY TILL, NORTHEAST PART OF NEWARK. From a photograph.

A PRELIMINARY PAPER

ON DRIFT OR PLEISTOCENE FORMATIONS OF NEW JERSEY.

BY PROF. R. D. SALISBURY.

I.

INTRODUCTORY.

The detailed survey of the Pleistocene (drift) formations of New Jersey was begun about the first of July of the past summer. It is the purpose of this survey to prepare maps which shall represent the distribution and the relation of the various types of drift formed by the ice, and by the waters emanating from it, during the glacial or Pleistocene period. It is also the purpose of the survey to prepare maps showing the distribution and relations of such other formations as shall be found to exist within the State, which were made contemporaneously with the drift, or during any part of the Pleistocene period.

The preparation of such maps involves much time and labor. No more than a beginning has been made. Their preparation makes it necessary to traverse practically the whole area of the State which was receiving deposits, of whatever sort, during the Pleistocene period. It will involve the careful study of the topography of each square mile of the territory mapped, the study of the cuts made by railways and roadways, the study of the excavations made in the process of building, the construction of sewers, the laying of water and gas-pipes, the sinking of wells, &c. The detailed results of the survey, therefore, cannot be expected to be ready for publication before much time has been given to the work.

With each sectional map of the Pleistocene formations it is proposed to publish a descriptive text, explaining and describing the nature of the various formations mapped, the method by which they originated, their relations to each other and to underlying formations, and the notable changes which they have undergone since their formation. Along with such descriptions, which will be adequate to the understanding of the maps, and of the surface formations of the areas represented on the maps, there may be suggestions concerning the economic significance of the formations.

Obligations contracted before this work was undertaken have limited the time which has thus far been devoted to it. Of the two months spent in the field, a considerable part was given to a general reconnoissance of that part of the drift-bearing area adjacent to the terminal moraine. Some of the general results of this reconnoissance will be embodied in the general discussion which follows. Others are of such a nature as not to be available for immediate publication, though they will be of service in the further prosecution of detailed work, and were necessary to it.

In addition to the work of reconnoissance, the detailed study and mapping of the surface formations has been begun, and has covered that part of Middlesex county which lies north of the Raritan, most of Union county and the southeastern portion of Essex county. Since the details of a scheme for mapping cannot be definitely fixed in advance of the work itself, it is probable that some portions of the area already studied in detail, will need to be reviewed in the light of facts which were subsequently developed. For this reason it is thought advisable not to publish maps for any portion of the State until a larger area has been studied. This plan will insure better results in the end, though delaying the time of the first publication.

Under these circumstances it is deemed advisable to make this report no more than a general discussion of the drift and of the Pleistocene formations in general, with especial reference to the phenomena of New Jersey. This report may therefore be regarded as in some sense a preface to the more detailed reports which will follow, when the work which must form their basis is completed.

According to the present basis of classification, the Pleistocene period of geological history began with the first of the two or more glacial epochs, during which the body of the drift which covers the northeastern part of the United States was produced. All the formations laid down upon the surface of the earth, at whatever point, during the Pleistocene period, are Pleistocene formations. At first thought, this statement of the case seems to give a definite basis for separating the formations which belong to the Pleistocene period from those of earlier date. But a little consideration will make it clear that even so definite a beginning as the advent of a glacial period might seem to be, does not remove all difficulty in defining the earlier limit of the Pleistocene period and of the Pleistocene deposits.

The especial feature of the ice period was an ice-sheet. But the ice-sheet was not universal, and, at the outset, its proportions were small. Its starting-point was a snow-field somewhere north of the eastern part of the United States. From this snow-field, which was its beginning, the ice-sheet extended itself until it covered the large drift-bearing area of North America. Between the date of its inception and the date of its maximum expansion, there was a long interval of time.

When the snow-field had been converted into an ice-field, as in snow regions of to-day, and when the ice had begun to move out from its center, after the fashion of glaciers of to-day, the Pleistocene period was well begun *in the regions where the ice existed.* But at that time the ice-sheet had in no direct way affected New Jersey, so far as her geological formations are concerned. We have no knowledge that, at the time the ice-sheet began its motion in the north, the course of geological history in New Jersey was anything more than a continuation of that which had preceded. No new chapter had begun, though, as the sequel shows, the last one was drawing to a close. The formations which were being made in New Jersey at the time the ice began its motion in Canada, bore none of the marks which the ice-sheet was impressing upon the deposits which were making further north. They bore none of the marks of the Pleistocene formations which were afterward made in New Jersey, when the ice had advanced further south. Shall the formations made in New Jersey while the ice was still confined to Canada, formations which were not influenced by ice-action in any direct way, be classed as Pleistocene?

What is true of New Jersey is true of a wide range of territory. The Pleistocene ice-sheet had an earlier existence in Canada than in the United States. Did the Pleistocene period begin with the beginning of the ice-sheet in Canada, or is it to be regarded as beginning in any region when the influence of the ice-epoch first made itself felt in the ongoings of geological history in that region?

Again, there were large areas which were never covered by the ice, and whose formations, accumulated during the time when the ice existed further north, do not appear to have been influenced thereby. They were made during Pleistocene time, as reckoned for the region further north. But if the Pleistocene period began at different times in different portions of the regions ultimately covered by the ice-sheet, and if it is there difficult to determine just when it began, it is yet more difficult to say, in regions never invaded by the ice and not directly influenced by it, when the Pleistocene began. It is difficult to determine the time relations of formations which have no community of origin, and in which, or in one of which, fossils are not present. It is extremely difficult, when, in addition, they are so situated as to sustain no stratigraphical relation to each other. From these considerations it will be seen that the division between Pleistocene and Prepleistocene is not so simple as it first seemed. Leaving the interesting questions which here arise concerning the exact point of time at which the Pleistocene began, it will be agreed that when the formations of New Jersey, or any other region, began to be directly influenced by the conditions of the ice-epoch, the Pleistocene history of such a region was begun.

There is no evidence now in hand which indicates that ice ever invaded southern New Jersey. But it cannot be doubted that geological history was there in progress while the ice lay further north. Such deposits as were then making in southern New Jersey were of Pleistocene age, and it is the business of the geologist to determine, if possible, the extent of such formations, and the manner in which they were formed.

It may not be out of place to remark that the difficulty encountered in attempting to draw the line of division between the Pleistocene and Pre-pleistocene formations is no greater than that encountered in the case of many other formations. The Pre-pleistocene formations graded into the Pleistocene. There is not everywhere a sharp break between them. The division between geological periods, in general, is of the same character. It is not always, or generally, the sharp line which it is popularly thought to be.

The Pleistocene formations of New Jersey embrace at least all which were made by the ice in the northern part of the State, and all which were made contemporaneously by water further south, whether the depositing water arose from the melting of the ice, or whether it was sea-water invading the territory now above its level. It is the purpose of the survey to determine the nature and extent of the various classes of deposits made by different agencies during the Pleistocene period, and to delineate them upon the maps. If there be portions of the State, as may well be, where deposition was not taking place during Pleistocene time, such areas would not appear upon maps showing the Pleistocene formations only. The value of such study and mapping is manifold. They will have an important bearing upon various questions which are of universal interest.

The availability of land for building sites is a matter of the first importance to a State situated as New Jersey is. Already considerable areas, especially in the northeastern part of the State, have been made use of for this purpose, and the future is sure to show still further development in this direction. The availability of land for building sites is dependent, to no inconsiderable extent, on the nature of the surface formations. The nature of the subsoil, to the depth reached by the foundations of buildings, by sewers, by water and gas-pipes, is a matter which receives attention wherever new sites are sought for building purposes. The local water-supply, as well as surface-drainage, is often influenced, in kind and quantity, by the depth and character of the surface formations, and no town or residence site is wisely selected without consideration of these questions.

Again, the surface formations influence, and often largely determine, the cost of constructing and maintaining good roads. The surface formations, too, influence and often determine, not only the nature and the character of the native vegetation available for ornamental purposes, but also the character of that which can be made to flourish by cultivation. These considerations cannot but have an influence, and sometimes a deciding influence, in determining the areas likely to be chosen for residence purposes. These are considerations which are of especial importance in the territory tributary to the great metropolis. They are considerations which will receive more attention in the future than they have received in the past.

The value of land for agricultural purposes, as well as for all other purposes to which land is put, is mainly dependent, apart from considerations of climate, on the character of the soil and subsoil. In a general way, this will be shown by the Pleistocene maps, which will therefore be directly serviceable to the agricultural interest of the State. The value of maps of the surface formations for agricultural purposes is much greater than may at first thought appear. It is probable that progress in agricultural pursuits, in the immediate future, will be greater than at any time in the past. In this progress, the knowledge which is to be its basis will be the results of experiments among agriculturists. Experiments which prove to be successful in one area, on a given kind of soil, will be likely to prove successful in other regions where the soil is similar. The Pleistocene maps will not be soil maps primarily, but they will so far indicate the general character of the soil and subsoil, in indicating the geological formations that form them, that it will be possible to make intelligent inferences concerning the areal limits within which the successful results of experience in one region are likely to be profitably extended. The results in this line, which it is possible to reach by the intelligent use of geological data, have never yet been adequately tested, but it seems reasonable to suppose that they may be very considerable.

The scientific and educational results which will follow, directly and indirectly, from the prosecution of the work, if it be well done, will be great, and will possess an interest and a value which will not be bounded by the confines of the State. New Jersey has the honor of being the first State to attempt a detailed mapping of its surface formation.

II.

AN OUTLINE OF THE PLEISTOCENE (DRIFT) FORMATIONS OF NEW JERSEY.

The Nature of the Drift.

The northern part of New Jersey is covered by a mantle of clay, sand, gravel and bowlders. These various materials may be confusedly mingled, or they may be more or less distinctly arranged in layers, one above another. Any one of the above classes of material may predominate over the others to any extent, or all may be associated in approximately equal proportions. This aggregation of surface material is called *drift.*

The thickness of the drift varies greatly. In some places it is so thin that the underlying rock is frequently exposed. Much more commonly it is so thick that the rock upon which it rests is exposed only where deep excavations have been made by natural or human agencies. In still other regions the covering of drift is so massive

PLATE Ia.—CLAY TILL, CENTRAL PART OF NEWARK.

that even deep wells fail to penetrate it to its base. These variations in thickness may be great within short distances. It frequently happens that one hill has barely drift enough to cover the rock, while the next adjacent hill may be essentially composed of drift. The drift may be thin on the hills, while it is deep in adjacent valleys, or the reverse may be the case. Thicknesses of drift varying from nothing to 100 feet may occur within a single square mile, or even within narrower limits. Within the city of Newark, for example, quarries show but a few feet of drift, overlying the rock at certain points, while at others, according to data derived from well-borings, the drift appears to have a thickness of 200 feet or more. While these variations in the thickness of the drift characterize certain regions, they are not universal. Over large areas its thickness may be nearly uniform. In such cases the depth of drift may be great or small.

In the early days of geology this surface material, which often effectually conceals the rock beneath, was commonly regarded as an obstacle to the study of the underlying formations, which were looked upon as the proper field for geological investigations. So long as this view concerning it prevailed, the drift received little attention. But within recent years it has become the object of critical investigation, and there is perhaps no department of geology which is now attracting a larger measure of popular and scientific attention, and no department which has yielded, and is yielding, more important results.

It was long since recognized that the materials of the drift did not originate where they now lie, and that, in consequence, they sustain no genetic relationship to the strata which they overspread. Long before the drift received special attention at the hands of geologists, it was well known that it had been transported from some other locality to that where it now occurs. The early conception was that this material had been *drifted* into its present position from some outside source by water. Hence it was designated "*drift*." There are conclusive reasons for believing that water was not the transporting agency, but the term "drift" is still retained. To clearly understand the origin of the drift, and the method by which it came to be where it is, it may be well to consider some elementary facts concerning climate in its geological relationships, even at the risk of repeating what is already familiar.

The Formation and Movements of Glacier Ice.

The temperature and the snowfall of a given region may stand in such a relationship to each other that the summer's heat may barely suffice to melt the winter's snows. If under these circumstances the annual temperature were to be reduced, or the fall of snow increased, the summer's heat would fail to melt the winter's snows, and some portion of the snowfall would endure through the summer, and through successive summers, and constitute a perennial snow-field. Were this process once inaugurated, the depth of the snow would increase from year to year. The area of the snow-field would extend itself at the same time, since the snow-field would so far reduce the temperature of the surrounding territory as to increase the proportion of the annual precipitation which would there fall as snow. In the course of time, and under favorable conditions, the area of the snow-field would attain great dimensions, and the depth of the snow would become very great.

As in the case of snow-fields of to-day, the lower part of the snow-mass would eventually be converted into ice. Two factors would be effective in accomplishing this result. 1. The pressure of the overlying snow would tend to compact the lower portions of the snow into ice. 2. Water, arising from the melting of the surface snow by the sun's heat, would percolate through the superficial layers of the snow, and, freezing below, would take the form of ice. By these means the snow-field becomes an ice-field, the snow being restricted to its superficial parts.

Eventually the increase in the depth of the snow will give rise to new phenomena. Let us suppose that, in the case of a given snow-field, the depth of snow or ice is greatest at its center, and that its thickness gradually diminishes toward its edges. The field of snow, if resting on a level base, would have some such form as that represented in the diagram.

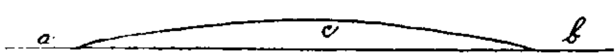


Fig. 1.

a, *b*, level rock surface on which the snow and ice accumulate; *c*, the snow and ice accumulated on the rock surface.

When the thickness of the ice has become considerable it is evident that the pressure upon its lower parts will be great. We are wont to think of ice as a brittle solid. If in its place we had some slightly plastic body, which would yield to pressure, it is evident that the weight of the overlying portions would press out the lower parts of the mass, and that these would extend themselves in all directions by a sort of flowing motion.

Under great pressure many substances which otherwise appear to be solid exhibit the characteristics of plastic bodies. Among the substances exhibiting this property ice is perhaps best known. Brittle and resistant as it seems, it may be moulded into almost any desired form if subjected to sufficient pressure, steadily applied through long intervals of time. The changes of form which may thus be produced in ice are brought about without visible fractures in its mass. Concerning the exact nature of the movement which takes place between the particles of ice there may be some question, but the result appears to be just such as might be brought about if the ice were capable of flowing, with extreme slowness, under great pressure continuously applied.

In the ice-field supposed we have the conditions for great pressure and for its continuous application. If the ice be capable of motion, as a plastic body, the result would be that the great weight of ice, pressing down upon the lower parts of the ice-field, would induce a gradual movement of the ice outward from the center of the field, so that areas surrounding the region of snow accumulation would gradually be encroached upon by the spreading of the ice. Observation shows that this is what takes place in every snow-field of sufficiently great extent and depth. Motion thus brought about is glacier motion, and ice thus moving is glacier ice.

Two factors would determine the limit to which the ice would extend itself: 1. The rate at which it advances, and 2. The rate at which the advancing edge is wasted. The rate of advance would depend upon several conditions, one of which, in all cases, would be the amount of pressure of the ice-mass which started and which perpetuates the motion. If the pressure be increased, the ice will advance more rapidly. If the ice advance more rapidly, it will advance further before it is melted. Other things remaining constant, therefore, increase of pressure will cause the ice-sheet to extend itself further from the center of motion. Increase of snowfall will increase the pressure of the snow- and ice-field by increasing its mass. If, therefore, the precipitation over a given snow-field be increased for a period of years, the ice-sheet's marginal motion will be accelerated and its area enlarged. A decrease of precipitation, taken in connection with unchanged wastage, would decrease the pressure of the ice and retard its movement. If, while the rate of advance diminished, the rate of wastage remained constant, the edge of the ice would recede, and the snow- and ice-field would be contracted.

The rate at which the edge of the advancing ice will be wasted will depend largely upon the climate. If, while the rate of advance remains constant, the climate becomes warmer, the melting will be more rapid, and the ratio between melting and advance will be increased. The edge of the ice will therefore recede. The same result will follow, if, while temperature remains constant, the atmosphere becomes drier, since this will increase the wastage of the ice by evaporation. Were the climate to become warmer and drier at the same time, the rate of recession of the ice would be greater than if but one of these changes occurred.

If, on the other hand, the temperature over and about the ice-field be lowered, melting will be diminished, and if the rate of flowage be constant, the edge of the ice will advance further than under the earlier condition of temperature, since it has more time to advance before it is melted. An increase in the humidity of the atmosphere, while the temperature remains constant, will produce the same result, since increased humidity of the atmosphere diminishes evaporation. A decrease of temperature decreasing the melting, and an increase in humidity decreasing the evaporation, would cause the ice to advance further than either change alone would do, since by both changes wastage is diminished.

If, at the same time that conditions so change as to increase the rate of movement of the ice, the climatic conditions so change as to reduce the rate of wastage, the advance of the ice before it is melted will be greater than when only one set of conditions is altered. If, instead of favoring advance, the two series of conditions conspire to cause the ice to recede, the recession will, likewise, be greater than when but one set of conditions is favorable thereto.

Greenland affords an example of the conditions here described. A large part of the half million square miles which this body of land is estimated to contain, is covered by a vast sheet of snow and ice, hundreds and thousands of feet in thickness. In this field of ice and snow there is a continuous, though very slow movement. The ice creeps slowly out from the heart of the icy continent, by a sort of flowing motion, and advances to the south and east and west until it reaches territory where the climate is such as to waste (melt and evaporate) the ice as rapidly as it advances. The edge of the ice does not remain fixed in position. There is reason to believe that it alternately advances and retreats, according as the ratio between flow and waste increases or decreases. These oscillations in position are doubtless connected with climatic changes. When the ice edge retreats this may be because the rate of ice wastage is increased, or because the snowfall is decreased. Increased wastage may accompany increased precipitation, when the recession will be greater than when but one of the two is operating. In any case when the ice recedes from the coast, it recedes until its edge reaches a position where the melting is less rapid than in its former position, and where the advance is exactly counterbalanced by the wastage. This represents a condition of equilibrium so far as the edge of the ice is concerned, and here the edge of the ice will remain stationary so long as the conditions are unchanged.

When for a period of years the rate of melting of the ice is diminished or the snowfall increased, or both, the ice edge advances to a new line where melting is more rapid than at its former edge. The edge of the ice will ultimately reach a position where waste and advance balance each other, and here its advance will cease, and here the edge of the ice will remain so long as climatic conditions remain unchanged. If the conditions determining melting and flowage be continually changing, the ice edge will not find a position of equilibrium, but will advance when conditions are favorable for advance, and will retreat when the conditions for advance are reversed.

Not only the edge of the ice in Greenland, but the ends of existing mountain glaciers as well, are subject to these fluctuations, and are delicate indicators of changes of climate in the ice regions where they occur.

The Work Effected by Glacier Ice.

As the edge of an ice-sheet, or as the end of a glacier, retreats, the land which it has previously covered is laid bare, and the effects which the passage of the ice has had may be seen. Some existing glaciers and ice-fields are now diminishing in size, and are therefore surrounded by areas which they recently occupied. In some cases one may actually go back under the ice now in motion, and see its method of work and the results it is accomplishing. The beds of living glaciers and beds which they have but recently abandoned, are found to present identical features. Because of their greater accessibility, the latter offer the better facilities for determining the effects of glaciation.

The conspicuous phenomena of abandoned glacier-beds fall into two classes: 1. Those which pertain to the bed-rock over which the ice moved, and 2. Those which pertain to the deposits of loose debris made by the ice.

1. *Effects of the ice on the bed-rock.*—The leading features of the rock-bed over which glacier ice has moved, are easily recognized. Its surface is generally smoothed and polished, and frequently marked by lines (striæ) or grooves, parallel to one another. An examination of the under surface of a living glacier, such as may be made from many a subglacial ice-cave, discloses the method by which the polishing and scouring are accomplished. The lower surface of the ice is seen to be thickly set with a quantity of clay, sand, and stony material of all grades of coarseness and fineness. Still more of the same material is pushed along beneath the ice. These earthy and stony materials in the lower portion of the ice, and beneath it, are the tools with which it works.

Thus rock-shod, the glacier ice moves slowly forward, resting down upon the surfaces over which it passes, with the whole weight of its mass. The grinding action between the stony layer at the base of the ice and the rock-bed over which the glacier moves is most powerful. If the material forced along over the surface of the rock, under the pressure of the ice, be fine, like clay, the rock-bed is polished. If coarser materials, harder than the bed-rock, be mingled with the fine, the rock-bed of the glacier will be striated as well as polished. If bowlders exist beneath the ice, or in its base, these may cut grooves or gouges in the underlying rock. The grooves may subsequently be polished by the passage of clay over and through them, under the pressure of the ice.

All these phases of rock wear may be seen beneath glaciers, where circumstances are favorable for observation, and about the termini of receding glaciers, on territory which they have but recently abandoned. There can thus be no possible doubt as to the origin of the polishing, planing and scouring.

There are other peculiarities less easily defined, which characterize the surface of glaciers' beds. The wear effected by the ice is not confined to a mere marking of the surface over which it passes. If prominences of rock exist in the path of glaciers, as is often the case, such obstacles oppose great resistance to the movement of the ice, and receive a corresponding measure of abrasion from it. They receive their greatest wear on the sides which oppose the current. Because the ice is so slightly viscous, it will not rest on the lee side of a prominence with the same pressure as upon the opposite ("stoss") side. That side of an obstacle, as a hill, which faces the direction in which the glacier is moving, will therefore suffer most wear. All roughnesses of surface and all projecting angles will be pressed upon with especial force, and in the course of time they will be worn or broken off. In time, rock prominences overridden by the ice will come to have not merely polished and striated surfaces, but rounded forms, exhibiting most wear on the sides which front the motion of the ice. Even the minor rugosities of a glacier's bed will suffer wear in a similar manner, and, until entirely effaced, will present similar forms.

Fig. 2.

Form of hill after it has been worn by the ice. The movement of the ice was from *a* to *b*. *a* is the "stoss" side.

So distinctive are the striations and planations accomplished by glacier ice, and so characteristic the topographic forms it produces, that, once they are familiar, they become the means by which the former extension of glaciers may be measured, and by which the former existence of glaciers, in areas now altogether free from them, may be demonstrated.

2. *Characteristics of glacial drift.*—When the ice of any given glacier began its motion, it did not carry the stony and earthy materials that may be observed in the basal parts of glaciers which have advanced some distance from their source. The materials carried in the lower part of the ice and pushed along beneath it, have been derived from the soil and rock over which the ice has moved. When the ice melts, these materials are left as an irregular covering on the

bed-rock over which it earlier passed. This covering represents the material which the ice gathered in its course, and carried in the direction of its movement. Its position marks the spot where the power of the ice for further transport failed. When the ice has disappeared, the whole surface previously occupied by it may be strewn with ice-transported debris. This material is known as glacial drift. From the method by which it has been gathered it is evident that it may contain fragments of rock of every variety which occurs along the course of the path followed by the ice. If the course of the glacier has been a long one, or if there be frequent changes in the character of the rock constituting its bed, the variety of materials in the drift may be great. The heterogeneity of the drift arising from the diverse nature of the rocks which contribute to it may be called *lithological heterogeneity*—a term which implies the commingling of materials derived from rock formations of different characters. Thus, it is common to find large and small fragments of shale, sandstone, limestone, granite, gneiss, schist, trap, &c., intimately commingled in the drift, wherever the ice which produced it passed over formations of these several rocks. Lithological heterogeneity is one of the notable characteristics of glacial formations.

Besides lithological heterogeneity, there is a *physical heterogeneity*, which owes its origin to the mechanical action of the ice. As first gathered from the bed of the moving ice, some of the materials are fine and some are coarse. The action of the ice in all cases is to reduce its underload to a still finer state. Some of the softer materials, as soft shale, may be crushed or ground to a powder. This constitutes what is known in common parlance as clay; not such clay as is used for the manufacture of pottery, but such as constitutes many of our clayey subsoils. Clayey material is likewise produced by the grinding action of ice-carried bowlders upon the rock-bed, and upon each other, when they are too resistant to be reduced bodily to the physical condition of clay. Other materials, such as soft sandstone, may be reduced to the physical condition of sand, instead of clay, and from sand to bowlders all grades of coarseness and fineness are represented in the glacial drift.

Since the ice does not assort the material which it carries, as water does, the clay and sand and gravel and bowlders will not, by the action of the ice, be separated from one another. As left by the ice, these physically heterogeneous materials are confusedly commingled.

The finer parts constitute a matrix in which the coarser are imbedded. Physical heterogeneity, therefore, is another characteristic of glacial drift. It is not to be understood that the proportions of these various physical elements, clay, sand, gravel, and bowlders, are at all constant. Locally, any one of these physical elements may be more abundant than the others, may even so far predominate as to nearly or quite exclude some or all of them. (See Plates I. and II.)

Since lithological and physical heterogeneity are characteristics of glacial drift, they constitute, together, a feature which is often of service in distinguishing glacial drift from other surface formations. It follows that this double heterogeneity constitutes a feature which can be utilized in determining the former extension of existing glaciers, as well as the former existence of glaciers where glaciers do not now exist.

Another characteristic of glacial drift, and one which clearly distinguishes it from all other formations with which it might be confounded, is easily understood from its method of formation. If the ice in its motion holds down rock debris upon the rock surface over which it passes, with such pressure as to polish and striate such surface, the material thus used as a tool will itself suffer wear, comparable to that which it inflicts on the surface over which it passes. Thus the stones, large and small, of glacial drift, will be smoothed and striated. This sort of wear on the transported blocks of rock, is effected both by the bed-rock reacting on the bowlders transported over it, and by bowlders acting on each other in and under the ice. The wear of bowlders by bowlders is effected wherever adjacent ones are carried along at different rates. Since the rate of motion of the ice is different in different parts of the glacier, the mutual abrasion of transported materials is a process constantly in operation. A large proportion of the transported stone and blocks of rock may thus eventually become striated.

From the nature of the wear to which the stones are subjected when carried in the base of the ice or beneath it, it is easy to understand that their shapes must be different from those of water-worn materials. The latter are rolled over and over, and thus lose all their angles and assume a more or less rounded form. The former, held more or less firmly in the ice or beneath it, and pressed against the underlying rock or rock debris while they are carried slowly forward, have their faces planed and striated. The planation and striation of a stone need not be confined to its under side. On either side or above it other stones, moving at different rates, are made to abrade it, so that its top and sides may be planed and scored. If the ice-carried stones shift their positions, as they may under various circumstances, new faces will be worn. The new face thus planed off may meet those which already existed at sharp angles, altogether unlike anything which water-wear is capable of producing. The stone thus acted upon shows a surface bounded by planes and more or less beveled, instead of a rounded surface such as water-wear produces. We find, then, in the shape of the bowlders and smaller stones of the drift, and in the markings upon their surfaces, additional criteria for the identification of glacier drift.

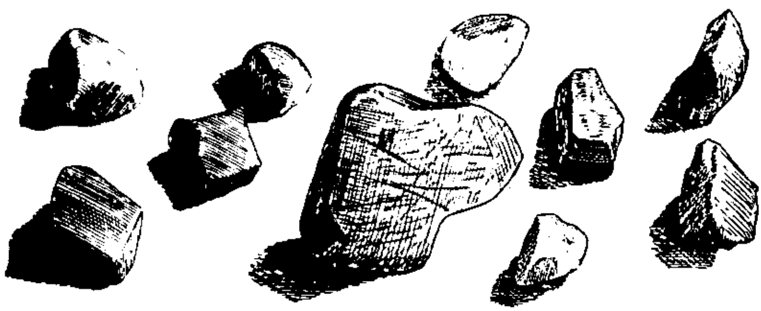


Fig. 3.

Illustrating forms of glaciated stone. The sub-angularity, and in some cases even the sharp angularity, distinguish these pebbles from those worn by water. The smoothness of some of the flat surfaces is no less characteristic than the forms of the pebbles.

Of the specific features which have been enumerated as characterizing territory over which ice has passed, but which it has now abandoned, viz., (1) the lithological and (2) the physical heterogeneity of the surface material; (3) the shape of and (4) the markings on the stone which constitute one element of the surface deposits; (5) the smoothing and striating of the bed-rock beneath the same, and (6) the form of the underlying rock-prominences (certain ones alone) may, under proper circumstances, be sufficient to demonstrate the former presence of ice. But it generally happens that where one of these marks is found some or all of the others accompany it, and in such cases the evidence of former ice occupancy is overwhelming.

Taken singly, the individual phenomena noted above may be imitated by the work of other agencies. There are other agents than glacier ice which may striate bed-rock, and bowlders as well. In special cases striæ produced by other means may closely simulate those made by glaciers, though the difference may generally be detected without difficulty by discriminating observation. So, too, confused deposits of materials of varying degrees of coarseness and fineness may be made by other agencies than glaciers. But such deposits will lack the other associated marks which characterize glacier formations.

The markings on the rock which once constituted a glacier's bed; the form or topography of its prominences; the heterogeneity, both lithological and physical, of its deposits; the striation and form of the ice-transported materials, taken together, constitute a volume of testimony whose meaning cannot be mistaken. Where these several features co-exist it may safely be concluded that glaciers have existed. Conversely, where glaciers have existed, some or all these features will testify to their former presence. This being true, it becomes possible to determine, as in Switzerland and Norway, how far existing glaciers have receded in recent times. It becomes possible also to determine the former existence of ice, wherever it has acted with force in recent geological times, even though no glaciers remain. The qualification as to time is to be constantly borne in mind, for in the course of the ages even the most distinct signs of glaciation may be obliterated. The winds and frosts, the rains and streams, working conjointly, may destroy the polished surfaces of the rock and the smooth contours of its hills. They may destroy the physical heterogeneity of the drift by reducing it all to fineness, or they may carry it away to some new resting place, destroying its distinctively glacial marks in the process.

The foregoing are not the only marks of abandoned glacier-beds. They are but the simplest and most easily-applicable criteria. There are other marks of glaciation, some of which are less susceptible of brief statement, and some of which are of less universal application. The foregoing are sufficient for our present purpose.

CRITERIA OF GLACIATION APPLIED TO NEW JERSEY AND ADJACENT TERRITORY.

Northern New Jersey presents all the phenomena here described. At many places within the Highland region of the State, the surface of the rock shows planation and striation, identical, in all essential respects, with the planation and striation produced by the moving ice-sheets and glaciers of to-day, and the rock-hills frequently show the peculiar form which is characteristic of ice-wear. Overlying these worn and polished surfaces of rock, there is the formation of drift, lithologically and physically heterogeneous, composed in part of materials transported from other and distant regions to that in which they now occur. The rock masses, great and small, of which the drift is largely made up, frequently possess the forms and the surface markings which characterize the materials deposited by glaciers at the present time. In many cases, the direction whence the bowlders have come is known, and the direction of transport corresponds with the direction of striæ upon the bed-rock. These phenomena, as well as many others scarcely less conclusive, leave little room for doubt that the region where they occur has been at some time covered by glacier ice.

The phenomena of New Jersey do not stand alone. They are similar to those of a very large area in the northeastern portion of the United States. Over the whole of the area where these phenomena occur it is believed that glacier ice once extended. To have covered so wide an area, including mountains and highlands, as well as valleys, the ice must have had such an areal extent that it is common to speak of it as a continental ice-sheet, rather than as a glacier, comparable to those of mountain valleys at the present time.

In New Jersey the direction of movement of this ice-sheet, as shown by the striæ, by the contours of the rock-hills, and by the direction in which the material has been transported, was east of south. Locally, the direction of ice movement departed from the general direction here indicated. Such variations appear to have been the result of local topographic influences. In New England the direction of movement departs still further from the meridional line. West of New Jersey the movement of the ice was at first more nearly to the south, while in the interior of the continent it was, in general, somewhat west of south.

If these varying directions of movement be followed back toward their source, they seem to radiate from an area north of the eastern portion of the United States. From an area in this part of the continent which seemed to serve as a center of dispersal, the ice moved to the southeast, south and southwest, as shown by the phenomena of striæ and transportation in the United States. The phenomena of the region further to the north show that there were also movements in other directions from this general center of distribution, but it is not to our purpose to enter into details concerning them.

SUMMARY STATEMENT OF THE DEVELOPMENT AND MOVEMENTS OF THE NORTH AMERICAN ICE-SHEET AND THE WORK WHICH IT ACCOMPLISHED.

The Area of the Ice-Sheet.

In an area north of the eastern part of the United States it is believed that an ice-sheet similar to that which now covers Greenland, accumulated in time past. From this area as a center, it spread in all directions, urged forward by the pressure of the ice and snow within the area of accumulation. From the Canadian territory the ice invaded the territory of the United States, and overspread nearly the whole of New York and considerable portions of New Jersey and Pennsylvania. To the east, New England was buried by the ice. To the west, its southern extension was still greater. It crossed the Ohio river in the vicinity of Cincinnati, and pushed out upon the uplands a few miles south of the river valley. Further west, its margin lay in southern Indiana, and reached nearly to the southern point of Illinois. West of the Mississippi, the line which marks the limit of its advance curves to the northward, and follows, in a general way, the course of the Missouri river.

The total area of the North American ice-sheet, at the time of its maximum expansion, has been estimated to be something like 4,000,000 square miles, and about thirteen times as large as the estimated area of the snow-field of Greenland at the present day. To have afforded the pressure requisite to such extensive movement, the ice must have possessed a thickness of many thousand feet at its center.

The Mobility of the Ice.

To a clear understanding of the work accomplished by glaciers, and especially of the formations made by them, definite conceptions of the nature and method of ice movement, and of the work which this movement effects, are necessary. The nearly-universal notion of the rigidity of ice, based on the phenomena of ice as ordinarily seen, is likely to lead to erroneous conceptions concerning the work of glaciers and ice-sheets.

It belongs to viscous bodies, when in motion, to adapt themselves to the irregularities of form of the channels or beds over which they move. The degree of adaptation will depend primarily upon the degree of mobility of the plastic body. It belongs to rigid bodies in motion over irregular surfaces to adapt their beds to themselves. Their tendency is to plane off such irregularities of surface as they meet. An obstacle which opposes a perfectly-rigid body will either stop it altogether, or will be overcome by it.

Between viscous and rigid bodies there is no sharp line to be drawn. The terms are relative. There are all degrees of rigidity and viscosity, and the substance which, under one set of conditions, seems to be perfectly rigid, may show itself to be viscous when conditions are sufficiently changed. The same body or substance may exhibit different degrees of viscosity under different circumstances. Such substances as tar, whose viscosity varies with temperature, are familiar illustrations. A viscous body with but a slight degree of internal mobility may so far approach rigidity that, when in motion, it exerts great pressure against any opposing body, and is reacted upon by it, in turn, with great force before its particles move upon each other in such wise as to reveal its viscosity. Moving bodies of viscous nature exert their greatest pressure against that side of an opposing object which faces the direction of their motion—that is, the struck, or "stoss" side. The disparity between the force exerted on this and other sides of the opposing body increases as the viscous body approaches rigidity.

In spite of its seemingly solid and brittle character, ice is viscous, or at any rate behaves as a viscous body when under great pressure. The degree of mobility of its particles is so slight, that ice in the form of a glacier does not readily yield to opposing obstacles, and, unless they be very resistant, may overcome them. If they be sufficiently resistant, however, and if the pressure behind the moving ice be powerful enough, it will move over or around them. But so grudgingly does the moving ice yield its right of way, and so reluctantly does it conform to irregularities in its path, that prominences are likely to suffer great abrasion from the passage of the ice. Ice appears to yield more readily under certain circumstances than under others. Glaciers move more freely in summer than in winter. Whether this is the result of increased mobility of the ice itself, or the effect of the greater amount of water contained in the ice, and produced by its melting, or whether it is the result of both these conditions, is an open question. Certainly the ice seems to have acted with much greater rigidity in some places than in others. This apparent difference is doubtless due in part to the differences in the amount of resistance opposed. It may also be due in part to variations in the mobility of the ice itself.

The Preglacial Land Surface.

Before the time of the ice invasion, the surface which it overspread had long been exposed to the common processes of degradation. It had been cut into valleys and ridges by the streams, and the ridges had been further dissected into hills. It is certain that its topography was comparable to that of many regions now known to us, over which the ice did not spread.

The characteristic features of a topography fashioned by running water are such as to mark it clearly from surfaces fashioned by other agencies. Rivers end at the sea (or in lakes). Generally speaking, every point at the bottom of a river's valley is higher than any other point in the bottom of the same valley nearer the sea, and lower than any other point correspondingly situated further from the sea. This follows from the fact that rivers make their own valleys for the most part, and a river's course is necessarily downward. This statement does not take into account the minor roughnesses of a stream's channel, or the lakes which may occur in its course. Such exceptions are so slight, or so rare, as not to merit consideration here. In a region of erosion topography the main valleys lead directly down to the sea. Tributary valleys lead down to their mains, and secondary tributaries lead down to the first, and so on. Or to state the same thing in reverse order, in every region where the surface configuration has been determined by rain and river erosion, every gully and every ravine descends to a valley. The smaller valleys descend to larger and lower ones, which in turn descend to those still larger and lower. The lowest valley of a system ends at the sea, so that the valley which joins the sea is the last member of the series of erosion channels, of which the ravines and gullies are the first. It will thus be seen that all depressions in the surface, worn out by rivers, lead down to lower ones. The surface of a region sculptured by rivers is therefore marked by deeper and shallower valleys and intervening ridges and hills, the slopes of which descend to the valleys. It follows that the surface is well drained. Ponds and lakes, as well as basin-like depressions without water, are absent or rare. The surface of the driftless area of southwestern Wisconsin, an area surrounded by the ice, but not covered by it, is a good illustration of the surface configuration developed by rain and running water. Other regions altogether beyond the limit of ice advance present the same general features. Such was the surface configuration of the drift-covered region in general, and of northern New Jersey in particular, before the ice invaded it. The details of its topography had been determined by river erosion.

The preglacial surface, characterized by hills and valleys, was doubtless overspread to a depth of several feet by a mantle of soil and earth which had resulted from the decomposition of underlying rock. This earthy material doubtless contained fragments and even large masses of rock like that beneath. These fragments and masses had escaped disintegration because of their greater resistance, while the surrounding rock had been destroyed. Such masses of rock characterize most soils and surface earths arising from the decomposition of underlying rock.

Fig. 4.

Diagram illustrating the relation of rock to the overlying soil derived by decomposition from it. The upper surface of the rock is irregular and much decomposed, and the overlying earth fills all the cracks.

The topography and the surface mantle of earth above noted, are the superficial features which characterize, in general, the territory outside the limit of ice advance, although they are less clearly illustrated in much of the extra-drift territory of New Jersey than in most other parts of the United States. The driftless area of Wisconsin shows the typical characteristics of a non-glaciated region with respect to surface soils, as well as surface configuration. From this and other areas we learn that it was a region of hills and valleys, the details of whose topography had been developed by streams, and whose surface was covered by a shallow layer of soil and residuary earth, that the ice invaded.

Glacial Modification of the Preglacial Surface by Abrasion.

As the ice advanced, seemingly more rigid when it encountered yielding bodies, and more viscous when it encountered resistant ones, it denuded the surface of the land of its loose and movable materials, and carried them along beneath itself or imbedded in its basal portions. This accumulation of earthy and stony material beneath the ice and in its basal portions, gave it a rough and grinding lower surface, which enabled it to abrade the surface over which it passed much more powerfully than the ice alone could have done.

Every hill and every mound which the ice encountered contested its advance. Every sufficiently resistant elevation compelled the ice to pass around or over it. But even in these cases the ice left its marks upon the surface to which it yielded. The powerful pressure of pure ice, which is relatively soft, upon strong, firm hills of rock, which are relatively hard, would be likely to effect little. The hills would wear the ice, but the effect of the ice on the hills would be slight. But when the ice is shod with earthy and stony debris derived from the rock itself, and therefore equally hard, the case is very different. Under these conditions the ice, yielding only under great pressure and as little as may be, rubs its rock-shod base over every opposing surface, and with greatest severity where it meets with greatest resistance. Its action may be compared to that of a huge "flexible rasp" fitting down snugly over hills and valleys alike, and working under enormous pressure.

The abrasion effected by a moving body of ice under such conditions would be great. Every inch of ice advance would be likely to be attended by loss to the surface of any obstacle over or around which it is compelled to move. The loss will be greatest at the most resistant and weakest points. It follows that the sharp summits of the hills, and all the angular rugosities of their surfaces, will be filed off and smoothed down to such forms as will offer progressively less and less resistance. If the process of abrasion be continued long enough, the forms, even of large hills, may be greatly altered and their dimensions greatly reduced.

Among the results of ice wear, therefore, will be a lowering of the hills and a smoothing and softening of their contours, while their surfaces will bear the marks of the tools which fashioned them, and

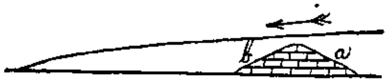


Fig. 5.

Illustrating the form of a hill shaped by rain and river erosion. The upper line represents the surface of the ice as it first passes over the hill.

will be polished, or striated, or grooved, according to the nature of the material which the ice presses down upon them during its passage.

Fig. 6.

Illustrating form of hill, such as that represented in Fig. 5, after it has long been acted upon by the ice. The arrow indicates the direction of the ice movement, and the dotted line above suggests the position of the upper surface of the ice when it passed over the hill in great thickness.

It was not the hills alone which the moving ice affected. Where it encountered valleys in its course, they likewise suffered modification. Where the course of a valley was parallel to the direction of the ice movement, the ice occupied its depression. The depth of moving ice is one of the determinants of its velocity, and because of the greater depth of ice in valleys, its motion here was most rapid, and its abrading action powerful. Under these conditions the valleys were deepened and widened.

Where the courses of the valleys were transverse to the direction of ice movement, the case was different. The ice was too viscous to span the valleys, and therefore filled them. But in this case it is evident that the greater depth of ice in any valley will not accelerate its motion, since the ice in the valley-trough and that above it are in a measure opposing each other. If left to itself, the ice in the valley would tend to flow in the direction of the axis of the valley. But in the case under consideration, the ice which lies above the valley depression is in motion at right angles to the axis of the valley. Under these circumstances, three cases might arise:

1. If the movement of the ice-sheet over the valley in any case was able to push the valley ice up the further valley slope and out upon the opposite highland, this work would retard the movement of the

upper ice, since the resistance opposing such movement would be great. In this case, the thickness of the ice is not directly and simply a determinant of its velocity. The depth of ice above the bottom of the valley will be influenced by the depth of the valley. The deeper the valley the deeper the ice. The deeper the valley and the more the volume of ice it contains, the more difficult will it be for the ice, moving at right angles to the valley, to push the valley ice up out of

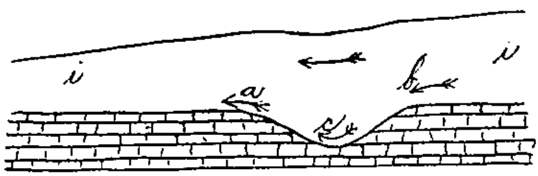


Fig. 7.

Diagram illustrating the movement of ice across a valley in the relations here described. *i*, *i*, is the ice, moving at right angles to the valley *c*, as indicated by the arrows; the slope *a*, *c*, will be so reduced that its angle of slope is less than that of *b*, *c*.

the valley-trough and upon the opposite highland. While, therefore, increasing the depth of the valley will increase the thickness of ice above its bottom, it will increase the rate of movement. On the other hand, if the great depth of ice over any valley be the result not of the depth of the valley, but of the thickness of ice above the valley, the velocity will be greater, the greater the thickness of the ice.

In the case under consideration, the bottom of the valley will not suffer great erosion, since ice does not move along it or press with the greatest stress upon it. That slope of the valley against which the ice movement is projected will suffer great abrasion. The valley will be widened, and the slope suffering greatest wear will be reduced to a lower angle. Shallow valleys, and those possessing gentle slopes, will favor the phase of ice movement here noted.

2. The upper ice *crossing* the valley might pass over the ice *filling* the valley-trough, leaving the latter stationary. In this case, the total depth of ice will not be a determinant of its velocity. It would be the thickness of the moving ice only, which would influence the velocity. The stationary ice in the valley would serve as a bridge, on which the upper ice would cross. In this case the valley would not suffer great wear by the ice, so long as this condition of things continued. Valleys which have great depth relative to the thickness of

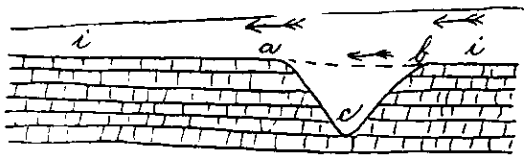


Fig. 8.

Diagram illustrating the relations specified in the text (2); the ice, i, i, fills the valley but remains stationary, the ice above crossing the valley on the ice which fills it.

the ice, and valleys whose slopes are steep, will favor this phase of movement.

3. In the valleys whose course is transverse to the direction of general ice movement, it is conceivable that transverse currents of ice might arise, following the direction of the valleys. If the thickness of the ice be much greater than the depth of the valley crossed, and if the valley be capacious, and if one end of the same be open and much lower than the other, it is conceivable that the ice filling the valley-trough might move along its course, while the upper ice continued in its primary course at right angles to the valley, crossing the same on the ice which is moving along it. In this case the valley would be deepened and widened, but this effect would be due to the movement along its course, and not to that transverse to it. So far as the writer is aware, no instance of this type of movement has been demonstrated, but it is possible that such movements existed where conditions were favorable.

The corrasive effects of ice action, therefore, upon the surface over which the ice-sheet passed, were locally dependent on pre-existent topography, and its relation to the direction of ice movement. In general, the effect was to cut down prominences. Thus, the ice acted as a leveling agent. But when it encountered valleys parallel to its movement, these were deepened, thus locally increasing relief. Whether the reduction of the hills exceeded the deepening of the valleys, or whether the reverse was true, so far as corrasion alone is concerned, is a question about which there is difference of opinion. But whatever the fact with reference to the corrasive effect of ice action upon the total amount of relief, the effect upon the contours was to make them more gentle. Not only were the sharp hills rounded off, but even the valleys which were deepened were widened as well, and in the process their slopes became more gentle. A river-erosion topography, modified by the wearing (apart from the depositing) action of the ice, would be notably different from the original, by reason of its gentler slopes and softer contours.

Glacial Modification of Preglacial Surface by Deposition.

Reference has already been made to the fact that glacier ice on melting leaves its bed covered with the debris which it carried along, on and in and beneath itself. Were this material equally distributed on and in and beneath the ice during its motion, and were the conditions under which this material was deposited everywhere the same, the drift would constitute a mantle of uniform thickness over the underlying rock. Such a mantle of drift would not greatly alter the topography. It would simply raise the surface by an amount equal to the thickness of the drift, leaving elevations and depressions of the same magnitude as before, and sustaining the same relations to each other. But the drift carried by the ice, in whatever position, is not equally distributed during the process of transportation, and the conditions under which it is deposited are not constant in the same area, or uniform in different areas.

The larger part of the drift transported by the ice in America appears to have been carried beneath the same, and in its basal portions. But since the surface over which the ice passed was variable, it yielded a variable amount of material to the ice. Where it was hilly the friction between it and the ice was greater than where it was plane, and the ice carried away more load. From areas where the surface was overspread by a great depth of soil and loose material, more load was carried away by the ice than from areas where there was less material in a condition to be readily transported. And again, when the subjacent rock formations were soft and readily worn, the amount of material carried away by the ice was greater than where the formations were hard and resistant. Because of the topographic diversity and petrographic heterogeneity of the surface of the country over which the ice passed, some portions of the ice carried much more drift beneath themselves than other portions. When, therefore, the ice finally dropped its load, greater depths of drift were left in some places than in others.

Not all of the material transported by the ice from its former position was carried forward until the ice melted. Some of it was probably carried but a short distance from its original position before it lodged. Drift was thus accumulating at some points beneath the ice during its onward motion. At such points the surface was being built up, while at other points, abrasion was lowering it. The drift mantle now existing does not, therefore, represent simply the material which was on and in and beneath the ice at the time of its melting, but it represents, in addition, all that lodged beneath the ice during its movement.

A considerable part of the drift transported by the ice was carried forward toward its thinned edge and there deposited. It follows that if the edge of the ice remained constant for any considerable period of time in the history of glaciation, large quantities of material would here accumulate, and a sort of ridge, or belt of drift, would be built up where the ice edge was stationary. Other things being equal, the longer the time during which the position of the edge of the ice was constant, the greater would be the accumulation of drift. Certain ridge-like belts, where the drift is thicker than on either hand, are confidently believed to mark the position in which the edge of the ice-sheet was constant, or nearly constant, for considerable periods of time.

Because of the unequal amounts of material carried by different parts of the ice, and because of the unequal and inconstant conditions of deposition under the body of the ice and its edge, the mantle of drift has a very variable thickness. And a mantle of drift of variable thickness cannot fail to modify the topography of the region it covers. The extent of the modification will be dependent on the extent of the variation in thickness. This amounts, in the aggregate, to hundreds of feet. The continental ice-sheet, therefore, modified the topography of the region it covered, not only by the wear it effected, but also by the deposits it made.

In some places it chanced that the greater thicknesses of drift were left in the positions formerly marked by valleys. In some cases the thickness of drift was so great that the valleys were completely filled, and therefore completely obliterated as surface features. Less frequently, drift not only fills the valleys, but even rises higher over their former positions than on either side, thus leaving low hills or ridges of drift along the site of the old valleys.

In other instances, instead of being deposited in the valleys, the greater depths of drift were left on the pre-existing elevations, making them still higher. In short, the mantle of drift of unequal thickness was laid down upon the pre-existing surface in such wise that the thicker parts sometimes rest upon hills and ridges, sometimes upon the slopes, sometimes upon the plains, and sometimes in the valleys. In regions where the thickness of the drift is great relative to the pre-existing relief, the topography may be completely changed. Not only may some of the valleys be obliterated by being filled, but some of the hills may be obliterated by having the lower land between them built up to their level or above it. In regions where the thickness of the drift is slight, relative to the pre-existing relief, the hills and mountains cannot be buried, and the valleys cannot be completely filled, so that the relative positions of the hills and valleys will remain much the same after the deposition of the drift as before.

In case the pre-glacial valleys were filled and the hills buried, the new valleys which in time the surface waters will carve out of the drift surface, will not always correspond in position with those which existed before the ice incursion. A new system of valleys, and therefore a new system of ridges and hills, will be developed, in some measure independent of the old. These facts and relations may be illustrated by the accompanying diagram:

Fig. 9.

Illustrating the relation of drift to the underlying rock. The surface of the rock is firm, not decomposed as in Fig. 4. The rock slopes are also gentler and smoother. The drift covers the rock in such wise that the higher points of the drift surface do not always correspond to the higher points of the rock surface. Post-glacial valleys now in process of excavation at *a*, *b* and *c* sustain no definite relation to the preglacial valley.

The inequality in the thickness of the drift leads to a further modification of topography. It frequently happened that in a plane or nearly plane region a slight thickness of drift was deposited at one point, while all about it much greater thicknesses were left. The area of thin drift would then constitute a depression, surrounded by higher lands representing the thicker deposits. Such depressions would have at the first no outlet. They are altogether unlike the depressions in a region whose topography has been shaped by rain and river erosion, for in such a region the depressions have outlets. A drift-covered (glaciated) country is, therefore, marked by the presence of depressions without outlets. In these depressions water may collect, forming lakes or ponds, or in some cases only marshes and bogs.

Depressions without outlets, in which water may collect, may arise through the agency of the drift in other ways. If deep deposits of drift be made at one point in a valley, while above it there is little or none, the deep deposit will form a sort of dam, above which waters may accumulate, forming a pond or lake. A ridge of drift may be deposited in the form of a curve or loop, with its ends against a rock-ridge, or against a second drift-ridge, in such wise as to leave a depression between them. In these and other ways depressions were made in the drift without outlets, many of which gave rise to lakes. So abundant are lakes and ponds in a drift-covered country, and so rare in other regions, that they constitute one of the more-easily recognized characteristics of a glaciated region.

In the course of time, the lakes and ponds formed on the surface of the drift will be destroyed by the action of streams, which work out a new system of valleys, draining or filling the lakes in the process. The process of destruction of the lakes is a gradual one, and so it comes about that the abundance and the condition of undrained areas in a drift-covered region is, in some sense, an index of the relative length of time, reckoned in terms of erosion, which has elapsed since the drift period.

The action of the ice was accompanied by the action of water on a somewhat extensive scale. The upper surface of the ice was continually melting by reason of the influence of the sun. The lower surface was likewise continually melting by reason both of the heat received from the earth beneath, and of that generated by the friction of the ice motion. From the margin of the ice, therefore, considerable volumes of water must have flowed, just as streams issue from beneath glaciers at the present time. In some cases the water issued from beneath the ice in valleys and coursed down them. Elsewhere, it issued on plains and spread widely over them, having no valley to confine it. In both cases the waters flowing from the ice carried such loads of silt, sand or gravel as they were able to transport. These materials were deposited whenever the transporting power of the water failed, building up level or gently-sloping plane surfaces.

The material thus carried forward by water beyond the edge of the ice, falls within the general class of drift. The materials were first carried by the ice and subsequently by the water. But since the transportation by water came last, the material was water-worn after it was ice-worn, and its glacial markings were in part or altogether destroyed. Water, too, assorts and stratifies the material which it deposits, so that drift deposited by water differs notably in physical constitution and in structure from that deposited by the ice. Its physical heterogeneity is much less, though the variety of rock constituents which it contains may be the same.

Since large streams sometimes issue from beneath glaciers at the present time, it must be that they have some course beneath the ice itself. In the much larger bodies of glacier ice in the past, the same must have been true on a yet larger scale, so that deposits of drift made by streams beneath the ice must have accompanied the movement of the ice itself. Such deposits are sometimes found above those made by the ice, sometimes below them, and sometimes interbedded with them.

Classification of the Drift.

The formations made by the ice and by the water accompanying it are highly complex. They vary in constitution, in structure, in topography, in topographical relations and in genesis. This is the result (1) of the various phases of ice action, dependent on a variety of conditions and relations, such as the topography and constitution of the land over which the ice passed, the thickness of the ice, nearness to its margin, &c.; and (2) of the nature and extent and relation of water action, contemporaneous with the ice or immediately subsequent to it. The two agencies, water and ice, seem to have co-operated in divers ways with the greatest degree of intimacy.

Broadly speaking, the drift falls into two great classes—(1) the stratified or assorted drift, and (2) the unstratified or unassorted drift. Generally speaking, the former is the drift deposited by water, and the latter that deposited by ice. But to this general statement many qualifications and minor amendments are necessary. These two general classes of drift are so intimately related to one another that it is sometimes very difficult to draw lines of definition between them. It frequently happens that the one lies above the other, and not rarely they alternate with each other several times between the surface and the bottom of the drift.

Till.—A large part of the drift is made up of an unassorted mass of clay, sand, pebbles and small stone, intimately commingled, together with larger masses of rock, known as bowlders. Any one of these constituents may be more abundant than the others, and the clay or sand (rarely the coarser constituents) may so far predominate over the others as to nearly exclude them. Those portions of the drift having this constitution and this structure, or lack of structure, are known as till.

The till* was deposited by the ice directly, not by the water accompanying it. In part, the till was deposited beneath the body of the ice during its onward motion. Wherever obstacles to the progress of the ice lay across its path, there was a chance that these obstacles, rising somewhat into the lower part of the ice, would constitute barriers against which stony debris from the lower part of the ice would lodge. It might happen also that the ice, under a given set of conditions favoring erosion, would gather a greater load of rock-debris beneath itself than it would be able to transport under the changed conditions into which its advance brought it. In this case, some part of the load would be dropped, and overridden by the ice.

Especially near the margin of the ice, where its thickness was slight and diminishing, the ice must have found itself unable to carry forward the loads of debris, which it had gathered further back in its course, where its action was more vigorous; for it will be readily seen that, if not earlier deposited, all material gathered by the under surface of the ice, however distant from its edge, will presently find itself at the edge of the glacier. For, given time enough, ablation will waste all that part of the ice occupying the space between the original position of the debris and the margin of the ice. Under the thinned margin of the ice, therefore, considerable accumulations of drift must have been taking place while the ice was still advancing. Under these circumstances, while the edge of the ice-sheet was advancing into territory before uninvaded, the material accumulated beneath the edge of the ice at one time, found itself much farther from the margin at another and later time. Under the more forcible ice action which existed back from the margin, the earlier accumulations made under the thin edge were partially or wholly removed, and carried down to or toward the new

* No account is here taken of *berg till,* which may closely simulate glacier till, though deposited by icebergs.

and more advanced margin, and here deposited, to be in turn disturbed and still further transported by the further advance of the ice.

Since in its final retreat the margin of the ice must have stood, necessarily, at all points once covered by it, these submarginal accumulations of drift must have been made over the whole country once covered by the ice. These deposits of drift, made beneath the marginal part of the ice during its retreat, would either cover these deposits made under the body of the ice at an earlier time or be left alongside them. The constitution of the two phases of till is essentially the same, and there is nothing in their relative positions to sharply differentiate them. They are classed together as subglacial till.

It will be seen that these subglacial accumulations of till were made under the pressure of the overlying ice. In keeping with these conditions of accumulation the till often possesses a firmness suggestive of great compression. It is often remarkably tough where its constitution is clayey. Where this is the case the quality here referred to has given rise to the suggestive name "hard-pan." Where the constitution of the till is sandy, rather than clayey, this firmness and toughness are less developed, or may be altogether wanting, since sand cannot be compressed into solid masses like clay.

The constitution of the till.—The till is composed of the more or less comminuted materials derived from the land across which the ice passed. The soil and all the loose materials which covered the rock entered into its composition. Where the ice was thick and its action vigorous it not only carried away the loose material which it found in its path, but, armed with this material, it abraded the underlying rock, wearing down its surface and detaching large and small blocks of rock from it. It follows that the constitution of the till at any point is dependent upon the nature of the soil and rock from which it was derived.

If sandstone be the formation which has contributed most largely to the till, the matrix of the till will be sandy. It sometimes chanced that the ice traversed areas of loose sand. In such cases it incorporated large quantities of sand into its lower portion, or pushed it forward beneath itself, sometimes mingling it but slightly with material of other kinds derived from other sources. Sand derived in this way, and deposited directly by the ice, falls within the general class of subglacial till. Occasionally sand nearly free from all other constituents thus comes to make up the body of the till. Such developments are generally local, and beneath them or above them there may be till of a very different constitution. In New Jersey such till was seen within the limits of Orange, on High street, where exposures, several feet in depth, were open to observation during the laying of sewer-pipes it the summer of 1891.

Where shale instead of sandstone made the leading contribution to it, the till has a clayey matrix. Any sort of rock which will be very generally reduced to a fine state of division under the mechanical action of the ice, will give rise to a clayey till.

The nature and the number of the bowlders in the till, no less than the finer parts, depend on the character of the rock overridden. A hard and resistant rock, such as quartzite or trap, will give rise to more bowlders in proportion to the total amount of material furnished to the ice than will softer rock. Shale or soft sandstone, possessing relatively slight resistance, will be much more completely crushed. They will, therefore, yield proportionately fewer bowlders than will harder rocks, and more of the finer constituents of till.

The bowlders taken up by the ice as it advanced over one sort of rock and another, possessed different degrees of resistance. The softer ones were worn to smaller dimensions or crushed with relative ease and speed. Bowlders of soft rock are, therefore, not commonly found in any abundance at great distances from the point of their origin. The harder ones yielded less readily to abrasion, and were carried much further before being destroyed, though even such must have suffered constant reduction in size during their subglacial journey. In general it is true that bowlders in the till, near their parent formations, are larger and less worn than those which have been transported great distances.

The bowlders which are carried furthest beneath the ice will be subjected to most wear. If bowlders were all of the same constitution, the relative measure of wear would be, in some rough sense, a measure of the distance of their subglacial transportation. And for any given kind of rock this is true. But since bowlders of certain kinds of rock are much softer than those of other kinds, and therefore are more readily worn, it follows that the softer bowlders may suffer more wear in a short journey than harder ones in a long one. For example, bowlders of shale, being but slightly resistant, generally suffer but a limited transportation before they show notable marks of wear, both in the forms they assume and in the markings which their surfaces receive.

Since the ice which covered the northern part of New Jersey had passed over wide stretches of territory before reaching this latitude, it had also passed over rocks of many varieties. The till of New Jersey, therefore, contains elements gathered from a wide range of territory. But in general it is true that the till of any locality is made up very largely of material derived from the formations close at hand. In the counties of Union and Middlesex, for example, the drift is very red, being derived largely from the red shales and sandstones of the immediate vicinity. A much lesser constituent of the drift has been derived from formations lying further north in New Jersey, and still further north in New York. Where the widely-transported material is in the condition of clay or sand it may be mingled with constituents of local derivation, in such wise that it is not easily recognized. But when in masses of sufficient size for ready identification, such as pebbles, cobbles and bowlders, it may be distinguished without difficulty. Since much of the till is in a fine state of division, it may be that a much larger proportion is derived from a somewhat distant source than would at first appear. But it is yet true, as observations over a wide range of territory demonstrate, that distant formations have contributed much less than those near at hand, to the till of any locality.

This fact seems to afford sufficient warrant for the conclusion that a considerable amount of deposition must be going on beneath the ice during its movement, even back from its margin. To take a concrete illustration, it would seem that the drift of northern New Jersey should have had a much larger contribution of material, derived from central and northern New York, than it has, if material once taken up by the ice was mostly, or even in large measure, carried down to its thinned edge before deposition. The fact that so little has come from these distant sources would seem to prove that a large part of the material moved by the ice is moved a relatively short distance only. If this be true, the ice must be conceived of as continually depositing parts of its load, and parts which it has carried but a short distance, as it takes up new material from the territory newly invaded.

Where rock is very soft and easily reduced to fineness it sometimes happens that the fine parts of the till overlying it and covering the regions in its lee, are mainly of local origin, while the bowlders are mainly from some more distant source, where the rock was harder, and therefore better able to endure transport without destruction. In case the ice has come from a region of soft rock to one of harder, the till might have a similar constitution. But in this case it would be the finer part instead of the coarser which had suffered the wider transport, and the bowlders would show less wear than in the other case.

For one reason or another, material which has been widely transported may be almost wholly wanting in the till. In such cases both the finer parts of the till and the bowlders are of local origin. The bowlders may be few or abundant. In some cases the till is largely composed of blocks of rock that seem hardly to have been carried from their original area. They have been disturbed in their positions and have had the fine parts of the till mixed with them so that they appear to have been kneaded into it. In such cases the rock masses are angular and rough, and frequently increase in size and number from the top of the till to its base. At the base they may be so abundant as to nearly exclude all other constituents. If the surface of the rock be much broken and its uppermost layers disrupted and crumpled, as is sometimes the case, and if the angular masses of rock in the basal part of the till become so abundant as to nearly exclude the finer constituents, it is sometimes difficult to say where the line between the bottom of the till and the surface of the underlying rock is to be drawn. The till overlying the rock at one of the quarries in Newark affords a good illustration of the relationship here described. (See Plate II.)

The subglacial till forms a somewhat general mantle over the glaciated area, and yet it is not universal; it failed of deposition in some places; it has been subsequently carried away by running water in others; it has been buried by the silts, sands and gravels deposited by the melting-ice waters in still others.

Subglacial till is frequently termed *bowlder clay*, a name which seems most appropriate where the till is largely composed of clay and imbedded bowlders. (See Plate I., representing cut through bowlder clay in Newark.) But "bowlder clay" would fail to be a definitive term for till composed of clay alone, or for that composed principally of sand or stony material. Another term which is synonymous with subglacial till is *ground moraine*. In the broader

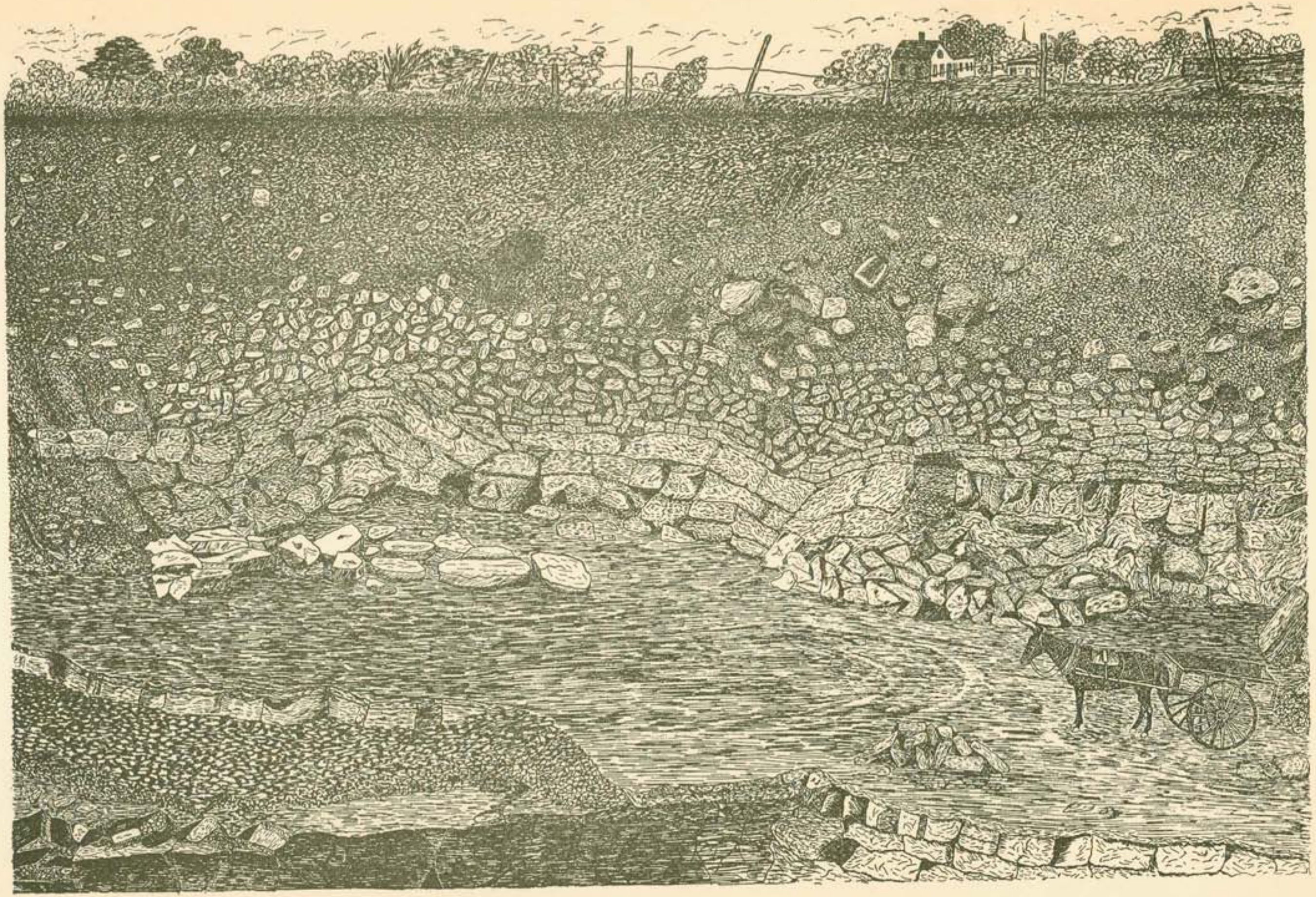


PLATE II.—Till, largely of local origin, grading through broken rock to undisturbed rock below. Quarry, north part of Newark. From a photograph.

sense of the term, all deposits made by the ice are moraines. Those made beneath the ice and back from its immediate margin are designated "ground" moraine, to distinguish them from other deposits made by the ice. Of all the glacier deposits, the ground moraine has the greatest extent, whether its area or its volume be considered. It also contains a greater proportion of planed and striated stone than any other part of the drift. Any stone or bowlder in the ground moraine stood a chance of being rubbed over other stone, or over the bed-rock beneath it, and of being rubbed over by sand or stone or clay imbedded in the ice above it, or on either side. In many places more than half of the rock fragments of the ground moraine show distinct glacial markings. The proportion of the fragments of the softer varieties of rock which show these markings is often much greater.

The topography of the ground moraine is, in general, the topography already described in considering the modifications of preglacial topography, effected by the ice. As left by the ice, its surface was undulating. The undulations did not take the form of hills and intervening valleys, but of swells and depressions standing in no orderly relationship to each other.

Special Forms of Till Hills—Drumlins.

In various parts of the great drift-fields of the United States, there are aggregations of till of such symmetrical form and regular arrangement, that they have attracted wide attention. The most notable of these are hills of somewhat elongate form, smooth and flowing contours, and regular slopes. Their horizontal axes sustain to each other a ratio varying from 1 : 2 to 1 : 6. Their end slopes, from 3° to 10°, are commonly gentler than their side slopes (10° to 20°).* In any given region their longer axes are approximately parallel with each other, and correspond in direction with the course of the ice movement in the same region. In length they vary from one-eighth of a mile to two or more miles. In height they range up to 300 feet, though drumlins more than 75 feet or 100 feet high are rare. They are composed of till, which is generally very compact. The proportion of striated material which they contain is high.

* Davis, American Journal of Science, III. Series, Vol. 28, p. 409 (1884).

Such hills are known as *drumlins* (sometimes *drums*). The definitive terms *elliptical hills*, *lenticular hills*, and *mammillary hills*, have also been applied to them, and these names may still be serviceable, for the purpose of designating varieties of drumlins.

There may be stratified drift within the body of the drumlins, overlain and underlain by till. The core of the drumlins is sometimes stratified material.* Certain drumlins have been thought to indicate periodic growth, as if layer after layer of till were added through a period of years.†

Various suggestions have been made concerning the mode by which drumlins have been developed. Their form has been ascribed to waves, or to waves assisted by subaërial erosion,‡ but it is not easy to see how waves could develop such forms, or why, if they could, the longer axes of the drumlins in any region should be so constantly parallel to the direction of ice movement in that region, as the striæ show them to be. Furthermore, they occur where there is no independent evidence that lake or sea-water has existed since the drift was deposited.

Their form, their structure and their arrangement seem to leave no room to doubt that they were made beneath the ice—that they are but phases or special developments of the ground moraine. But, thus restricted, there are various hypotheses as to the mode by which the drumlins came into existence. They have been regarded as hills first carved out of an older sheet of drift by subaërial erosion, and later modified in form and contour by the passage of a second ice-sheet over them.§

Were this the true explanation of the drumlins, they should be composed mainly of old drift. At most, they would be merely coated with new drift, deposited by the later ice invasion. So far as the drumlins with which the writer is familiar are concerned, they appear to be composed wholly of new drift. If all the weathered portion of the old till were worn away by the later ice-sheet, leaving the unweathered portion only, it is not certain that this could be distinguished from the new till. In this case, the point here suggested would be without force. Again, the drumlins have been regarded as

* Upham, Proc. Bost. Soc. Nat. Hist., Vol. 24, pp. 232-3 (1889).

† Upham, op. cit., pp. 235-6.

‡ Shaler, Illustrations of the Earth's Surface, p. 63.

§ Shaler, Ninth Annual Report U. S. G. S., pp. 550-1.

the hills of older terminal moraines, overridden and reshaped by later glaciers. But neither the distribution nor the composition of drumlins seems to favor this hypothesis. It seems altogether probable that the drumlins are built up beneath the ice, and not fashioned from hills overridden by it. It has been suggested that their development beneath the ice is analogous to the development of sand-bars* in a stream, and this suggestion probably has some measure of truth in it.

Wherever any slight obstruction which the ice could not remove, stood in its way, debris, urged forward beneath the ice, might lodge against it. Such an obstacle might be a prominence of resistant rock,† or a mound of drift which, for one reason or another, the ice at that point was unable to remove. The obstacle was thus enlarged by the lodgment of drift against it, though its obstructive effect was not necessarily thereby increased, since the additions would so dispose themselves as to give the obstacle that form which would offer least resistance to the moving ice. Under special conditions such an obstacle, once its growth was started, might continue to grow so long as ice passed over it, and its resulting form would correspond to that of a drumlin.

Were such accumulations made in any place beneath the thin outer portion of the ice during the period of its advance, they might subsequently be destroyed by the greater erosion accomplished by the greater depths of ice which would come to rest upon them at a later time. Even were all the drumloid forms which might be accumulated beneath the thin part of the ice-sheet during its advance, destroyed by the ice resting upon them when it had spread further, it might yet be true that they would accumulate beneath the thinner part of the ice as it receded. For it is to be borne in mind that even in receding there was forward movement, though this movement was more than counterbalanced by edge-melting. The drumlins are sometimes regarded as thus formed beneath the ice, but so near its margin that its thickness and eroding strength were not great, and its transportive power slight.

But it is not altogether clear that drumlins or drumloid aggregations of till formed beneath the thinner parts of the advancing ice, would be always destroyed when the ice became thicker at the same point. The erosive power of the ice would doubtless increase with

* Kinahan and Close, General Glaciation of Iar-Connaught (Dublin, 1872).

† Chamberlin, Third Annual Report U. S. G. S., p. 306 (1881-2).

increasing thickness up to a certain undetermined point, beyond which it might not continue to increase, at least not in the same ratio. Increased depth of ice means increased pressure upon its lower parts. Increased pressure upon the ice means increased fluidity (mobility), and increased fluidity means decreased erosive power. It is conceivable that the erosive power of the edge of the ice may have been relatively low, because of lack of pressure upon the underlying surface; that further back from its edge the erosive power may have been greater, because of the increased weight with which the ice rested upon its substratum; but that still further back, the erosive power ceased to increase, because the greater pressure of the ice rendered it too mobile, or too fluid, to be effective as an abrading agent.

If there be anything in this suggestion, drumloid forms developed in the vicinity of the ice's edge during its advance might, to some extent, escape destruction during further progress of the ice, and might have another period of growth, when, in its recession, the thin part of the ice-sheet again lay over the same region. Indeed, it is not clear that growth might not take place beneath the very thick ice.

The drumlins have never seemed to the writer the anomalous forms that they are sometimes thought to be. It seems to him the strange thing, rather, that drumlins are not more common. Their occurrence in certain regions, and in certain regions only, seems to him the only anomalous thing about them. Their distribution needs explanation. It is not clear that any of the suggestions which have yet been made concerning their development, would not apply to one region as well as to another. Much less would they seem to apply only to the areas where the drumlins occur.

In New Jersey, drumlins are not now known to have much development. The elliptically-shaped hill in East Orange (the corner of Munn street and Central avenue being at about its center) appears to be a drumlin. Another occurs a mile and a half west of Rahway, on the road running east and west along the south side of Robinson's branch; on the topographic map its height is shown to be 106 feet above mean tide.

While the drumlin type is fairly distinct, drumlins grade into hills which are not drumlins. When they become somewhat irregular in form they are sometimes designated drumloids, drumloid hills or immature drumlins. It is not certain that some of them may not be over-mature drumlins—that is, drumlins made irregular by unequal surface deposits upon regular drumlin forms.

Hills, the greater part of whose mass is rock, may have drift so banked against them, and spread over them, as to closely resemble drumlins. Such hills are known as *veneered hills.** If there be no exposure to reveal the rock, veneered hills may be mistaken for drumlins. Some of the lenticular hills about Newark appear to belong to this class.

A deposit closely simulating glacier till may be made by water and ice jointly. When shallow lakes existed along the margin of the ice, as was sometimes the case, bergs of ice detached from the ice sheet floated out upon it, carrying burdens of stone and clay which were distributed over the lake's bed. Such materials would be dropped from the ice wherever in its melting its hold upon them was loosened, or wherever the berg grounded. In some cases but a slight degree of stratification was developed in the fine materials thus deposited, and the coarser are scattered through the fine much as in true till. Till thus formed is known as *subaqueous* till or *berg till.* It can generally be distinguished from glacier till "(1) by a more homogeneous clayey base; (2) by a more uniform distribution of imbedded erratics; (3) by occasional traces of indistinct lamination; (4) by its surface expression; (5) by its distribution, and (6) by its stratigraphical relations. It is manifest, upon consideration, that the finer material settling down from suspension in water would distribute itself with greater uniformity than is possible to clay accumulated under a moving glacier. It is also evident under the law of probabilities that erratics, falling from floating ice as it melts, would be dispersed with a general regularity unless there were currents or other circumstances that determined concentration along certain lines or in certain areas. The rock fragments often stand in the clay on their edges or points, as though they had been received on a soft mud bottom as they fell through the water. Where lamination is observed, the lower clayey leaves may sometimes be seen to be flexed beneath the stone, while the upper ones curve over it as though it had depressed the former in its fall, while the latter had been subsequently formed over it." † Berg till has not as yet been recognized in New Jersey. If it exists it will be found in some of the plane tracts of the State, where the topographic relations were such as to allow the formation of temporary lakes at the margin of the ice.

* Chamberlin.

† Chamberlin, Third Annual Report U. S. G. S., pp. 297-8 (1881-2).

Englacial and Superglacial Till.

Mountain glaciers of the present day carry considerable loads of rock debris upon their surfaces. This is derived, for the most part, from the slopes of the mountains between which they flow. This surface material is composed of large and small blocks of rock, Most of it was not detached by the glaciers themselves, and its presence upon them is not the result of any activity on the part of the ice. Whatever causes operate to loosen masses of rock from mountain slopes, have detached these blocks,. and they have rolled or fallen down into the valleys below. Where a glacier occupies the bottom of a valley, its surface becomes the lodging-ground for such debris.

It will be readily seen that this superglacial material would be markedly unlike the drift subglacially transported. In the first place, it is carried quietly along without being subjected to ice-pressure, or to the abrasion which rock moving over rock effects. It would, therefore, be carried forward, if no accident, such as falling into crevasses, befall it, until it arrives at the end of the glacier—that is, until it has reached the point where the melting (and evaporation) of the ice counterbalances its forward movement. Among the surface blocks of rock there might be a slight amount of motion, and therefore of wear, since all parts of the surface of the underlying ice do not move with equal velocity. Such movement would tend to wear the rock masses and produce finer products. But much of the rock thus borne arrives at the edge of the ice in a physical condition much like that which it possessed at the beginning of its journey. The blocks of rock are largely angular, exhibiting still the fracture-faces which they possessed at the time of their disruption from their parent mountains. Some fine material would fall upon the ice, along with the coarse, and some might be washed upon it by waters descending from the slopes above, while, from wider sources, the wind might mingle dust and sand with the debris otherwise accumulated upon the ice. In this way it is conceivable that the stones upon the ice might come to have associated with them a considerable quantity of clayey earth and sand. On existing glaciers the amount of this fine material is generally very subordinate to that of the coarse. Rarely does it become sufficiently abundant to form a matrix for the coarser material.

Since the end of the glacier is being constantly melted off, the material it bore upon its surface is continually being dropped at its end. Such material as the ice-sheet bore upon its surface in glacial times would have been treated in a similar manner, and since, in its retreat, the edge of the ice lay along all lines northward from the position of its extreme advance, such surface material as may have existed would have been dropped upon the surface of the ground moraine, and should now overlie it. So far as it consisted of bowlders, these should be more angular than those of subglacial till, and if found in the relations in which the ice left them, should be scattered over the surface of the ground moraine. If in any case there was fine material upon the ice in such quantity as to form a matrix for the bowlders, or in such quantity that the whole of the surface drift was enough to form a distinct layer, this material, deposited upon the surface of the ground moraine, would constitute *superglacial* or *"upper" till,* and would be so classified wherever its surface origin could be determined.

Such materials as were carried forward in the ice above its basal portions and below its upper surface may be called *englacial.* By the melting of the upper surface of the ice englacial material would approach the upper surface. By the melting of the lower surface of the ice the englacial material would continually approach the bottom of the ice. All englacial material will ultimately become subglacial or superglacial. It cannot remain englacial permanently. Whether in any given instance the englacial material reaches the upper or the lower surface depends (1) upon the relative thickness of the ice above and below it, and (2) upon the relative rates of waste of the two surfaces. Could the material which had suffered transport in the ice above its basal parts be distinguished, after its deposition, from that which is carried forward at the upper and lower surfaces, it would receive the name of *englacial till.* Such a class of till has a theoretical existence in regions once glaciated, though its discrimination from super- and subglacial by transported material would be difficult, if ever possible.

In the case of such an ice-sheet as that which invaded the United States, little material could get upon the surface of the ice after the fashion of mountain glaciers, unless in the early stages of its development, for elevations of land which projected through the ice, and which could have yielded materials to its upper surface, were mostly wanting. Like the ice-sheet of Greenland to-day, the surface of the ice-sheet with whose work we are dealing must have been essentially free from surface debris at the time of its maximum advance, as well as during all the time of its great extension. Where the ice covered hills and mountains it must have derived material from their tops which projected up into its mass. This material was englacial until it became either superglacial or subglacial.

It has been held by some glacialists that drift which starts in a subglacial position may become englacial * or even superglacial, by rising, by one process or another, through the ice. This hypothesis would seem to be necessary if the amount of superglacial and englacial ("upper") till be so great as it is sometimes believed to be, for it is altogether improbable that any such amount of material as is sometimes reckoned to the classes of till under consideration, existed upon the ice at the outset, or so near the upper surface as to finally become superglacial by the ablation of this surface. It is not difficult to conceive that much of the englacial material carried by ice which has passed over a mountainous region, might become superglacial, as a result of superficial melting. But in plane regions, and in ice which has passed over plane regions, for the most part, it is not clear that much englacial drift could become superglacial by surface ablation, since most of the englacial material, in the beginning, must have been near the lower surface of the ice.

The hypothesis that subglacial material worked its way to the top of the ice is made necessary further, in order to explain the presence of material which has suffered very little transportation, and that over a flat country, in the so-called superglacial ("upper") or englacial till. The same hypothesis would seem to be called for to explain the somewhat abundant presence of striated bowlders in the till which is regarded as superglacial. For, like the superglacial material, the englacial drift, unless its quantity be very great (at least locally), relative to the amount of inclosing ice, is not likely to receive much wear. There is likely to be little grinding and crushing, the products of which are "rock-flour" or the "clay" of subglacial till. The differential motion of the ice would involve some friction among the englacial material, so that wear, similar to that of the debris beneath the ice, might affect it. But such wear would be on a much less extensive scale in englacial than in subglacial material unless the amount of englacial material was very great.

* By englacial, as here used, is meant a position above the *basal* part of the ice. The basal part of the ice is very generally believed to have carried much debris.

As might be inferred from the preceding paragraphs, there is much difference of opinion among glacialists as to the amount of till which is to be classed as superglacial (counting as superglacial all that was ultimately transferred from a subglacial or englacial to a superglacial position). Since this difference of opinion exists, it is clear either that the criteria for distinguishing the two classes of till are not well defined or that many glacialists have not been able to apply them successfully.

In general, superglacial till, having been subject to less pressure, should be less compact than subglacial. Its bowlders should be less worn, and a large portion of them should be of more distant origin. The finer material of the drift, if existing glaciers give us safe data to reason from, should be relatively less abundant in superglacial till than in subglacial. The finer material, too, should be, to a less extent, the product of mechanical comminution.

There is another source than mechanical comminution for the finer materials of superglacial till. This has been alluded to already. During the course of the glacial period, the winds doubtless blew much dust upon the accumulating snow which made the ice, and later, after it had spread beyond the region of accumulation, upon the ice itself. Much of that which was buried in the accumulating snow would come to be superglacial in the end, though for a time englacial. When the drift deposits were first made, the dust which had such an origin may have been sufficiently different from that made by the mechanical action of the ice to have afforded means of discrimination. But in the course of the time that has elapsed since the deposition of the drift, the action of rains and frosts, and of plants and animals, has very materially altered the uppermost part of the till, and the changes which these agencies have produced when operating upon subglacial earths, have been such as to render them more and more like the earths which might have accumulated upon the ice by the process indicated, thus obscuring any differences that might have existed at the outset. Any distinction, therefore, between superglacial (and englacial) and subglacial till, based on the character of the finer materials, is one which cannot always be made.

Some of the criteria relied upon for the indentification of superglacial till, have the misfortune to be such as can be produced in other ways, and in particular such as must be produced by the weathering of the surface of subglacial till.* The weathering of such till includes the action of frost and heat, drought and rain, sun and air, plants and animals. These agencies tend to loosen up the compacted material of the subglacial till. The material thus changed lies at the surface of the unaltered subglacial till, just the position which the loose superglacial till, when present, must occupy. The upper surface of subglacial till which thus loses its compactness comes to be very like the superglacial till which was never compressed. The difficulty in the application of this criterion does not hold where the depth of the till, regarded as superglacial, is greater than the depth to which the loosening effect of weathering has extended, as is sometimes the case.

Again, the greater oxidation and leaching which is claimed for the superglacial till must be the necessary accompaniment of the loose texture which characterizes the upper surface of the drift, whether this looseness of texture be original (superglacial till) or acquired (weathered surface of subglacial till).

The greater infrequency of striated bowlders in the uppermost part of the drift, regarded as "upper till," might be accounted for, in many cases, by the corrosion which their surfaces have suffered since their deposition. This suggestion does not necessarily vitiate the criterion in all cases, or perhaps in most, but it indicates that there are limits to its application. So with other criteria which have been relied upon for the discrimination of upper till. Some which appear to be good are rarely applicable. Others which are more widely applicable do not appear to be decisive.

For discriminating superglacial from subglacial material, the criterion which seems to the writer most decisive, and most easy of application as well, is the *relative abundance of unworn or slightly-worn bowlders of distant origin.* This criterion is liable to more exceptions in mountainous regions than in plane ones.

The writer is not disposed to believe that superglacial (and englacial) till has not a real existence, though he is inclined to believe that its quantity has been overestimated, so far as our country is concerned, and that the criteria, which are commonly relied upon for its identification, are by no means such as to make its recognition certain, except in favored localities.

---

* For criteria of englacial and superglacial till, see American Geologist, December, 1891. Upham.

Terminal Moraines.

It has already been indicated that the ice carried much of the material gathered beneath itself to or nearly to the limit of its advance. It is generally held that the marginal portion of the ice-sheet was more heavily loaded—certainly more heavily loaded relative to its thickness—than any other. The thinned ice toward its margin was constantly losing its transportive power, and at its edge this power was altogether gone. Since the ice was continually bringing drift down to its margin, the rate of accumulation of drift beneath the edge of the ice must have been greater than elsewhere.

Whenever, at any stage in its history, the terminus of the ice remained constant in position for a long period of time, the submarginal accumulation of drift would come to be great; and when the ice disappeared the site of the margin, for the time during which it was stationary, would be marked by a broad ridge or belt of drift, thicker than that on either side. Such thickened belts of drift, due to the causes here noted, are known as *terminal moraines.* The terms *marginal, submarginal* and *frontal* moraines have also been applied to them, because of their positions with reference to the margin of the ice during the time of their accumulation, and the term *lodge* moraine,* referring to the method of their formation. The last term was first used to distinguish moraines accumulated in the manner here indicated from other and subordinate varieties of terminal moraines.

From the conditions of their development it will be seen that these submarginal moraines may be made up of materials identical with those which constitute the ground moraine within (north of) it. As might be inferred, many a section of a terminal moraine shows material identical, in all essential respects, with that of the subglacial till, close at hand. But water, arising from the melting of the ice, played a much more important rôle at its margin than further back beneath it. One result of its greater activity may be seen in the greater coarseness which generally characterizes the material of the marginal moraine, as compared with that of the adjacent ground moraine. This arises, in part, at any rate, from the fact that the water carried away some of the finer constituents, which it was able to transport, leaving behind the coarser parts, which it was not able to transport. A further evi-

* Chamberlin, Bulletin Geological Society of America, Vol. 1, p. 28 (1890).

dence of the relatively greater activity of the water near the margin of the ice is to be seen in the greater proportion of stratified material, as compared with the ground moraine.

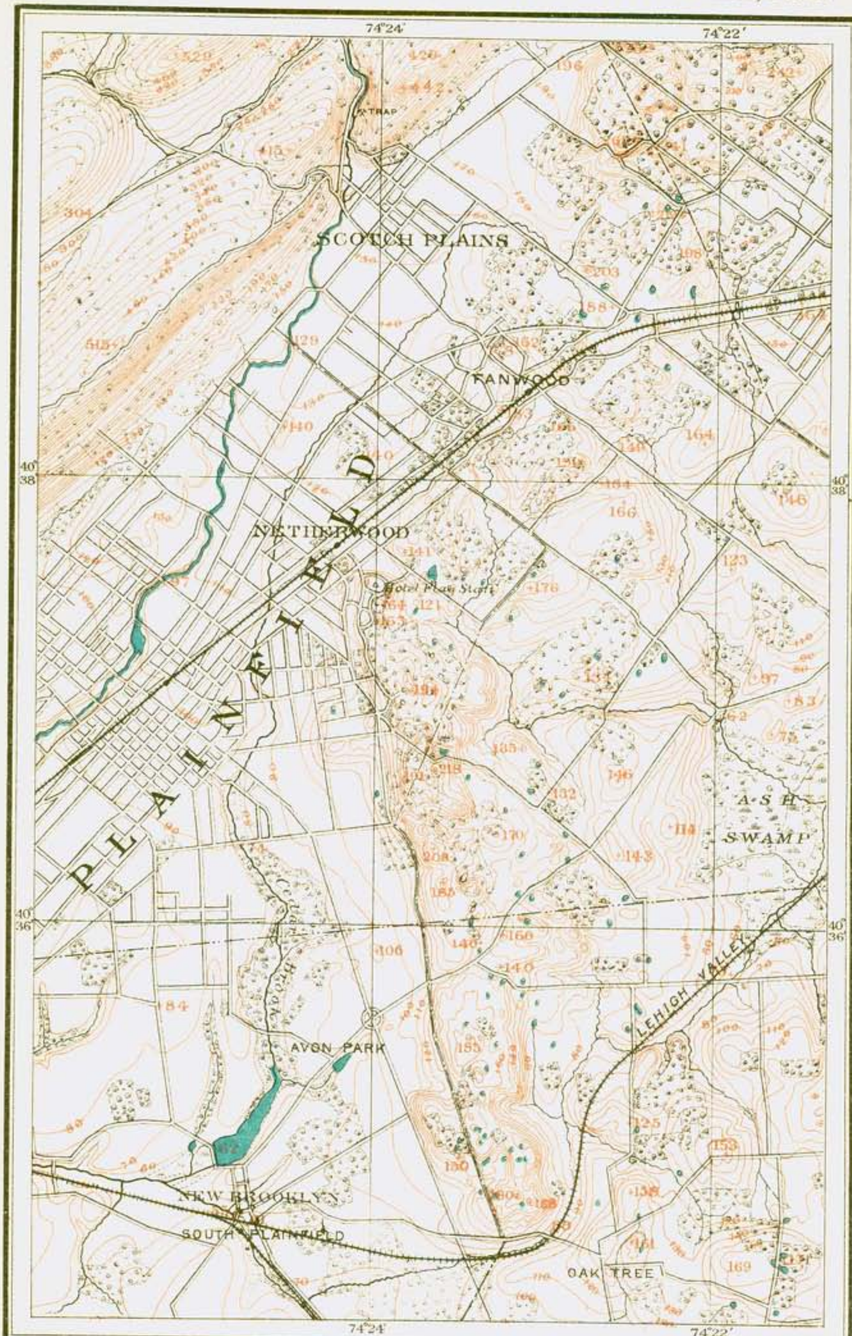
Such materials as were carried upon the ice would be dropped at the edge of the ice, and would rest upon the surface of the marginal and submarginal accumulations. If the surface of the ice carried many bowlders, it might happen that great numbers of them would be dropped along the line corresponding to the ice's edge, wherever the edge remained practically without motion for a considerable time. In this way a sort of bowlder-wall might be built up, resting upon the material accumulated at the edge of the ice. Such bowlder-walls have not been described in America, but they exist in Germany and perhaps in other parts of Europe. In Germany it is these bowlder-walls which have received the name of terminal moraines (*Endmoräne*). In the United States such bowlder-walls, were they known, would be classed as *dump* * moraines—a variety of terminal moraines made from the material which was carried on the ice and "dumped" at its terminus. To restrict the name terminal moraine to these bowlder-walls or "dump" moraines, is to shut out from the category of terminal moraines other varieties of moraine formed at the terminus of the ice. In this country the material, where such there was, having such a mode of deposition, has not been generally distinguished from other marginal accumulations made by the ice. The bowlder belts, which have a somewhat local development in some of the interior States, are probably identical in genesis, though not in form, with the bowlder-walls or *Endmoräne* of Germany.

Since all the marginal accumulations are essentially one in position, and since all are phenomena of the margin of the ice, and for the most part not yet satisfactorily discriminated from each other, no attempt will be made to delineate them separately upon the maps. But for a clear conception of the multitudinous phases of the ice's work, it is important to bear in mind that a part of the material of a terminal moraine may have had such an origin.

The terminal moraines therefore embrace (1) the material accumulated beneath the edge of the ice while it was stationary, or nearly stationary, for a considerable period of time, so as to form thick ridges or belts of drift; (2) that carried on the surface of the ice and dumped at its margin, as well as (3) such material as the ice pushed

* Chamberlin, Bulletin Geological Society of America, Vol. 1, p. 28 (1890).

SECTION OF MORAINE, NEAR PLAINFIELD, N.J.



up in front of itself by the forward motion of its edge. Of these three classes of material, that accumulated beneath the edge of the ice is believed to have been much more important than the others—that is, the material "lodged" beneath the ice edge is greatly in excess of that "dumped" at its margin or "pushed" before it.

At various stages in its final retreat the ice made more or less protracted halts. The halting-places are marked by marginal moraines, greater or smaller, in proportion to the duration of the halt.

A terminal moraine is not the sharp and continuous ridge we are wont to think it. The great terminal moraine of New Jersey, like terminal moraines in general, is a belt, rather than a ridge, of drift. In width it varies from a fraction of a mile to several miles. It is often but slightly higher than the area on either side, and sometimes even lower than that on the one side or the other. But the depth of drift is generally greater than that on either hand.

Topography of Terminal Moraines.

By far the most distinctive feature of the terminal moraine is not its ridge-like character, but its topography. Nearly everywhere it is characterized by depressions without outlets, associated with hillocks and short ridges comparable in dimensions to the depressions. In the depressions occur many marshes, bogs, ponds and small lakes. The shape and abundance of round and roundish hills have locally given rise to such names as the "knobs," "short-hills," &c. In other places the moraine has been named the "kettle range" from the number of the kettle-like depressions upon its surface. But it is to be kept in mind that it is the association of the "knobs" and the "kettles," and not either feature alone, which is the especially characteristic mark of the terminal-moraine topography.

The accompanying plates, III. and IV., illustrate the topography and the topographic relations of the terminal moraine. Plate III. is a reproduction of a portion of the topographic map (sheet 6), in the vicinity of Plainfield. Through the area represented on the map runs the terminal moraine. The course of the moraine may be readily traced by the irregularity of the contour lines. Beginning northwest of Westfield the moraine runs slightly west of south through Fanwood; thence, in the same general direction, just east of Netherwood; thence, in a southerly direction, to Oak Tree, bearing slightly to the east. Its average width is about one mile. The abundance of hills and short ridges, with their intervening depressions, which mark the surface of the terminal moraine, express themselves on the map by the irregularity of the contour lines along the belt indicated. The contour lines on either side of the moraine belt are much more regular. Some of the depressions among the hills contain water, thus constituting ponds or small lakes.

It will be seen that the altitude of the moraine belt, as a whole, is greater than that of the land on either side. The moraine belt is, therefore, ridge-like, and the short hills and abrupt little ridges which mark its surface are but constituent parts of the larger, broader ridge, or terminal-moraine belt.

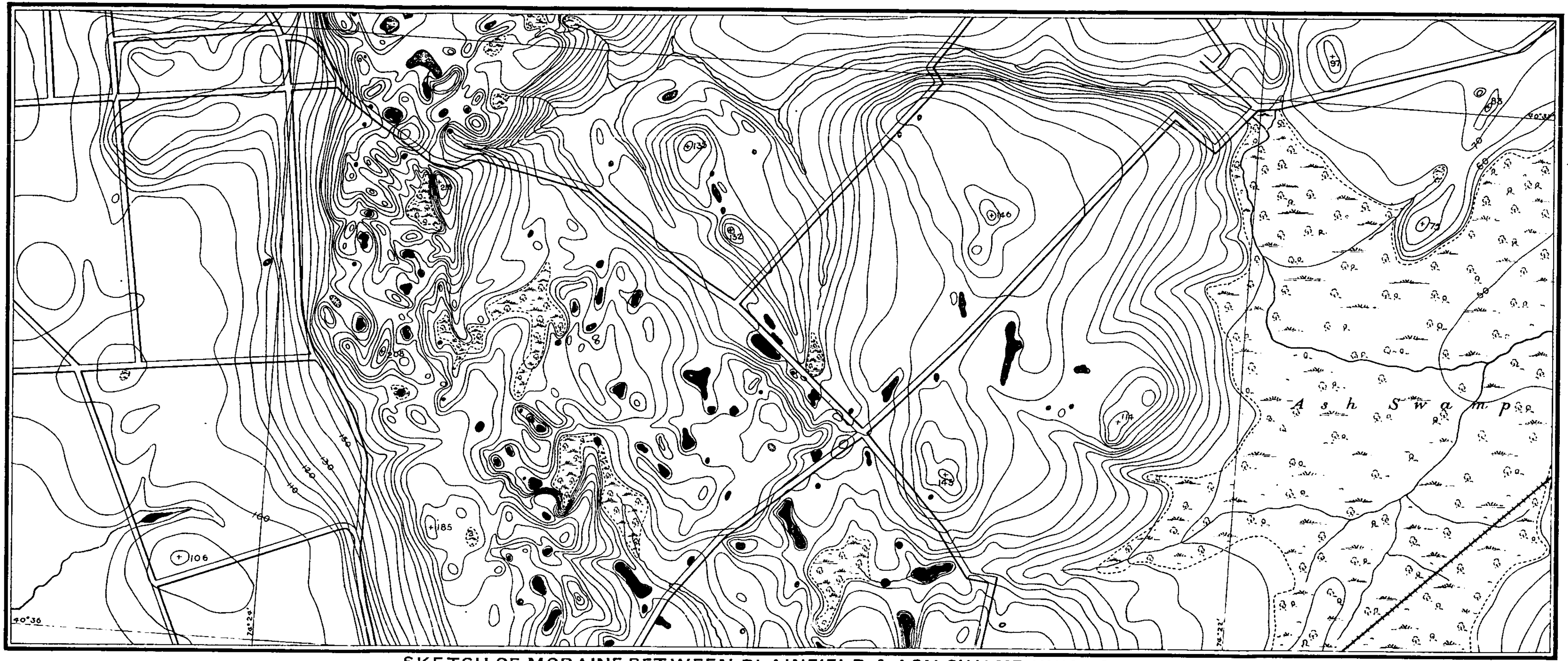
The area immediately west of the moraine represents an "overwash" plain (see p. 96). It consists of gravel and sand deposited by waters emanating from the melting ice. The high land in the northwest corner of the map, rising with steep and regular slope above Scotch Plains, represents the slope of a rock ridge. The regularity of its slopes, as shown by the regularity of the contour lines, is in striking contrast to the irregularity of the slopes of the moraine.

East of the terminal belt, the edge of the ground moraine is shown. Between this and the terminal moraine there is no sharp line of demarkation. The one grades into the other. Ash swamp represents a feature common to the inner face of a terminal moraine, where ill-drained areas are likely to occur.

Plate IV. represents a portion of the same area on a much larger scale. On this plate the contour lines are at intervals of five feet instead of ten. All the depressions which contain water (ponds) are here indicated. It will be seen that the terminal-moraine belt is a belt marked by an abundance of ponds. It should be borne in mind that the actual number of hollows or depressions is much greater than the number of ponds, since only those depressions whose bottoms are relatively impervious, retain the water which falls and flows into them, thus making ponds.

The following are among the many localities in New Jersey where the moraine may be seen in its typical development:* The northwest part of Perth Amboy; just north of Metuchen; at Oak Tree, and between Oak Tree and Netherwood and Fanwood, east of Plain-

* For general description of terminal moraine of last ice epoch, see Third Annual Report U. S. G. S., pp. 291-402. Chamberlin.



SKETCH OF MORAINE BETWEEN PLAINFIELD & ASH SWAMP, UNION CO.

600 5 4 3 2 1 0 600 1200 1800 2400 FEET

field; east and southeast of Morristown; a mile or two north of Hackettstown; and north of Butzville. A subordinate terminal moraine, marking a halt in the retreat of the ice, has an interrupted course west-southwest from Waverly, passing by Lyons Farms and south of Union (Connecticut Farms). It has its best development about two miles northeast of Cranford. Other recessional moraines will probably be found when the whole glaciated area of the State shall have been studied.

The manner in which the peculiar topography of terminal moraines has been developed is worthy of note. In the first place, the various parts of the ice margin had unequal amounts of drift to deposit. This alone would have caused the moraine to have been of unequal height and width at different points. In the second place, the margin of the ice, while having the same *general* position during the making of a moraine, was yet subject to many oscillations. It doubtless receded to some slight extent because of increased melting during the summer, to advance again during the winter, when the melting was less. In its recession, the ice margin probably did not remain exactly parallel with its former position. Some parts receded more and some less, so that the details of the line of its margin may have been quite different at the close of a summer's season from those at the beginning. When the ice again advanced, its margin may have again changed form in some slight measure because of unequal rates of motion, so as to be parallel neither with its former advanced position nor with its position after its greatest temporary retreat. With each successive fluctuation in position, the details of the ice margin may have altered, and all the time the depositions beneath the edge would conform in position to the varying margin. There might be considerable change in the outline of the edge of the ice, even when there was no general recession or advance, as existing glaciers show. Any cause which would induce variable rates of melting or advance at the margin of the ice would help to bring about this result.

It may have been true of the margin of the ice-sheet, as of glaciers at the present time, that there were periods of years when the edge of the ice receded, followed by like periods when it remained stationary or nearly so, and these in turn followed by periods of advance. During such advances, the deposits made during the period of recession would be overridden and disturbed.

If the margin of the ice during a halt following the re-advance, did not correspond exactly in position with the earlier advanced margin, the submarginal ridges of drift formed at the two stages of advance would not correspond in position. The later might touch the earlier at some points, when the two submarginal ridges would become one, and fail to reach it at other points, when there would be a depression between them. The ice in its re-advance might pass beyond its earlier position at some points, overriding such deposits as had been earlier made. If the ice were to retreat and advance repeatedly during a considerable period of time, but always within narrow limits, while the details of its margin were frequently changing, the result would be a complex or "tangle" of minor morainic ridges of variable heights and widths, formed beneath the edge of the ice during the halts which intervened between the periods of movement. Between and among these minor ridges there would be depressions of large and small size and of variable shapes. Thus, it is conceived, the peculiar hillocks and hollows which characterize the terminal moraine may have arisen.

DRIFT DEPOSITS MADE BY WATER.

1. In Connection with the Ice.

Even during the advance of the ice, and while it was in most vigorous action, continuous melting was in progress. It is to be kept in mind that it is the ratio between the advance and the wastage which determined the position of the edge of the ice at every time and place. The surface wastage was greatest near the edge of the ice, because here the climate was warmer than elsewhere upon the ice. At the edge, and reaching back considerable distances from it, surface melting was always in progress. This gave rise to large quantities of water, some of which ran over the surface of the ice to its edge, and was there precipitated upon the surface of the land beyond it, and some of which fell into crevasses in the ice. Part of the water which found its way into the crevasses was doubtless carried forward, for greater or less distances, in the ice itself, but most of it found its way ultimately, if not immediately, to the surface of the ground beneath the ice, and flowed along this surface.

The water which flowed over the surface of the ice often formed more or less well-defined streams, which from their position are known as *superglacial streams.* The water which flowed upon the land surface beneath the ice was likewise often concentrated into well-defined streams called *subglacial streams.* Some of these attained the dimensions of large rivers. The Rhone river of to-day issues as a considerable stream from beneath the Rhone glacier. Above the terminus of this glacier the river has a subglacial course of undetermined length. In this part of its course it is a subglacial stream.

The water which descended into the ice from its surface through crevasses, or through smaller cracks or pores, had a various course. It is possible that it was sometimes concentrated into streams which had longer or shorter courses within the ice itself. On one of the Alaskan glaciers* at the present time, an englacial stream appears at the surface of the ice, issuing from an ice tunnel, pursues a superglacial course for a short distance, and plunges again beneath an ice arch and pursues for an undetermined distance an englacial course. Such streams may be designated as *englacial streams.* It is probable that englacial streams had but short courses, in general, before they reached a subglacial position.

The rain which fell upon the surface of the ice augmented the volume of surface water produced by melting, and swelled the various classes of glacial streams, in proportion to its quantity. The subglacial waters derived from above would be increased by the melting of the under surface of the ice. The friction generated by the movement of the rock-shod ice over the surface of the land, as well as the heat derived from the earth by conduction, would bring about this under-surface melting, which would not be restricted, like the surface melting, to a wide margin of the ice-sheet, but would take place everywhere beneath it. The total volume of water originating by the melting of its under surface, was probably greater than that which arose from superficial melting during the time when the ice was in vigorous motion. Near the margin of the ice, the melting at the upper surface was probably greater than that at the lower, at all times. In the later stages of the history of the ice-sheet, its motion became very sluggish, and while its areal extent was still great, parts of it appeared to have lost their motion altogether, and to have become stagnant. Where this condition of things obtained, and especially if it were due to warmer climate, as it may have been, the superficial melting probably exceeded the basal.

* Russell, An Expedition to Mount St. Elias, Nat. Geog. Mag., Vol. 3, p. 106 (1891).

It is conceivable that, under special conditions of topography, subglacial waters might have become englacial. But, at best, this was a rare occurrence, and no instance of the kind is known to the writer among present glaciers. In the nature of the case, it would be difficult to observe the phenomenon here referred to, even if it were a common fact.

The melting of the ice was not confined to its upper and lower surfaces, though here the wastage was greater than elsewhere. In its motion, various parts of the ice were under varying strains and stresses at the same time, and the same part at different times. Wherever the stress was such as to crush the ice, as must have sometimes been the case, the crushing would involve friction, and therefore heat and more or less of melting. Again, pressure lowers the melting point of ice, and, under pressure, various parts of the ice might be reduced to a liquid condition because of increased pressure, especially if the temperature, before such increase, was near the melting point. In either case, the movement of the water would probably be but slight before the conditions which caused the change from the solid form would be altered, and the water would again be converted into ice. But, meantime, some part of it might have joined an englacial or subglacial stream, and thus be brought into conditions which prevented its return to a solid form. Data are not at hand for determining, even approximately, the amount of water which is produced by the process here indicated, or what proportion of it joins the glacial drainage.

Not all the water on the surface of the ice was concentrated in streams during its superficial course. Where the surface of the ice was smooth and plane and the rate of melting very uniform, the water, doubtless, formed thin, superficial sheets rather than definite streams. Likewise, and to a much greater extent, the subglacial waters failed to be confined along well-defined channels. Subglacial pools (miniature lakes) probably had a temporary existence at many times and places, and thin sheets (rather than streams) of water probably covered small plane or depressed areas beneath the ice, where the ice temporarily failed to rest upon the land surface. Such areas would correspond to hollows on the under side of the ice, or to small depressions in the land surface, which the ice failed to fit into and fill during its passage.

Osars. Eskers.—In all these various positions the water did its peculiar work. The superglacial streams wore channels and valleys in the ice, much as streams wear channels and valleys in the surface of the land. Other things being equal, valleys would be more easily excavated in ice than in rock, since ice is softer than rock, and since the streams would deepen their courses by melting their beds, as well as by abrasion. Wherever there was rock debris upon the surface of the ice this would be slowly gathered into the channels of the streams by the movement of the water into them, as well as by the action of gravity, which would carry it down the ice-slopes bordering the valleys. If the ice which occupied the space of the valley-trough before the latter was excavated, contained drift, such drift would accumulate at the bottom of the valley as the imbedding ice was melting or worn away. Some part of the material, accumulated by one process or another in the superglacial valley, would be removed by the water coursing through it. If the water was unable to remove all of the material, the finer would go and the coarser would remain.

In process of time, if the stream held its course without interruption, a very considerable filling of gravel and bowlders might be made in the bottom of the superglacial valley. Over and through this filling, the water would move. Should the ice on which such a valley exists become stagnant, as ice did to some extent during the declining stages of glaciation, the ice beneath and around the valley would melt, and the sand and gravel and bowlders accumulated in it would be let down, gradually and gently, upon the surface of the land immediately beneath the original channel in the ice. When the ice was gone, this ice-channel drift would appear as a ridge, coinciding in geographic position with the old superglacial stream. If the superglacial stream had tributaries, as is possible, their valleys might have been partially filled with debris like that of the main stream, and when the ice had melted, the position of the tributaries would be likewise marked by ridges of assorted drift. Such ridges would stand in the same relation to the ridge of the main stream as the tributary rivers to their main. Since the slope of the upper surface of the ice was toward its edge, the surface streams would have their courses determined thereby, and the courses of the resulting ridges would correspond in a general way with the course of the ice movement.

It is not necessary that the ice should become stagnant before its melting in order that the material accumulated in the superglacial valley should be deposited as a ridge upon the land. Although over-balanced by melting, the ice had a forward motion during its recession in many if not in most places. In this case there might be superglacial streams, as in the case of the stagnant ice, and such streams might accumulate much gravel in their channels if the surface or upper part of the ice furnished it. As the edge of the ice is melted the ice-valley drift would be delivered on the land in proper form, as the ice melted from beneath it, and by the progressive recession of the ice's edge the superglacial valley drift would come to constitute a ridge of stratified sand and gravel marking the site of the superglacial valley.

Ridges of assorted drift, such as we may conceive would arise under the circumstances as here sketched, are known, and it is believed that they may have been formed in the manner described. Such ridges of drift are known as *osars* (Åsar) or *eskers*. They have sometimes been described under the name of kames and serpentine kames, but there seems to be sufficient reason for discrimination between them and the formations usually described under the term kame.

The superglacial valley might become very deep, even cutting through the ice. In this case the stream would come to rest upon the land beneath the ice and would flow through an ice cañon. The accumulation of drift in its bed would be much the same as before. The only important modification that would result would be from a tendency of the ice to move in on either side of the ice cañon, as if to close it up. Even if worn back by the stream as rapidly as it tended to close in, it would still bring debris to the stream channel from either side, thus adding a new contribution to the debris accumulated by the stream's own action. This contribution might be less assorted and less definitely stratified than that finding its way into the ice valley by other means. The lateral movement of the ice toward the cañon would probably be so slow, and its contribution of drift so slowly made, that the stream would rework all or most of it, carrying away the finer parts and arranging the coarser in more or less regular layers. The movement of the ice, as here suggested, would be likely to disturb and contort the regular stratification of the material arranged by water alone.

In the channels of streams beneath the ice a very similar process of accumulation might be going on. The stream beneath the ice would be subject to conditions much more variable than those of streams on land surfaces, where there is no ice. The velocity of a subglacial stream would probably vary greatly from time to time, and from place to place.

On passing from their subglacial to their open-air courses, existing streams carry much silt and sand and gravel. The same is probably true of them during their subglacial courses. If so, wherever their velocity is checked they are likely to deposit some portion of their load, and the portion deposited would be the coarser portion, since this is most difficult to carry. A subglacial stream might thus build up its channel, and if the subglacial course of the stream was closely confined by the overarching ice, the stream might not be able to abandon its bed, even though this be higher than the land surface on either hand. Thus the subglacial stream might come to flow on a subglacial ridge accumulated in its channel, because the only course accessible to it was along the crest of this ridge. In this case the ice would tend to press in on either hand and close up the valley, the same as if the channel had been cut down through the ice from surface to base. In the one case, as in the other, the more or less reguler stratification produced by the stream in the deposits made in its channel would be disturbed and contorted.

After the melting of the ice, ridges thus developed, and representing the courses of subglacial streams, would have the same general aspect as ridges formed in the channels of superglacial streams, and let down upon the surface of the land by the melting of the ice, or the same as that of ridges formed in cañons which have been cut from the top of the ice to the land surface beneath. Among the gravel ridges known as osars, it is altogether possible that some may have been formed in subglacial streams. Such osars might have lateral osars joining them, just as those formed on the ice in superglacial valleys.

It is not to be inferred that every superglacial stream or every stream beneath the ice constructed osars. They may have failed to do so because of insufficient material, or because their life histories were too brief; for all the streams on and in and beneath the ice are subject to great vicissitudes of conditions, and their existence, in any given position at least, is liable to be brought to a sudden end.

Not every stream which built an osar, or which gathered the material that might have become an osar, left permanent record of its work. If the stream ceased to exist, or if its position was changed before the movement of the ice ceased, the ice would be likely to override the ridge which might otherwise have been an osar, partially or completely destroying it, or burying it by a deposit of till made directly by the ice.

The water on and under the ice which was not confined in channels was doing a work comparable to that of the streams. Instead of ridges, patches of gravel and sand were probably accumulated on the ice, where the surface waters could get the materials to work upon. When the ice melted such of these patches as had not been earlier destroyed were let down upon the surface of the land. It is not probable that such accumulations were extensive, and it would be very difficult, if not impossible, to discriminate them from other like deposits which might now be similarly disposed, though produced by very different methods.

Subglacial waters likewise, even though not confined in channels, would exhibit their proper activity. As on plains at the present time, such waters might spread sand and gravel over such areas as were subject to their action, burying whatever deposits had been earlier made in the same locality.

Such deposits of sand and gravel would be stratified as water deposits are. They might be subsequently disturbed or altogether destroyed by the action of the ice, or they might be buried by its deposits (till), if it subsequently came to rest upon the surface earlier covered by the water, but not pressed upon by the ice. Such changes were probably not of infrequent occurrence during the ice period.

Kames.—Associated with the terminal moraines in many places, there are hillocks of variable shapes and sizes, composed of stratified sand and gravel. As their composition and structure show, they are the result of water action, not of ice action—or, at any rate, not of ice action alone. The common association of these hills and hillocks with the terminal moraine suggests that they are features developed at the margin of the ice. The gravel of these hills is often but little worn. Some of the rock fragments composing it are angular, and many are but slightly de-angulated. The stratification of the sand and gravel is generally very distinct, but often very irregular. The irregularity has arisen in two ways. Part of it is original, indicating peculiar conditions of deposition, and part of it is acquired, for it is of such a character as to indicate that the original stratification has been much disturbed since it was produced. In these cases, the lines of lamination show bendings and contortions and even sharp foldings, which water could not produce in its deposits without the co-operation of some other disturbing agent. The structure of these hills and hillocks seems to warrant the conclusion that their material, once stratified by water, and by water moving with swift and changeable currents, as indicated by the original irregularity of the stratification, was contemporaneously or subsequently subjected to pressure by some powerful agent which was able to distort the original bedding planes produced by the water. So far has this disturbance gone in many places that it is probable that the shape of the hills themselves may have been materially changed by it. Hillocks of the structure, composition and associations here noted are known as kames.

It is frequently the case that otherwise well-defined kames are covered by a thin mantle of till. The till indicates the presence of glacier ice, and this was probably the disturbing agent which displaced and distorted the stratification which the water had earlier developed. A till-covered kame may be seen in the western part of Rahway, south of Robinson's branch, and in the valley of the East Rahway, from Orange mountain to South Orange and beyond, several such kames occur.

While most abundant in and near the terminal moraine, kames are by no means confined to it. If they be the phenomena peculiar to the ice margin, as their frequent association with the terminal moraine suggests, they might occur in any region where the ice margin has been. Since, during its retreat, the ice margin covered all the territory north of the position of its maximum advance, kames might be found anywhere north of the moraine, where conditions were favorable for their development, if they be marginal phenomena. And such is their distribution. But north of the main terminal moraine they are less numerous than in and near it, and are much more commonly than otherwise, associated with secondary or recessional terminal moraines. Such moraines are sometimes essentially composed of an aggregation of kames. In New Jersey, the recessional moraine already referred to, running west-southwest from Waverly, is locally made up of kames, so far as its constitution is indicated by present exposures. That kames were made by water seems certain from their constitution and structure. That they were frequently made in the immediate presence of ice and somewhat modified by it, seems certain from the till which sometimes covers them, and from the pressure to which they have clearly been subject.

It is not the habit of water, unaided, to construct hills of the materials it carries. When tributary streams, much swollen by floods, and carrying heavy loads of debris, meet a more sluggish main stream, it is possible that the water-carried debris would be so deposited, and the deposits so shaped by the currents, as to constitute small hillocks. It is conceivable that where strong currents meet in such wise as to antagonize each other, both would drop their loads of debris, and the eddies, which would result from their contest with each other, might help to heap these deposits into hillocks, and might excavate hollows between them. Basin-like and irregular hollows, such as might have been produced by eddies in conflicting currents, are frequent accompaniments of kames. But while such activities as those here suggested seem to adequately explain certain kames, they do not seem adequate as an explanation of all the hills which are now grouped together under the name *kames.* It is not improbable that further study will result in the recognition of various types of kames, formed in different ways.

It is possible that some of the kames may have had their forms impressed upon them beneath the ice; that they are cast, so to speak, in ice moulds. Then, too, the activity of the waters at and beneath the margin of the ice, where the latter no longer rested heavily upon the ground, was doubtless great, and constantly varying in strength, and the currents constantly shifting in position. The work of the water in this position, and under these circumstances, would be ever and anon interfered with and modified by the action of the ice, whose margin was subject to constant fluctuations from the seasonal and periodic changes in climate, and from the variation in the activity of the marginal and submarginal waters. While these seem to be the general conditions under which kames were developed, the precise method by which all kames may have been builded is difficult of conception.

Kames differ from osars (1) in being mounds and hills rather than ridges, though kames may be somewhat elongate, and (2) in being commonly arranged in positions at right angles to the movement of the ice, instead of parallel with it, as is the case with osars. Isolated kames cannot be said to exhibit arrangement. But when the kames are in belts, as when associated with terminal moraines, the belts are approximately at right angles to the motion of the ice, or parallel to its margin. Such belts of kames were produced by waters whose direction of movement, though frequently shifting, was mainly at a high angle to the belt itself. On the other hand, the movement of the water producing osars was approximately parallel to the direction of ice movement, and parallel to the direction of the resulting ridge. Where single kames are elongate, their greatest diameter is, more commonly than otherwise, parallel to the edge of the ice, and at right angles to the direction of its motion—that is, the reverse of the relationship shown by the osar ridges.

In size kames vary greatly. From mounds a few rods across and a few feet high, they range to hills a mile or more in diameter, and a hundred feet or more in height. With a diameter so great as the maximum here stated, a kame is usually elongate and more or less ridge-like. Their slopes are frequently about as steep as the incoherent material of which they are composed will lie.

2. Water Deposits Beyond the Margin of the Ice.

A. *Valley drift.*—So far as the water which flowed beyond the margin of the ice was confined in valleys its current was swift, wherever the gradient was not very low. This follows from the great volume of water which such streams had. Under these circumstances the streams issuing from the glaciers must have carried great quantities of debris, since the glacial grinding was constantly producing it under circumstances such that it might be taken up readily by the streams. Much of the debris was deposited in the valleys through which the swollen streams coursed. Drift, therefore, is not confined to the limit of ice advance, though the strictly glacier drift is so confined. That which lies beyond was deposited by water. The valley drift carried beyond the edge of the ice, by streams originating from it, was coarser when the streams were swift, and finer where they were slow. From the nature of the deposits of valley drift, therefore, the relative velocity of the streams which did the depositing may be inferred. At the time of that glaciation of New Jersey which is represented by the heavy drift-sheet which is bordered on the south by the terminal moraine, the streams which flowed from the ice were swift, for they carried down large quantities of gravel and sand, with which they partially filled their valleys. The gravel and sand thus deposited have been designated *valley drift,* to distinguish it from other forms of stratified drift. The drift thus deposited in a valley has sometimes been called a *valley train* of sand and gravel.

Such valley trains have their source, at any given stage of their deposition, at the margin of the ice. As the ice margin changed, the geographic source of the gravel likewise changed. Where the ice margin remained constant in a position for a long period, the gravels would take their source for a corresponding length of time. It thus happens that the terminal moraine, which represents a long period of time during which the ice edge was nearly constant in position, marks the source of heavy valley trains of river-carried sand and gravel.

In New Jersey such valley trains of gravel occur in the valleys of several streams. In the judgment of the writer, the gravels composing the terrace at Trenton belong to this class. These gravels have long been known under the name of "Trenton Gravels." Their geological relations have been the subject of much dispute. Especial interest attaches to them, because of the association of paleolithic implements with them. Gravels corresponding to them occur at various points in the valley of the Delaware, generally forming a well-defined terrace. Though not now uninterruptedly present from the moraine at Belvidere to Trenton, these gravels doubtless once filled the bottom of the valley throughout this entire distance, and even further south, although they are said to have no development below the vicinity of Trenton on the east side of the river at the present time. Where they are not present on the New Jersey side of the valley, they often occur on the Pennsylvania side. Where they are present on neither side, they are confidently believed to have been removed by the river since the time of the last glaciation.

The materials of this valley train are coarsest in the vicinity of the moraine, and become finer and finer further down the stream. The occasional large bowlders which occur in the gravel and at its surface, were probably carried down the stream by icebergs detached from the edge of the ice-sheet, and carried southward by the current. If bowlders were imbedded in it or frozen to it, even a small berg of ice, because of the lightness of ice, would be able to carry large masses of rock and still float upon the water.

B. *Overwash plains.*—Where the country beyond the margin of the ice was flat, the water spread widely over it, carrying its burden of gravel and sand, depositing it where its transportive power failed. Since the velocity of such waters was slight, compared with that of waters having a similar origin but confined in channels whose banks might retard the flow, they would not be able to carry material of so great size, nor such as they might at first move, to any considerable distance. Water, marginal to the ice and arising from it, would cover the flat tracts of land over which it spread, with stratified gravel, sand or silt—according to its strength of movement. Such plains of drift deposited by water beyond the edge of the ice have received various names. Among them, *overwash plains*, *morainic aprons* and *border plains*, may be mentioned. Where the plain of deposition is narrow and extended in the direction parallel to the movement of the water, the deposits will closely resemble those made in a wide valley, both in kind and distribution. Overwash plains may thus merge into valley trains.

The gravel and sand plain on the edge of which Plainfield stands, is an example of such an overwash plain; or, more accurately, it is a plain partaking of the nature both of a valley train and of an overwash plain. So far as it was built up from the northward, it was by water starting from the ice margin about one mile northeast of Scotch Plains, and flowing west of south through a preglacial valley. Thus far it corresponds to a valley train, and has a slope down the valley to the west of south. So far as it was built up by waters discharged from the ice's edge lying east of the valley, and flowing in a westerly direction toward the valley, it partakes of the nature of a morainic apron. The position of the ice-edge from which the water thus flowing emanated, is marked by the terminal moraine from Netherwood southward. That part of the plain thus built up has a slope to the south of west. The deposition from the two directions was probably going on at the same time, and the resulting plain is a unit, though two slightly-different phases of the activity of water co-operated in its construction.

It sometimes happens that the slope of the land which the ice invaded was locally against it. In such cases water sometimes accumulated between the ice barrier behind and the land barrier before, making a temporary lake. Under such circumstances the melting ice discharged its waters into the lake. Since the currents would be arrested on meeting the quiet body of water, its load would be dropped, and formations of gravel and sand would be made on the iceward border of the lake. If the waters joining the lake had little current, silt, instead of sand and gravel, might constitute the deposit. The

7

growth of the formation would be on the same principle as the growth of a delta. The finer material carried by the water would sink less readily than the coarser products. They would therefore be more widely distributed over the lake bottom. In the interior of the United States there are extensive plains of silt thus accumulated. No formations known to be of this character have come under the observation of the writer in New Jersey, but they may yet be found. They are not rare in other parts of the drift-covered area.

As the ice retreated, border plains of gravel and sand were sometimes developed similar to those which were found at the margins of the ice at the time of its maximum advance. The plains of stratified drift made along its border during the recession of the ice, buried the till or whatever phase of drift previously occupied the ground. Gravels accumulated beneath the ice by subglacial waters might stand in the same relation to underlying till.

If, after a border plain of gravel had accumulated, the ice temporarily advanced over it, the border plain might be destroyed or its stratification disturbed, or it might be buried by till deposited upon it. Gravels deposited by subglacial waters might be covered with till subsequently, in such wise as to be indistinguishable from overwash plains buried by till.

The thickness of the sand and gravel of these border plains was dependent in large measure, upon the length of time the ice stood in such a position as to allow the border waters to flow over the same territory and make deposits upon it. The rate of supply of detritus would be a second determinant of the depth of the gravel and sand. The actual variations in thickness are great. It may be several scores of feet or it may be so thin as to be scarcely recognized as a layer independent of the material beneath it. Overwash plains generally have less depth of drift than valley trains.

Pitted plains.—The plains of stratified drift are not always plane. Their surfaces are sometimes marked by depressions. These may be deep and kettle-like, or more rarely trough-like in form ; or shallow, being mere sags in the surface. Plains thus characterized are known as *pitted plains.* Their position generally corresponds with that of overwash plains, though they sometimes occur where there is no terminal moraine associated. Where the depressions become conspicuous, they are sometimes accompanied by mounds and small hillocks, so that the plain becomes undulating. When this character is marked, the hillocks take on a form and structure such that, individually, they correspond to small kames. Overwash gravel plains may thus merge into pitted plains, and pitted plains into areas of kames. In origin, pitted plains and kame areas probably have much in common. It is probable that the ice played an important rôle in shaping the surface of those plains which become so rough as to be classed as kame areas rather than as overwash plains. Valley trains likewise are sometimes pitted.

Gradation of Types of Drift Into Each Other.

The various classes of drift here enumerated are sufficiently distinct from each other to be easy of recognition where typically developed. But from the circumstances under which they were made it will be readily seen that any form of drift may grade into others. This results from the fact that one phase of ice action grades into another, and from the fact that water and ice co-operated and alternated with each other in all conceivable relations. It follows that distinct as the various phases of drift are, taken in their typical development, it is often extremely difficult to make sharp distinctions between them in the field.

No types of drift are better defined than the till and stratified gravel. But it has already been pointed out that till may assume different phases, according to the nature of the rock from which it was derived. It may be more or less clayey, more or less sandy, more or less gravelly, more or less bowldery. But the difficulty of discriminating till does not lie here. When the ice passed over beds of gravel which had been made by subglacial or extra-glacial waters, its action upon them was various. If it simply buried them they would be gravel beds still, though overlain by ground moraine. If the ice so worked upon them as to roughen their surfaces and distort their stratification, without destroying it, undulatory tracts of gravel would result, the hillocks of which might bear some resemblance to kames, though their material would generally be more water-worn. If the gravel deposits were buried by till in the process, the kame-like hills would be till-coated, as is sometimes the case. If the ice so worked upon the stratified gravel beds as to destroy their stratification, removing them never so little and depositing them anew, with little admixture of other material, the gravel, though gravel still, would become ground moraine. Its structure, or its absence of structure, would be the result of ice action, and not the result of water action. The original stratified gravel, even if deposited in advance by waters emanating from the ice itself, constitutes the formation over which the ice afterward passes, upon which it works, and from which it makes its ground moraine. And here, as elsewhere, the ground moraine is dependent on the character of the formation from which it is derived. If the ice's work upon the gravel was protracted or vigorous, the latter might be worn and crushed so that its character as gravel was largely or even completely destroyed. In this case the gravel might be changed to typical till. But the work of the ice upon the gravel was sometimes only enough to destroy its stratification. It would be but unstratified gravel, though deposited by the ice, and therefore moraine.

The process of destruction of the stratification may have proceeded to any extent. It may be disturbed only; it may be largely destroyed though locally preserved, and the ratio between that part which has lost its stratification and that which has not, may vary in either direction until the one class or the other is excluded. If the stratification has been completely destroyed, the gravel is to be regarded as ground moraine. But if it has just failed of complete destruction, the gravel seems hardly to belong to the category of assorted drift or to that of unassorted. It is customary to speak of such deposits as made up of stratified drift, re-worked or re-arranged by the ice. But it is not found practicable in the mapping of the drift formation to recognize a class of drift intermediate between that which is stratified and that which is not, although drift possessing an intermediate character occurs. To carry the classification thus far in the mapping of the drift would lead to endless complications. It goes without saying that stratified sand deposits may stand in the same relations to till as the stratified gravel deposits. Thus it often becomes a matter of extreme difficulty to draw a line, separating till on the one hand from stratified sand and gravel on the other. Often no such line can be drawn without doing violence to the facts.

In another way the till and the stratified deposits of drift present difficulties when their delineation upon maps is attempted. The stratified drift may overlie the unstratified, or *vice versa*, to any depth. One foot of stratified sand may overlie many feet of till, or the reverse may be the case. The areas where this condition of things obtains might be mapped as sand, because their uppermost portion is sand, or they might be mapped as till, because the main part of the drift material is till. Were the thickness of the surface layer in such cases uniform the matter would be simplified. But it is often very variable. A surface layer of sand may be wanting at certain points, thin over associated areas of small extent and deeper over other areas of like extent and relation, and the thickening and thinning follow no law which expresses itself at the surface. The areas where such changes occur are often very small—too small to be separately represented on maps of the scale in use. Here there is another obstacle to the accurate delineation of the drift formations.

As if the lateral and vertical variations and gradations between till and stratified drift were not enough, a further difficulty is encountered, in that the extent of the complicated conditions of things which is known to exist cannot be defined. Exposures revealing the facts are only here and there, and all that is left by which to judge of the nature of the drift is the surface soil and its products, and the local topography.

The discriminations between the stratified and unstratified drift are hardly more difficult to make than those between certain other classes of drift. The lines which must be drawn upon the map limiting the position of the terminal moraine are sometimes arbitrary. Its outer border is frequently well marked, as, for example, where it is bordered by an overwash plain with a smooth surface. When the border plain is undulatory, as it sometimes is, the definition is less sharp. But the inner border of the moraine is frequently ill-defined. The main part of the terminal moraine is formed beneath the margin of the ice, and under the peculiar conditions there existent. The conditions which are peculiar to the margin of the ice become less and less pronounced back from the edge. They disappear gradually; they do not cease suddenly, and it is not easy to say how far back from the absolute edge of the ice the strictly marginal conditions extended. The distance is probably a variable one, dependent on many factors, such as local topography, thickness of the ice, vigor of its action, softness or hardness of the rock, &c.

The terminal moraine corresponds to this condition of things. Its outer and central portions are often sharply enough marked, but on the inner face it grades back by almost imperceptible degrees into the ground moraine. The line between the inner face of a terminal moraine and the adjacent ground moraine is, therefore, in many instances an arbitrary one.

These and many other complications make the delineations of drift formations upon the map a matter of extreme difficulty. And not only a matter of difficulty, but they make it impossible to make perfectly-accurate maps. Such maps would require exposures many times more abundant than they now are. For definiteness of representation upon a map, too, lines must needs be drawn between formations, when the separation between them is not marked by a line, but by a belt or area of gradation.

EXTRA-MORAINIC GLACIAL DRIFT.

Until the present study of the Pleistocene formations of the State was undertaken, in the summer of 1891, no evidence had been published, so far as the writer is aware, that glacier drift existed in New Jersey south of the terminal moraine which crosses the State from Belvidere to Perth Amboy. That drift deposited by water had a considerable distribution south of the moraine, as at Trenton, was well known.

In 1889 President T. C. Chamberlin and the writer visited certain localities in New Jersey and Pennsylvania, south of the terminal moraine. In New Jersey, south of Belvidere and between that point and Phillipsburg, as well as at corresponding points on the west side of the Delaware, surface features were observed at that time which led us to suspect that an older glacial drift existed in New Jersey and Pennsylvania, and that its exposed portion lay south of the terminal moraine referred to above. It was inferred that this extra-morainic drift corresponded in age to that lying south of the terminal moraines in the interior. But the observations made were too few and too indecisive to make their conclusion certain, and it was never published.

When the writer first visited New Jersey, early in the summer of 1891, he learned from Prof. Smock that he likewise had been led to think that there might be an older sheet of drift in New Jersey, south of the terminal moraine, deposited by an ice-sheet which antedated that whose southern limit was marked by the well-known terminal moraine. The relevant facts which Prof. Smock had accumulated were generously put into my possession, together with the inferences which had been drawn from them. Prof. Smock further pointed out several localities where the surface formations which seemed to justify the inference concerning an older drift, could be well seen.

These localities were visited, and the materials whose origin was in question were examined in detail. Two of these localities were railway cuts near Pattenburg and High Bridge respectively, in Hunterdon county. In both situations the surface formations were found to be such as to make it seem certain that they were glacier drift; not drift transported beyond the terminal moraine by water, contemporaneous with the formation of the moraine; not material transported by water at any time either before or since the formation of the moraine; and not a "fringe"—whatever that may be—nor any dependency whatever of the terminal moraine, nor any form of derivation from it.

The cut at High Bridge is about fifteen miles south of the terminal moraine. Here the drift has a maximum thickness of about thirty feet. It is composed of a clayey material, which, in some parts of the cut, is mingled with sandy and gravelly material, and set with bowlders, the largest of which reach a diameter of several feet. Among the stony material there are bowlders of various sorts. Bowlders of shale cannot be said to be abundant, but they are certainly not rare. Repeated examinations failed to discover a single piece of shale so much as three inches in diameter, and which still retained the form it possessed when the drift was deposited, which did not show glacial striæ upon its surface. In many cases the pieces of shale had disintegrated into fragments, and even among the fragments, those which still preserved portions of the original surface, frequently showed striæ in great perfection upon such surfaces. In some cases small bowlders or bowlderets of shale were seen, whose surfaces showed glacial markings in the clearest manner, but which were yet so far disintegrated that they could not be lifted from their places without falling into scores of pieces. Though the striæ were found to be much more common on the shale than on harder sorts of rock, as would be expected, they were not wanting on other kinds of rock. More than one hard sandstone and quartzite showed striæ no less decisively than the shale, and one large bowlder in the face of the cut has one surface, seven feet across, planed and striated.

Just east of Pattenburg a railway cut shows the same condition of things, with the additional feature that the stratum of shale on which the drift rests, shows evidence of having suffered violent mechanical action. It is crushed and crumpled, as if pushed upon horizontally by great force.

A similar condition of things is found to exist over the whole of the northern part of Hunterdon county, and over that part of Morris county which lies south of the moraine. Along the highways shallow cuts frequently expose material which shows physical and lithological heterogeneity, an absence of stratification, and the presence, and often the abundant presence, of striated stones imbedded in a matrix of clayey earth. These phenomena may be seen at various points between Oxford Church and Little York, between Little York and Oxford Furnace and between the latter place and Washington. They are especially well exhibited at and near Little York, where this extra-morainic till lies considerably higher than the moraine to the north.

In places this drift forms a tolerably continuous sheet. This is especially true where the topography is such as to have been unfavorable to erosion. On steep slopes and sharp summits it is generally wanting, as also in the narrower valleys. On the broader uplands and gently-sloping hills, and in broad valleys, it finds its chief development at the present time. It can hardly be doubted that it once formed an essentially continuous sheet over a large area south of the terminal moraine, and that its interrupted existence at the present time is the result of subsequent erosion.

Concerning the relation of this drift to the terminal moraine, we hold no doubtful opinion. That it could not have been derived from the moraine by overwash or by any phase of water transportation, is clear, since (1) it does not possess the structure of an aqueous formation; (2) it is much too heterogeneous to represent the work of an assorting agent; (3) the surface upon which it rests sometimes shows the effects of mechanical force, such as water could not produce; (4) the soft shale bowlderets could not have suffered transportation by water, even for a few miles, without having lost all traces of striæ, especially in the presence of abundant harder stone; and (5) its topographic distribution is such that water, issuing from the ice which made the terminal moraine, could not have been the transporting agent, for, as at Mount Bethel, it covers the tops of high elevations three hundred feet or so above the moraine, a mile or two further north, and, without modification of character, occupies depressions at least five hundred and fifty feet below its greatest known altitude. Such a formation with such a distribution and such relations, is not the work of water.

The case is no better if it be looked upon—as the corresponding formation in Pennsylvania has been—as a "fringe" of the moraine; for, however this "fringe" may be conceived to have arisen, we suppose that it is assumed to have an intimate connection, both in time and in genesis, with the moraine itself. But the drift here under discussion is not believed to have had any genetic connection with the moraine, or any time relation to it, except one of great separation. It is composed of materials which are, in some measure, inherently unlike those which compose the moraine. But especially its physical and chemical condition puts it into sharp contrast with the material of the moraine and with the sheet of drift of which the moraine is the southern border. Essentially, all the stony material it contains, except the hard sandstones and quartzites, shows the effects of long-continued weathering. Much of the granitic material has so far lost its integrity that it cannot be handled without falling into pieces. The matrix, both by its color and by its chemical character, shows that oxidation and leaching, both as regards extension and intention, have taken place on an extensive scale.

To adequately appreciate the difference between this drift and that of the moraine the two should be set in contrast. While the one exhibits oxidation, leaching and disintegration in an advanced stage of development, *even to its base, where it is thirty feet thick*, the other has not suffered oxidation and leaching on any such scale as to make them apparent more than two or three feet from the surface, and the softest and most easily-disintegrated varieties of rock often present a degree of freshness which, so far as the eye can see, might characterize masses of rock worked out of their parent ledges within the memory of living men. We hold, therefore, that this extra-morainic drift represents the remnant of a drift-covering once much more extensive and more uniformly present than now, and that, like the drift in and north of the great terminal moraine, it was formed by an ice-sheet, but by an ice-sheet which overspread New Jersey much earlier than that which made the terminal moraine and the main body of drift which lies north of it.

It is a matter of great interest to know how much earlier. But to this question no definite answer can now be given. Suffice it to say that if the chemical and physical condition of the material be a safe criterion to gauge by, the extra-morainic drift must be at least several times as old as the morainic. That is, according to this standard of measurement, the interval which elapsed between the first and the last glacial formations of New Jersey was several times as long as that which has elapsed since the last. This extra-morainic drift is regarded by the writer as the equivalent of the oldest glacial drift of the interior.

The phenomena here described as indicating a drift-sheet older than that represented by the moraine and the drift north of it, are not confined to Hunterdon and Morris counties. The extent of the territory over which these phenomena occur is not known, though many facts concerning its extension are already in the possession of the Survey. The railway cuts southeast of New Brunswick afford similar evidence in this part of the State. Glacial-striated bowlders have also been

Fig. 10.

Drift resting on distorted shale. The latter appears to have been disturbed by mechanical force, the upper portions of the miniature folds being worn away. Railway cut just southeast of New Brunswick. From a photograph.

found between Monmouth Junction and Deans, along the line of the Pennsylvania railway, and at Kingston, on the Millstone river, three miles northeast of Princeton, though they are by no means common in either place.

In Pennsylvania there are drift deposits well south of the moraine in similar situations. Glaciated bowlders, imbedded in clay which presents the general aspect of till, have been found near South Bethlehem, several hundred feet above the Lehigh river, and at various other points south of the Lehigh, at distances from the moraine comparable to those at which the corresponding formation in New Jersey occurs. Drift closely resembling till, and containing striated rock material, occurs on the west side of the Delaware near Fallsington,* three or four miles southwest of Trenton, and, with Mr. C. E. Peet, the writer found similar deposits at Bridgeport, Pa., opposite Norristown, still further south. Bridgeport is the southernmost point at which glacially-striated material has been seen by the writer. Glaciated bowlderets were here taken from clay of such character that, were the locality known to have been covered by ice, its reference to till would be fully warranted. Bridgeport is about fifty miles south of the terminal moraine.

It is not intended to convey the impression that every region where glaciated stone may be found was necessarily once covered by glacier ice. The possibility of transportation of glaciated material beyond the edge of the ice by water, is distinctly recognized. But it is not believed that water alone, or water-bearing glacially-derived bergs, could produce all the results which are here recorded. Neither the structure of the extra-morainic drift, nor its physical make-up, nor its geographic or topographic distribution, is consistent with such an hypothesis.

At several points in New Jersey south of all the localities thus far mentioned within the State, there are topographic features which are easy of explanation if ice once extended to the region where they occur, but which seem to be very difficult of explanation on any other hypothesis. The features here referred to characterize the region from Washington, Middlesex county, southwest to Fresh Ponds and beyond, and also the region east of Trenton, from White Horse to Hamilton Square. The topography in these regions is very much like that of a subdued terminal moraine.

The determination of the southern limit of ice action during the earlier glaciation is likely to be a matter of some difficulty. In its southern extension the ice reached the region of the "yellow-gravel" formation. Invading a region whose surface was composed of such loose material, the thin edge of the ice would probably do little more than work it over, destroying such structure as it once had, and de-

* This locality was first made known to the writer by Prof. Smock.

positing it again without wide transportation in much the same condition as that in which it found it. There would be some admixture of material brought from more northerly sources, but this might be but slight. This condition of things would be especially favored if the region invaded by the edge of the ice were so low as to be covered by a shallow depth of water, as might have been the case. In this event bowlders would have been carried beyond the edge of the ice-sheet by floating ice, and scattered over a wide area beyond the reach of the glacier, so that a sharp line marking the limit of drift, or even of glacier drift, would not exist.

The age of the "yellow-gravel" formation has been long in question, and, so far as the writer is aware, no certain conclusion has yet been definitely reached concerning it. But from its relation to the older glacial drift, the writer is inclined to believe that it antedates this drift, and that it is therefore Pre-pleistocene. The definite determination of this question is one of the problems which will engage the attention of the Survey in the further prosecution of its work. New Jersey is probably the best locality for the determination of the relation of this formation to the drift, and this determination will have an important bearing upon the problems of coastal-plain geology, now under investigation at the hands of Mr. McGee, of the United States Geological Survey. The relation of the "yellow gravel" to the earlier glacial drift and the age of the former are, therefore, problems which have a wide interest beyond the limits of the State. It is perhaps true that no other area of equal extent affords a more inviting field for the study of Pleistocene geology, or within which determinations of more importance can be made concerning the later stages of geological history. Within the State occurs the passage from the Pleistocene glacial formations of the North to the Pleistocene water and land (non-glacial) formations of the South. The determination of the relations of these two phases of the Pleistocene formations is of prime importance.

NOTE.—It is proper to note here that the proof of this report was not read by Prof. Salisbury.

ECONOMIC GEOLOGY.

(109)

GEOLOGICAL WORK IN SOUTHERN NEW JERSEY.

BY C. W. COMAN.

OAK-LAND AND PINE-LAND BELTS AND THEIR RELATION TO AGRICULTURE.

The region here considered is that part of the State which lies to the southeast of the belt of marl outcrops, and is bounded on the southeast and southwest by the Atlantic ocean and Delaware bay respectively. The area so delimited, the form of which approximates a right-angled triangle, with a considerable spur extending from its right angle in Cape May county, includes about two-fifths of the whole State. Its greatest breadth, or the base of the triangle, from Salem to a point on the sea-shore five miles south of Sea Isle City, is fifty-three miles; and from Long Branch, the apex of the triangle, to Cape May Point the distance is nearly one hundred and ten miles. The outcrops of the upper marl-bed in Monmouth county are here included, but as with these inconsiderable exceptions, the upper marl from Brindletown, near New Egypt, northeastward is deeply buried beneath later deposits, the middle marl may be considered as the western boundary from New Egypt to the sea-shore at Long Branch.

The political divisions covering this area include the whole of Cumberland, Cape May, Atlantic and Ocean counties, considerably more than half of Salem, Gloucester and Camden counties, nearly three-fourths of Burlington and the southeastern half of Monmouth county.

The surface is in general level or gently-rolling, nowhere greatly elevated above sea-level, the highest point being only 308 feet above tide-water. The streams have nowhere cut deeply into their beds, but flow generally in inconspicuous valleys very nearly on the general level of the surface. This topography is due partly to its newness, the streams not having yet had time (with their small inclination and elevation) to excavate deep valleys; in part to the nature of the surface materials, loose sand and gravel not readily lending themselves to the production of bold contours; and in part to the undisturbed condition of the strata, lying as they do almost horizontally without fold or distortion of any kind.

The following excerpts from the report of C. C. Vermeule in the Final Report of the State Geologist—Vol. I., Topography, Magnetism and Climate—describe this region from the topographer's standpoint:

"From Long Branch southward sixteen miles, to Bay Head, the fast land comes out to the ocean front and rises at the north in a bluff, *30 to 40* * feet high; southerly, it is a low coast, fringed with sand dunes. * * * The shore is broken by Shark River bay, some 3 miles long, which has a contracted inlet which occasionally closes, cutting off the tides, and by Manasquan river, a tidal estuary 5 miles long with a width of one-quarter to one-half mile, and bold, picturesque banks from 70 to 100 feet high in places. Deal lake and Wreck pond are similar estuaries. A line of fresh-water ponds, just back from the coast line, have been utilized to add to the attractiveness of the several settlements.

"The ridge running off from Freehold east to Asbury Park, and forming the divide between the Navesink and the Manasquan, and the Shark river water-sheds, has already been noticed. It is an irregular line of gravel-capped hills. The highest of these, known as the Hominy hills, 2½ miles south of Colt's Neck, is 308 feet above tide. A spur of this irregular, gravelly ridge runs off southeast between Shark and Manasquan rivers to Manasquan village, carrying an elevation of 100 feet within two miles of the ocean. * * *

"Southward from Bay Head, the piny region is fringed along the ocean front by a strip of tide-marsh, bays and creeks from 3 to 6 miles in width. * * *

"The drainage of the eastern slope of southern New Jersey is southeast, along lines running quite direct from the water-shed line to the ocean. * * *

"As we proceed southwest, the slope becomes more gentle. It rises from 10 to 20 feet per mile, or in places steeper, north of Tuckerton, but southward from there, the rise from the marsh back to 100 feet elevation averages only 3 feet per mile. In this portion the area above 100 feet elevation within 25 miles of the sea is very trifling. The highest point of Cape May county is but 50 feet above mean sea-level, and more than half of Atlantic county is below 50 feet, as is nearly half of Cumberland. The fall of the streams of this slope is quite uniform. Above the head of tide the average fall of the Manasquan is 5½ feet per mile. The Metedeconk falls 6⅔ feet, and

* An error has in some way here crept in. The bluff is now only about 25 feet high.

Toms river 6½ feet, the distance used in each of these three cases being 12 miles. Cedar creek falls 7 feet per mile for 7 miles, Mullica river 5 feet for 16 miles, and Great Egg Harbor river 5 feet for 25 miles. Maurice river averages 5½ feet for 20 miles. The head of tide, however, while it is but 3 to 5 miles back from the edge of the fast land on the first three streams, is 17 miles back on the Mullica and 12 miles on the Great Egg Harbor rivers. These figures are sufficient to show that it is not a lack of fall along the stream-lines which causes the swampy borders, but a lack of lateral fall at right angles to these lines.*

"Ridges and valleys and slopes have been spoken of in a way which may distract the reader's attention from the extremely level character of this whole pine country, but to guard against this he must keep in mind the figures which have been given. Casting the eye over this plain from any point of vantage, such as one of the small round hills which rise from its surface here and there at wide intervals, we see an unbroken extent of dark-green pine forest as far as the limit of vision, stretching away in long, gentle swells, as level as the ocean itself. So level is it in places that the greater height of the timber in the swamps gives the appearance of a ridge on what is really the lowest ground of the plain, and the uninitiated may be easily deceived thereby. It is often impossible for even a practiced eye to judge which way the ground descends, and in passing along the long, straight roads cut through the timber, it frequently seems that one is always at the bottom of a hollow, the ground appearing to rise in both directions, whereas it is either level or sloping all one way."

Until within a few years the agricultural possibilities of this part of the State have received little attention. With notable exceptions in Salem and Cumberland counties, which have rich, heavy loam soils, and have long been cleared of forest and under cultivation, the soils are generally light, and farmers have viewed them with disfavor, deeming them incapable of productive cultivation. By far the greater part is still in forest, the proportion of cleared to uncleared land in 1888, at the completion of the topographic survey, being less than one to four, and the total acreage of cleared land at that date was only 430,730 acres, while 1,326,000 acres still remained in forest. And of this cleared area the greater part lies in the old-settled portions of Salem, Cumberland and Monmouth counties. The timber of the uplands consists chiefly of the short-leaved pitch pine (*P. rigida*), and white, red, black and chestnut oaks.

* That is, the streams are bordered by swamps because of the extreme shallowness of their valleys.

The pine occupies the poorest tracts almost to the exclusion of other trees, but is by no means confined to such tracts.

On the Delaware bay slope the Jersey pine (*P. inops*) is quite common. A heavy undergrowth of the dwarf or chinquapin oak renders much of the forest almost impassable, especially where it is interlaced with the thorny greenbriar, abundant on nearly all of the low ground which is not actual swamp. Where the coarser underbrush is not too dense, the ground is generally well covered with the various species of huckleberry bushes, the fruit of which forms a natural crop of considerable value, and the gathering of which, in season, furnishes employment to hundreds of berry-pickers.

The swamps, except a few, mostly in Burlington and Ocean counties, which are nearly treeless and overgrown with grass, cranberry vines, &c., are even more densely wooded than the upland. From a little distance a cedar swamp presents the appearance of a solid mass of dark green, while even when in the midst of it the eye can penetrate but a few yards among the thickly-clustering, smooth, gray trunks. The gum and maple swamps are scarcely less dense, and are even more difficult to penetrate, because of the abundance of underbrush, amid which the poison sumac (*Rhus venenata*) is sure to be encountered by the unwary. The trees are often very large, exceeding 100 feet in height. The demand for white cedar for shingles, siding, planking for boats and such other purposes as require great durability under exposure to weather, far exceeds the supply. As the early growth of a tree is much more rapid than when approaching maturity, the swamps are cut off before the cedars are much more than half grown, with a view to securing as much timber as possible within a given number of years, and as a result of this system there is little large cedar in market. But a more urgent reason for cutting as soon as the timber is at all marketable lies in the danger from forest fires, which annually sweep over thousands of acres of South Jersey, destroying the timber of the uplands and penetrating the cedar swamps as well, where the latter are not well filled with water.

The pine and oak timber, too, is generally cut off young; seldom allowed to stand twenty years, and in more cases cut after ten to fifteen years' growth, and to this, with the frequent burnings, is due the small size and stunted appearance of the trees over most of the region, giving it a forbiddingly-barren aspect, which is only in part really deserved. The name "Jersey Barrens," loosely applied to this part of the State, which expresses the popular opinion of the character of its soil, is, as the detailed description following will show, misleading, being fairly applicable to less than one-third of its area. That timber may attain a good size on such soil is evidenced by the few examples where the trees have been allowed to attain a natural growth. The grove at Point Pleasant, just south of the Manasquan river, contains many large trees; there are a few very fine oaks and pines about Absecon, on the mainland, abreast of Atlantic City; and the grove just south of Winslow contains as heavy timber as is often seen in the State.

Most of the older clearings border navigable water, their owners having been fishermen, oystermen, or, in earlier days, whalers, and depending more on the water than on their farms for a livelihood. Then, too, when travel was chiefly by water the interior was cut off from communication with the markets. Moreover, the privilege of access to the salt marshes and bays for salt hay and seaweed, fish, mussels, crabs and salt-marsh-mud (cheap and convenient fertilizers, enjoyed by the shore farms), had much weight in determining their location. Thus it occurs that while the sea and Delaware bay shores have had for years a border of clearings and villages, the greater part of the interior has been, until a time comparatively recent, an almost unbroken wilderness, although the soil of the interior is on the whole in no way inferior to that nearer the shore.

The advent of artificial fertilizers and the extension of railway facilities have removed the disadvantages of the inland farms, and new settlements are now rapidly springing up along the lines of the various railroads.

The region is well watered. The principal streams are, beginning at the north: Shark river, Manasquan river, Metedeconk river, Toms river, Mullica river, Wading river and Great Egg Harbor river. These flow into the Atlantic. Flowing into Delaware bay are: Maurice river, Cohansey creek, Stow creek and Alloways creek. And, in addition, all the large creeks flowing into the Delaware river south of Trenton, take their rise in this region.

Several of these streams are navigable for some distance from their mouths. Three-masted schooners ascend Cohansey creek as far as Bridgeton, and the Maurice river to Millville. At the shipyard on Dennis creek, near Dennisville, coasters of several hundred tons are launched and taken down the creek to the bay. Great Egg Harbor river is navigable to Mays Landing, and Mullica river to Green Bank, but not to vessels of such size as enter the Maurice river.

These streams also furnish valuable water-power. That at Millville is one of the finest in the State, and those of Mays Landing, Weymouth, Pleasant Mills, Batsto and Harrisville are not much inferior. A feature of peculiar value with these streams is their equable flow, running full with scarcely any variation summer and winter, with no disastrous floods and no season of extreme low water. The cedar swamps in which most of the streams take rise, yield their water slowly and thus form storage reservoirs for maintaining this equable flow notwithstanding inequalities of rainfall.

Geologically, this is the most recently-formed portion of New Jersey, with the exception of the later glacial drift, and the recent river alluviums.

With the exception of the beaches, the recent alluvium of the shores, and the marl of Cumberland county, which is Miocene, it is all provisionally classed as Pliocene Tertiary.

The beds exposed, either in outcrop or section, are clays, sands and sandy or loamy gravels. In places the sand and gravel have been cemented, since deposition, by infiltration of iron in solution, to a stony mass of considerable hardness. These "ledges," though never of any considerable extent, are pretty generally distributed, and as the stone is easily quarried and fairly durable, it is much used for foundation walls aud other rough work. In the neighborhood of Millville, Vineland and Bridgeton much of the ironstone has a very pretty, subdued, reddish-brown tint, and has been used in buildings with good effect.

Unlike the marl and the other older formations lying to the west and north, these Pliocene and recent formations are seldom uniform over any great area, the lithological aspect of a given horizon varying greatly from place to place—that is, a stratum which is at one place clay may at another place appear as sand, gravel or perhaps a clay of entirely different appearance from the first. These changes are not due, except in a few cases, to displacement of the strata, but to variations in deposition. Before or during the deposition of the upper gravel, the subjacent clays and glass-sands were considerably eroded, and the gullies and channels of the uneven surface thus formed being filled with gravel, are a further cause of the apparent lack of continuity of the strata. These cases, however, are easily distinguished from the above. The variations may be abrupt, as where a lens-shaped mass of clay lies in a stratum of sand, which incloses it, with a distinct line of demarkation between the two, or so gradual that it would be difficult to fix upon a dividing line. Examples of both the interposition of the lenses of clay in sand, and of the gradual passage from one to the other, were to be seen last summer at the clay-pit of the Clayville Manufacturing Company, between Vineland and Millville. At the gravel-pit just south of Absecon, on the Camden and Atlantic railroad, are lenses, or "pockets," of clay, some of which are only a few feet in extent. These are not eroded remnants of more extensive beds, but were originally laid down as they now occur. Many other examples might be given.

This lack of continuity, or uniformity of the strata, makes the task of classifying the formations overlying the upper marl, one of difficulty. It appears safe to assume, however, that they lie parallel with the upper marl—that is, dipping toward the southeast at the rate of about 27 feet per mile. From observations taken, the dip of the clays and glass-sands appears to vary from 8 to 30 feet per mile, but it is probable that this discrepancy is due not to any real distortion of the strata, but to the error of confounding beds similar in appearance but belonging to different horizons.

Most of the clays are suitable for ordinary brick and tile manufacture, and some have long been used for terra-cotta and other better-class ware.

All of the specimens examined microscopically contained a high percentage of silica, consisting, in fact, of fine quartz-sand held together by a little true clay (kaolin), the proportion of the latter never rising as high as 50 per cent.

The purer of the siliceous white sands are used in glass-making, and being found in practically inexhaustible quantity, and of easy access, are the foundation of one of South Jersey's largest industries.

The gravel with an admixture of loam, particularly that of a deep-reddish tinge, indicating the presence of considerable oxide of iron, makes excellent road-building material, and its abundance and excellent quality make good roads, no less essential in the rural districts than in the cities, possible throughout nearly every part of South Jersey.

The soils of this region may be loosely classified as yellow gravel or gravelly loam, and white-sand soils, or, since the differences of forest growth correspond pretty closely with variations in the nature of the soil, as oak-land and pine-land soils; oak preponderating on the better gravelly loam, and pine on the white sand.

This is the classification adopted in the report of 1878, and in the map accompanying that report the respective oak and pine areas are provisionally marked out. It should be used with caution, since the kind of timber is not an invariable indication of the quality of soil beneath. The same areas may be clad in oak and pine forests successively, oak succeeding pine, and pine, oak, when either is cut off. But, as stated in that report, the term "pine land" is used to designate land too poor to support a thrifty growth of oak, while the term "oak land" is applied to that on which the oak timber attains a fair size, whether the timber actually predominating be oak or pine.

MONMOUTH COUNTY.

Within the limits of Monmouth county there are two pretty well-defined tracts of pine land, namely, the Hominy Hills pine land and the Manasquan river pine land. There is a small tract lying west of Asbury Park, of inconsiderable extent, which may be called the Whitesville pine land.

Hominy Hills Pine Land.

The Hominy Hills pine land extends from near Centreville and Green Grove westward about 6 miles, and its greatest breadth from north to south is a little more than 3 miles. It includes the southern part of Shrewsbury and Atlantic townships, and about 2 square miles of Howell township. The surface is quite hilly, the highest of the Hominy hills rising to 308 feet above tide, and the whole tract is very poor, the soil being white sand on the lowlands and white sandy gravel and coarse white sand on the hills. A great deal of the lowland is also too wet for cultivation, even if otherwise fit. With a few exceptions this tract is all in forest, the timber nearly all pine, small and stunted-looking.

Manasquan River Pine Land.

The Manasquan river pine lands extend in a narrow belt, with an average breadth of a little more than a mile, from the Manasquan river below Herbertsville to the outcrop of the middle marl along the headwaters of the same stream. The clearings about Herbertsville show a good yellow-gravel soil, but south of the small stream bordering these clearings is only clean white sand. About the junction of the Lakewood and Squan Bridge road and the road leading southwest from Herbertsville, there is a little dark, sandy loam which has been cleared and appears to be good. That part of this tract lying northwest of Southard was not visited, but judging from the number of clearings, there must be a considerable part of it fit for cultivation. This belt comprises a part of the towns of Freehold and Howell.

North of the Hominy Hills pine land lies the fertile and well-cultivated area, comprised in the towns of Ocean, Eatontown and Long Branch, and south, between it and the Manasquan pine, stretches the belt of Squankum oak land, most of which possesses a heavy loam or gravelly-loam soil.

The Squankum oak land is well cleared between Shark river and Manasquan river for a distance of two or three miles back from the sea-shore, and along two narrow belts, on each side of the gravelly ridge running down from the Hominy hills, one following the course of the Manasquan river and including Allenwood, Allaire, Squankum, Farmingdale, West Farms and Fairfield; the other occupying the shallow valley in which runs the Hopeville road. The ridge itself which forms the divide between the Shark and Manasquan rivers, is still well covered with timber, the soil being slightly inferior to that of the adjoining lowlands. There is, in fact, a marked difference in the distribution of good and poor soils between Monmouth county and most of the region south of the Metedeconk river.

Here the best land is found along the river slopes, while in Ocean, Burlington, Atlantic and eastern Cumberland counties the soil of the valleys is almost invariably poorer than that of the higher ground forming the divides. In Salem county, western Cumberland and Cape May the character of the soils does not appear to bear any relation to the topography.

The explanation of these differences, which depend on geological structure, cannot here be entered into, as the study of the stratigraphy of this region is still in progress. The clearings on the northern side of Shark river include some of the best farm-land of Neptune township. West of the New Jersey Southern railroad, the swamps bordering branches of the Manasquan river occupy about 1,000 acres, but these are partly utilized for cranberry-growing.

OCEAN COUNTY.

Leaving out about 2,500 acres of the northwest corner of the town of Plumstead, this county would lie wholly beyond the marl belt, and it also contains a greater area of land worthless, except for forest, than any other county except Burlington. The difference between the heavy marl soils and the lighter gravelly loam and sandy soils of the country east of the marl is nowhere more forcibly presented than in the contrast in Plumstead, between the northwestern corner, in which marl occurs, and the remainder of the township. The marl area is all cleared and in productive farms. Adjoining the marl are scattered clearings, while still farther away the forest is unbroken.

This county includes the following pine-land and oak-land tracts, beginning at the north: Metedeconk river oak land, which overlaps into Monmouth county; Metedeconk river pine land, Toms river oak land, Upper and Lower Toms river pine lands, Forked river oak land, and most of the Forked River-Rancocas pine land, and Barnegat oak land. The Burlington Plains pine tract overlaps the western border a little, and the northeastern corner takes in about 7,000 acres of the poorest of the Manasquan river pine lands.

Metedeconk River Oak Land.

The Metedeconk river oak-land tract extends from the junction of the north and south branches of the Metedeconk river northwestward to the county line. It is bounded on the north by the Manasquan pine-land, along a line passing through Southard and Georgia and terminating near Clayton's Corners. The southern boundary is formed by the south branch of Metedeconk river, and the Toms river oak land, which adjoins it, from a point on the river about three miles above Lakewood, to its western termination. The quality of soil on this tract varies considerably. The farmed tracts east and north of Lakewood have a fine, light, sandy-loam soil, in places apparently very good, with quite heavy sod along the roadside and thrifty-looking crops and orchard trees, while adjoining fields, with a soil only a little more sandy, appear scarcely worth planting. Much of this difference is undoubtedly due to different methods of cultivation. This belt is pretty well cleared up along the north branch of the Metedeconk river, and between Jackson's Mills and New Prospect. There are some good-looking farms also along the Squan Bridge road, but most of the remainder is still in forest. The timber is mixed pine and oak, with rather a preponderance of pine.

Metedeconk River Pine Land.

The Metedeconk river pine land lies south of the south branch of Metedeconk river, in a belt which is at Lakewood about one mile broad, widening southward so as to take in the headwaters of Kettle creek, and reaching the alluvium of the shore from Mosquito cove to the mouth of Metedeconk river, where it is continuous with the Manasquan pine land. As the wooded land between Toms river and Mosquito cove, lying east of a line drawn from Island Heights through a point just east of the White Oak Bottom clearings, is nearly all poor and sandy, it also may be properly included in this pine belt. The soil throughout is very poor. From the Lakewood clearings to the shore road there is not a single cultivated field, except those lying about the villages of Silverton and Cedar Bridge. This barren expanse of white sand covered by a forest of stunted pine trees, which is unbroken save by the bare patches where the poverty of the soil is such that not even the hardy pitch pine can maintain its place, is never likely to be profitably cultivated. As a source of timber and firewood, and for climatic reasons, such land has its value. The presence of so large a body of pine adds greatly to the attractiveness of Lakewood as a resort for invalids, the air of a pine forest being popularly believed to be peculiarly health-giving. This very poor land includes most of the town of Brick and the eastern end of Dover. Metedeconk Neck and the neck lying between Mosquito cove and Kettle cove have a somewhat better soil and are partly cleared, but even here three-fourths of the area is still in forest.

In the immediate vicinity of Point Pleasant, extending to about a mile west of the railroad, there is a heavy, gravelly-loam soil, apparently fertile.

Toms River Oak Land.

South of the Metedeconk river pine land is the Toms river oak-land belt, the southern border of which is defined by the Toms river and the pine swamp skirting the Ridgeway branch, while on the north, west of the termination of the Metedeconk river pine land, it merges with the Metedeconk river oak land. It is nearly divided into two by a narrow strip of pine land, bordering both sides of the north branch of Toms river from Berksville nearly down to the village of Toms River, which may be called the Upper Toms river pine land. This strip is less than a mile in breadth below Holmansville, but widens at the head of the river to about 2 miles. The soil and subsoil are white sand, very poor, and the timber is chiefly pine, with white cedar, gum and maple in the deeper swamps. The clearing at Cassville, and others between that place and Holmansville, are on this strip, but their appearance is not encouraging.

The largest clearings in the Toms river oak belt lie between White Oak Bottom and Toms River village. The well-to-do appearance of most of these farms, with thrifty orchards and well-cultivated fields, attests the good quality of the soil, which varies from sandy loam to heavy clay loam, generally with much gravel. The farms along the road leading through White's Bridge, Holmansville and Vanhiseville show an excellent soil of yellow-gravel loam. The clearings of Siloam, Jackson's Mills, New Prospect and Pleasant Grove also are on this tract. Southwest of the Upper Toms river strip of pine land the soil is inferior. There are quite extensive clearings south and southeast of Cassville, but they are only partly cultivated and do not look promising. The timber is mixed pine and oak, the latter predominating. The poorer land above mentioned is largely covered with chestnut oak, which rivals the pitch pine in ability to live on the driest and most sandy of soils.

Toms River Pine Lands.

The Toms river pine land includes the town of Berkeley and part of Manchester and Jackson.

It is well defined along its northeastern border, which conforms quite closely to the course of the Ridgeway branch and Toms river, but on the south the demarkation is not equally sharp, as much of the oak land on that side (the Forked river belt) is nearly as poor as the adjoining pine land. The timber of both belts consists almost wholly of pine, but south of a line following the course of Cedar creek to Dover Forge, running thence by Giberson's Mills and Horicon, to the edge of the Collins' Mills clearing, and then northward to within about a mile of Midwood, the soil is chiefly gravelly loam, or at any rate underlaid by the gravel at a depth of a few inches, while on the north is found little but white sand, and this line may be considered the boundary. East of the Toms river and Waretown branch of the New Jersey Southern railroad, south of Toms river, oak trees mingle with the pines, the soil is evidently better than farther inland, and there are numerous clearings. There is also a tract of three or four hundred acres on the Manchester-Toms River road with a fairly-good gravelly-loam soil. The remainder of the upland of this tract is a dreary waste of stunted pines growing from a white-sand soil, scarcely an acre of which is fit for cultivation. At Horicon, just on the edge of this belt, grapes and garden vegetables are successfully cultivated, but the vineyards between that place and Manchester have been abandoned and are now scantily overgrown with weeds and bushes.

In this tract of nearly 70,000 acres, exclusive of that lying between Toms river and Cedar creek, and east of the railroad, less than 200 acres of upland are under cultivation. There are, however, between four and five hundred acres of cranberry meadow, and the area of swamp available for cranberry-growing is many times this. As cranberries, where the meadows are properly located and cared for, yield better returns than almost any other crop, it is possible that even the poorest of these tracts may in time support a considerable population engaged in this kind of farming.

Forked River Oak Land.

The Forked river oak land is a belt, averaging about 3 miles in breadth, bordering the Toms river pine land on the south; covered with pine timber, but distinguishable from the pine-land on either side by a greater proportion of gravelly-loam soil. This belt crosses the towns of Plumstead, Manchester and Lacey. The best land of this tract lies about Whiting's, on the Forked River-Bamber road, near Lacey station, and in the vicinity of Cedar Creek, Good Luck and Forked River, near Barnegat bay. Most of the cultivated land is near the bay, but this is mainly because it lies near salt water. The early settlers never liked to live more than an hour's journey from their clam-beds and fishing banks. The forest growth on this belt is not such as indicates a fertile soil, and the appearance of the Lacey and Bamber clearings, which are practically uncultivated, is not encouraging, but the subsoil is sufficiently retentive to make the gradual improvement of the soil possible, and this, with its railway facilities, should make it worthy the attention of prospective settlers.

Forked River-Rancocas Pine Land.

The next belt south, the Forked River-Rancocas pine land, is narrow where it crosses the New Jersey Southern railroad, probably not more than a mile wide, although its limits are not well defined, but widens towards both ends. Measured along the course of Oyster creek, which marks the southern border, to about a mile above Wells' Mills, it is between 5 and 6 miles wide. Thence, the line runs with a sweep westward nearly to Howardsville, through Webb's Mills, and a little south of Buckingham, beyond which point the belt widens rapidly, extending westward through the swamp and flat pine land, south of Brown's Mills and New Lisbon, until it joins the Atsion river pine-land in the town of Southampton, Burlington county. This belt includes about half of Lacey township, crosses western Manchester, and takes in the southwestern corner of Plumstead and southeastern Pemberton. East of the New Jersey Southern railroad there are no swamps, except the cedar swamps which closely border the streams, and the land, which has a mean elevation of over 100 feet, is somewhat rolling, the Forked River mountain, a saddle-backed mound of gravel, partly iron-cemented, 180 feet high, being the most conspicuous prominence. The very slight relief of this region may be inferred from the term " mountain " being applied to a hillock which rises less than 80 feet above the general level of the surrounding country. West of the railroad are extensive cedar swamps, and flat pine land, which is overflowed every wet season. The Philadelphia and Long Branch railroad crosses this part of the belt between New Lisbon and Whiting's. The soil of these wet pinelands is white sand and white gravel, from which most of the elements of plant-food have been leached away. It is not probable that they would ever repay the expense of drainage; but the deeper swamps having an unfailing supply of water, are well adapted to cranberry-growing, and several hundred acres, mostly in the town of Pemberton, have been put to this use.

Barnegat Oak Land.

The Barnegat oak land, the next in order, also lies partly in Ocean and partly in Burlington counties. It may fairly be made to include all the shore settlements from Waretown to the Mullica river, a belt of the woodland extending back from these clearings three to five miles, and a tongue running northwest, with an average breadth of between four and five miles, to the New Jersey Southern railroad, and from there curving around westward until it meets the Shamong oak land. The best lands of Little Egg Harbor and Bass River townships, in Burlington county, and Eagleswood, Stafford, Union and Ocean townships, in Ocean county, lie in this tract. Wheatland is on it. The prosperous appearance of the farms at Four Mile and Hedger House shows the excellence of some of the soil in the western part of the belt. The quality of the soil varies much in different localities. About Nugentown it is sandy and poor enough to be classed as pine land, while just south, about Tuckerton, a heavy gravelly loam prevails. Not all the best land is confined to the shore, although this has been most extensively cleared. The Wheatland clearings have a good, gravelly-loam soil, and at Millville, five miles west of Barnegat village, there is a heavy loam, with much gravel on the higher ground, similar and equal to the best of the productive Hammonton land.

BURLINGTON COUNTY.

As Burlington county extends entirely across the State, from the Delaware river to the Atlantic ocean, it exhibits a great diversity of soils. A belt between fifteen and twenty miles wide across the northwestern end includes the outcrops of the three marl-beds, with their intervening sands, the clay marl, plastic clays and the Delaware river alluvium, and on these formations are found the heaviest and most fertile farm lands of the State. But southeast of this belt lies a tract containing more than 500 square miles, four-fifths of which is a desolate wilderness of fire-scarred pines interlaced with swamps, through which the traveler may journey for hours without seeing a house or meeting another human being. This description is applicable to nearly the whole of the Burlington Plains pine land, which occupies all the central part of this tract, extending from the Barnegat oak land on the northeast to the Atsion river (below Atsion) on the southwest, and has an extreme northwest-southeast dimension of about twenty miles. The Shamong oak land and the upper part of the Atsion river pine land are also included in this part of Burlington county, as well as the western extension of the Forked River-Rancocas pine land and Barnegat oak land, which have already been mentioned in the description of Ocean county.

Burlington Plains Pine Land.

Lying northwest of Munion Field and drained by the east branch of Wading river, is the region known as the East and West Plains, on which little of the timber exceeds the height of a man, and some considerable stretches are entirely bare. Standing on any little knoll one can look over miles of scrubby little pines from two to ten feet high, with here and there a patch of bare sand, dazzling white in the sunshine, without a trace of vegetation. In places there is a rather dense undergrowth of huckleberry and other bushes and coarse grass, but most of the surface, where covered at all, is carpeted with the grayish-green poverty grass (a kind of moss or lichen, the name of which is sufficiently suggestive of the quality of soil on which it is found). Yet the soil of a part, and the subsoil throughout nearly the whole of the plains is a heavy, retentive loam, in appearance not inferior to other soils on which large crops have been produced. Analyses of the plains' soil and subsoil show them to be deficient in lime and potash. Neither of these elements of plant-food is difficult to obtain or very expensive. The greensand marl furnishes both in a cheap, though rather inconveniently-bulky form. If either of the two lines of railroad surveyed from the sea-shore to Atco and Medford respectively, during the past year, be built, this region will be made accessible to settlers, and experiment will determine the feasibility of its cultivation. At present, aside from the cranberry bogs, this region is almost worthless. That parts, at least, of the plains have not always been in their present treeless condition is evinced by the blackened circles occasionally found, relics of former charcoal-burning, which, of course, could be carried on only where there was timber. North of the plains, in Woodland township and eastern Shamong, the country is almost equally poor, and much of it is pine swamp. The soil is white sand, with gravel on the higher knolls.

Along the Mullica river there is considerable good, loamy soil in small tracts, alternating with white sand, which have been partly cleared. The villages of Bass River; New Gretna, Wading River, Lower Bank, Green Bank, Herman and Crowleytown mark these. Some of the land about Batsto is very fair, and much of the southern part of Washington township, south of Washington village, has a gravelly soil, although interrupted by sandy areas which are exceedingly poor. The timber here is mixed oak and pine, showing the better character of the soil. This pine-land belt is crossed by the New Jersey Southern railroad, and clearings have been made at Woodmansie, Shamong and Harris stations, but the attempt to cultivate such soils is of questionable advisability. If protected from fire they yield, as woodland, a good annual percentage on their present valuation, but for farming they hardly warrant the expense of clearing.

*Shamong Oak Land.**

The Shamong oak land is an area with a very irregular boundary, which includes Tabernacle, Sooy Place, Friendship, Fox Chase, Flyat, Small's and Dellett's, with a southward spur to Atsion, between the main Atsion river and Wesickaman creek. Northeastward from Sooy Place it joins the Barnegat oak land. The best lands of Shamong township and a little of western Woodland lie in this tract. South of Atsion, between the Atsion and Batsto rivers, the timber is nearly all oak, but the soil is poor and sandy. West of Batsto river, near Batsto, the soil becomes better again, with the re-appearance of gravel.

The best soil of this tract is peculiar, and unlike that of any of the other oak-land tracts. It is a fine loam, free from pebbles—not of the usual yellow or reddish-yellow tinge, but nearly black. The subsoil at a depth of ten inches or a foot is yellow, and rather sandy. While all the staple crops—corn, small grain, potatoes—yield well on this dark, loamy soil, it appears to be especially adapted to the growth of grass, and hay forms a principal crop. The roadsides are well grass-grown, and the turf resembles in thickness and toughness that of a Western prairie. There are also some gravelly soils and some

* Named from Shamong township, in which it partly lies, and not to be confounded with the Shamong on the New Jersey Southern railroad, which lies in the Burlington Plains pine lands.

pretty poor sand on this tract. Doubtless much of this land owes a good share of its fertility to the care it has received, as the farmers haul marl from the pits at Chairville and near Red Lion, and have continued this practice for years, probably more formerly than at present, since the use of marl has lessened under the competition of manufactured or "chemical" fertilizers. But the character of the soil along the roads, which presumably have never been marled, shows the superiority of this tract over the surrounding pine land. A great drawback is the lack of shipping facilities, but this would be removed by the construction of one of the proposed new railroads.

Atsion River Pine Land.

The Atsion river pine land lies west of the Mullica and Atsion rivers, beginning at a point about ten miles from the head of Great bay, widening toward the northwest, to two or three miles above Atsion, where it is crossed by the river of that name. North of the Atsion it becomes still broader, and extends to within about a mile of the marl belt. At Batsto, it is about one and one-half miles wide; at Atsion, about four miles. That part of this pine-land tract which lies within the limits of Burlington county has much more oak than pine timber, except the borders of the swamps, which are studded with sickly-looking pines, but the oak is chiefly chestnut oak, which no poverty of soil can displace. The soil is white sand, and white, sandy gravel. There are some large cranberry bogs in the town of Medford, but very little of the upland is cultivated.

As the remainder of the oak-land and pine-land belts are so apportioned among the counties that each can be more intelligibly described as a unit than with primary reference to the county lines, they will be taken up in this manner.

South and west of the river from which it takes its name, the Atsion river pine-land belt is poorer than the part already described in Burlington county. The timber is nearly all pine, the soil white sand, south of Atsion, and white gravel and sand west of that place. This white gravel is quite different from the ordinary yellow gravel of the surface, the pebbles being smaller and more angular. It may be the outcrop of another bed. About twenty square miles of this part of the belt are in Camden county, the remainder in Atlantic county.

Mullica and Egg Harbor Divide Oak Land.

The Mullica and Egg Harbor divide oak-land belt extends from the marl district to the sea-shore, along both sides of the Camden and Atlantic and Reading railroads, and includes nearly two-thirds of Atlantic county and most of the southeastern half of Camden county.

At the shore this tract extends from the tidal marshes of the Great Egg Harbor river to those skirting the Mullica river, a distance of nearly twenty miles, but farther inland the pine-land belts converge, narrowing the oak land to about eight miles at Hammonton. The timber is mixed pine and oak. The character of the soil varies considerably from place to place, but is usually a yellow, gravelly loam, and even where the surface is light and sandy the subsoil is generally sufficiently retentive. In a few place, as at Winslow, outcropping clay-beds give heavy clay soils over limited areas.

This tract is worthy of especial examination, because here, more than in any of the other areas which have been reviewed, the farmers have adapted their methods to suit the peculiarities of the soil. Unable to compete with Western farmers, or even with those of more favored parts of their own State in producing live stock and the other general staples of the farm—grain, hay, &c.—they have turned their attention to raising fruit, particularly small fruits, grapes and the various berries, and to truck-farming. Not enough corn and hay are produced to satisfy the local demand. It does not pay to raise them. The land is more valuable for other purposes.

The Hammonton tract includes some of the oldest and best-cultivated farms in the belt, and as it embraces a variety of soils, from heavy clay loam to white sand, the experience of its farmers may be considered as typical of what can be done with such land. The figures given below were furnished by Mr. L. H. Parkhurst, one of the largest and most successful fruit-growers of Hammonton. The figures are considerable higher than the average for the town, but they are instructive, as showing what may be accomplished with proper skill and experience.

YIELD PER ACRE IN 1891.

Strawberries	3,000 quarts.
Raspberries, red	2,000 "
Raspberries, black cap	2,300 "
Blackberries	1,200 "
Grapes	5,000 pounds.
Pears	80 barrels.

Peaches and apples also yield well. In comparing these returns with others from different localities, it should be remembered that these were not the results of kitchen-garden experiment, but of cultivation on a large scale. The farm referred to has 140 acres in fruit alone. The German settlers of Egg Harbor City have made a specialty of grape culture and wine-producing, in which they have been eminently successful. It is claimed that the red and white still wines and champagne of Egg Harbor are equal to the best imported from Europe. While this may be rather warm commendation, it is certain that these native wines have many admirers and find ready purchasers. A few years ago it was feared that this industry would be totally destroyed by the prevalence of mildew and black-rot on the vines and fruit, but these fungi are now readily destroyed by spraying the vines with some fungicide. The most approved preparation for this purpose is "Bordeaux mixture," composed of lime and sulphate of copper. The production of wine this year exceeded 100,000 gallons.

Although most of the Hammonton tract has a good, gravelly-loam soil there are parts which are very light. To the farmer accustomed to deal only with heavy clay soils, the sight of these fields of white sand, with their rows of blackberry and raspberry canes, overburdened with luscious fruit, is a singular one. In reality such fields are less sandy than they appear, as beneath the surface film, weather-bleached, and in part consisting of fine sand drifted on by the wind, the soil is darker in color and less purely siliceous. But the secret of success with such land is in the liberal use of superphosphate and other artificial fertilizers. Barnyard manure, muck, composts, &c., are not much used except for top-dressing grass plats, and mulching trees. It is the prevalent opinion that on these very light soils the greater part of slow-acting manures is lost by leaching away during the winter, or wasted in forming wood and leaf during the season that the plant is not producing fruit, while the more concentrated and soluble fertilizers can be applied directly to the roots just at the right time to force the buds or aid in ripening the fruit. This practice brings greater immediate returns. Whether in the long run such usage results in the deterioration of the land, is a disputed point. It is certain that some of the shore farms, on which, for generations, the farmers have been hauling muck and salt-marsh mud, have been greatly improved thereby, but at a great expenditure of time and labor.

The sea-shore front of this belt, as elsewhere, is well cleared and settled. From Somers Point, on Great Egg harbor, to Leeds Point on Great bay, the estuary of Mullica river, a distance of 16 miles, there is a continuous clearing, varying in width from one-half to one and one-half miles, and to drive along the road between these points is like passing along a village street, so closely set are the farm-houses and summer residences. The villages of Somers Point, Bethel, Sea View, Uncle Tom, Linwood, Bakersville, Newell, Smith's Landing, Pleasantville, Mount Pleasant, Absecon, Conoverville, Somersville, Oceanville, Centerville and Leeds Point are on this shore clearing, and Smithville, Higbeeville, Johnsontown, Port Republic and Unionville continue the line back along Great bay and the Mullica river.

A rear line of clearing, following the course of Patcong creek, includes Steelmanville and Bargaintown. Originally selected because adjacent to the sea, this shore belt now enjoys the additional advantage of being crossed by several lines of railroad, constructed chiefly to meet the increasing demands of summer travel, but affording an outlet for the produce of the region as well.

Besides Egg Harbor City and Hammonton, already mentioned, there have sprung up on the lines of the Camden and Atlantic and Philadelphia and Atlantic (Reading) railroads many newer agricultural towns. Pomona and Germania are east of Egg Harbor City, and, like the latter, are the centers for thriving German colonies. In the vicinity of Ellwood there are about 1,000 acres of cleared land, most of it equal to any at Hammonton. The clearings about New Germany, southwest of Hammonton, embracing about 1,200 acres, most of which has an excellent gravelly-loam soil, are also tributary to these roads. Winslow, Waterford and Atco are glass-manufacturing places, but, having much good farm land about them, are not wholly dependent on this industry. On the West Jersey and Atlantic railroad, east of Mays Landing, two new towns, Riga and McKeetown, have recently been laid out, with a view to attracting the stream of Hebrew immigration now flowing into this part of the State.

Egg Harbor River Pine Land.

Bordering the Mullica and Egg Harbor divide belt on the southwest is a narrow strip of pine land along the Great Egg Harbor river. It extends from near Scull's Landing, in Egg Harbor township, nearly up to New Brooklyn, in Camden county. South of Weymouth it is almost wholly confined to the east side of the river, and is nowhere more than 3 miles broad. Below New Germany it divides, one fork, from one-half to three-quarters of a mile wide, extending between Hammonton and New Germany to about half a mile west of the Hammonton road, and the other, still narrower, following the course of the main stream. The soil is poor white sand, and much of it is swampy. There is little timber but pitch pine, and most of that is small and thinly set. The largest clearing is at Mays Landing, a manufacturing place.

Atlantic and Delaware Bay Divide Oak Lands.

The oak land of the Atlantic and Delaware bay divide includes parts of Gloucester, Atlantic and Cumberland counties. In its general features of soil, forest and means adopted in bringing it under cultivation it is similar to the railway oak belt. The soil of the southern part is, as a rule, somewhat lighter than that about Vineland, Newfield, Clayton and the northern half generally, and this part still remains an almost unbroken wilderness. The new Philadelphia and Sea-shore railroad opens the wildest part of this tract, and settlements may be expected to soon spring up along its line.

On the Vineland tract attention is paid chiefly to the special crops which have been found best adapted to this soil, of which mention has been made in connection with the railway oak belt. Wine is made here also. In Gloucester county, nearer the marl belt, the usual farm products are more depended upon. On the farm of Mr. John M. Moore, of Clayton, which is a model of its kind, are raised corn, hay and small grain and root crops, as well as some fruit.

His experience is valuable and suggestive, as showing what may be achieved on land too often stigmatized as unproductive.

East of the last-named belt is a narrow strip of sandy land bordering the Maurice river from a little south of Iona to below Manumuskin. The Maurice river pine land lies mostly on the east side of the river. Above Millville its average breadth is less than 1½ miles, but below that point the belt widens. At Manumuskin it is between 3 and 4 miles broad. This belt extends along the West Jersey railroad to just south of Muskee creek. Some shreds and patches of it extend down the left bank of Maurice river also, in the shape of dune-like mounds and ridges of sand, and some flat sandy land, interspersed with better tracts. The soil of this belt is white sand, very poor, supporting a stunted growth of pines, with a few oaks. Some of this land on the Vineland tract has been cleared and then abandoned. Most of this tract is in eastern Cumberland county, the northern part just touching Salem and Gloucester counties.

Delaware Bay Slope Oak Land.

All the territory west of the Maurice river, including the western half of Cumberland and about two-thirds of Salem county, may be fairly characterized as oak land, with the exception of about 3,000 acres lying west of Cohansey and Jericho, known as the Salem Barrens, and much of this area has a heavy loam soil which will bear comparison with that of any part of the marl belt. The excellence of the farm lands of Alloway, Pilesgrove and Pittsgrove, in Salem county, has long been known. Deerfield township, in Cumberland county, has a soil which owes much of its present fertility to liberal applications of marl in years past. Greenwich and Hopewell are well-known truck fields. But a large part of this region still remains in forest. This is especially true of the towns of Millville, Fairfield, Lawrence, Downe and Commercial. The soil of these wooded areas is not equal to that of the cultivated townships just mentioned, but that it is quite up to the average of the oak lands on the other side of the Maurice river is shown by the success of the Jewish colonists at Alliance, Rosenhayn and Carmel.

Cape May County Oak Land.

In Cape May county there is some very light soil, but none so poor as to be fairly classed as pine land. The timber is mixed pine and oak, but mostly small, owing to frequent cutting, but on Beesley's Point some large old oaks show what size the timber would attain if left undisturbed. Most of the cleared land lies along the shore on both sides of the cape, but, as has been pointed out, this choice of the shore, instead of the interior, has had no particular reference to the quality of the soil.

Owing to its location, between the sea and Delaware bay, and in the extreme southern part of the State, Cape May enjoys a milder climate than other parts of New Jersey. Cotton has been successfully grown here; and delicate plants, as the English ivy, which elsewhere must be taken into the house at the approach of winter, may safely be left in the open air the season through. As the spring is a week or ten days earlier than in the central part of the State, garden vegetables can be brought to market that much earlier—a considerable advantage, since prices are always high for the earliest produce.

In the "Geology of Cape May," published in 1857, the late Dr. George H. Cook makes the following remarks concerning the soils of this region, which are not only equally true at the present time, but worthy of reprint, as showing Prof. Cook's early appreciation of the agricultural possibilities of this part of the State:

"The soils are generally light; there are none which are clayey, and very few which would be designated as heavy loams. The term, sandy loam, would designate almost all the soils of the county. Spots are occasionally found which are decidedly sandy, but these are not of any considerable extent. Tracts of loamy soil are also found. The varieties of soil run into each other so much in all parts of the county, that it is not possible to give descriptions which would be of any local value. In most cases, the subsoil is similar to the soil, except in the want of organic matter. A more tenacious subsoil has been found in a few places; as on Stipson's island, and at Fishing creek.*

"The soil is particularly well adapted to the growth of truck or market-garden produce. Early potatoes, tomatoes, melons, &c.,

* For analyses of some of these soils, see *Geology of the County of Cape May*, Trenton, N. J., 1857, pp. 70, 72, 74.

thrive here. Apples, pears, peaches, blackberries, strawberries, cranberries, &c., can be raised in abundance, and are very fine. The spring is between one and two weeks earlier than in the central part of the State; and for raising early crops this would give very great advantage; but the distance from market, and want of proper facilities for conveyance, have discouraged enterprise in this line of business."

[The latter part of this sentence is no longer applicable, since the cape is now traversed throughout its whole length by the West Jersey railroad, and a new road, the Philadelphia and Sea-shore, has been completed as far as Sea Isle City, and has the road-bed graded nearly to Cape May City, so that there is now no part of the county more than six miles from a railroad station.]

"FOREST TREES—UPLAND.

White oak	*Quercus alba.*
Black oak	*Quercus tinctoria.*
Red oak	*Quercus rubra.*
Pin oak	*Quercus palustris.*
Peach oak	*Quercus phellos.*
Scrub oak	*Quercus nigra.*
Chestnut oak	*Quercus castanea? Quercus Muhlenbergii.*
Turkey or Spalt oak	*Quercus obtusiloba.*
Yellow pine*	*Pinus mitis.*
Spruce pine	*Pinus inops.*
Red cedar	*Juniperus Virginiana.*
Persimmon	*Diospyros Virginiana.*
Dogwood	*Cornus florida.*
Hickory (white-heart)	*Carya tomentosa.*
Hickory (red-heart)	*Carya alba?*
Wild cherry (introduced?)	*Cerasus scrotina.*
Chestnut (introduced?)	*Castanea vesca.*
Sassafras	*Sassafras officinale."*

"FOREST TREES—TIMBER SWAMP.

White oak	*Quercus alba.*
Black oak	*Quercus coccinea?*
Beech	*Fagus ferruginea.*
Sweet gum	*Liquidamber styracifolia.*
Sour gum, or pepperidge	*Nyssa multiflora.*
Spoonwood	*Magnolia glauca.*
Aspen	*Populus tremuloides.*
Maple	*Acer rubrum.*
Holly	*Ilex opaca.*
Ash	*Fraxinus Americana.*
Elm	*Ulmus Americana.*
Yellow poplar	*Liriodendron tulipifera."*

* This tree is the pitch pine, *P. rigida.*

"The original growth of timber on the upland has been all cut off. The growth of the young timber is rapid; from fifteen to twenty years is long enough for it to get sufficient size for firewood, and it is then cut off. An acre cut off in this way will yield about as many cords of wood as it has been years in growing; thus, a twenty-years' growth will turn out twenty cords per acre.

"With land at a low price the growing of firewood has in many cases been found profitable. The greatest drawback to this business is the fires, which are too common, and which sometimes destroy hundreds of acres of growing timber."

This part of the State, and especially Atlantic, Cumberland and Cape May counties, has attracted much attention of late on account of the heavy immigration of Russian Jews likely to ensue from the various colonization plans now on foot. Fears have been expressed that these immigrants might prove an undesirable addition to our population. But thus far the Hebrew colonists have proved industrious and economical, and have gained a good reputation for prompt settlement of debts. The older colonies appear to be eminently successful, and while it is yet too early to express an opinion of those which have but just been organized, there appears no reason to doubt that they will be equally so. The following quotation from a late number of the "Philadelphia Record" refers to the Baron de Hirsch colony at Woodbine, and shows the character of the work being done there: "The sixty 30-acre homesteads at Woodbine are nearly ready for the balance of the Hebrew colonists. The preparation of the soil for planting is being pushed forward rapidly, and 15,000 fruit trees will be set out as soon as the weather permits. A large acreage of berries will also be planted. * * * Twenty acres have been reserved in the center of the tract for a public park. A synagogue, public school and hotel will go up on its boundaries. Mr. Sabsovitch, its superintendent, fixes its population at four hundred by early spring."

In the following tables giving the area of cleared upland and forest in the territory southeast of the marl, the figures for the towns entirely included in this territory are taken from the Final Report of the State Geologist, Vol. I., 1888. In the case of towns only partly included, the respective areas were carefully measured on the topographic sheets, but, of course, without attaining the accuracy of a survey:

MONMOUTH COUNTY.

Townships.	Cleared Upland. Acres.	Forest. Acres.
Neptune	3,553	3,892
Atlantic	1,208	4,552
Ocean	9,450	2,905
Eatontown	1,700	1,700
Shrewsbury	1,575	4,825
Freehold	1,880	9,028
Wall	13,004	11,672
Howell	13,913	25,480
	46,283	64,044

OCEAN COUNTY.

Berkeley	2,091	24,735
Brick	6,456	26,432
Dover	6,494	18,040
Eagleswood	1,036	5,215
Jackson	9,873	53,123
Lacey	2,621	53,748
Manchester	1,857	51,416
Ocean	972	9,210
Plumstead	5,327	16,811
Stafford	2,800	20,003
Union	1,386	15,768
	40,913	294,501

BURLINGTON COUNTY.

Bass River	1,573	43,261
Evesham	582	7,818
Little Egg Harbor	3,253	17,920
Medford	896	16,064
New Hanover	2,060	4,980
Pemberton	2,547	26,253
Randolph	1,150	34,710
Shamong	7,852	37,153
Southampton	4,339	14,861
Washington	627	25,943
Woodland	403	74,344
	25,282	303,307

ATLANTIC COUNTY.

Absecon	1,066	1,330
Buena Vista	4,940	32,163
Egg Harbor	9,266	34,034
Egg Harbor City	659	5,312
Galloway	6,873	37,201

Townships.	Cleared Upland. Acres.	Forest. Acres.
Hamilton	1,197	71,493
Hammonton	7,142	21,663
Mullica	2,266	32,817
Weymouth	2,362	35,625
	35,771	271,638
CAMDEN COUNTY.		
Gloucester	8,947	6,413
Waterford	5,741	24,739
Winslow	9,524	28,386
	24,212	59,538
GLOUCESTER COUNTY.		
Clayton	7,416	6,437
Franklin	11,509	25,531
Glassboro	4,669	2,605
Harrison	3,380	460
Mantua	3,234	576
Monroe	7,824	21,511
South Harrison	3,453	2,227
Washington	10,584	3,864
	52,100	63,211
CUMBERLAND COUNTY.		
Bridgeton	5,041	3,126
Commercial	4,907	9,047
Deerfield	14,899	11,607
Downe	4,228	16,146
Fairfield	7,767	9,719
Greenwich	6,313	1,702
Hopewell	17,439	2,393
Landis	16,134	28,631
Lawrence	6,284	11,090
Maurice River	5,514	53,060
Millville	3,876	24,341
Stow Creek	9,289	2,116
	101,691	172,978
CAPE MAY COUNTY.		
Cape May City	177	....
Dennis	6,178	25,677
Lower	6,924	6,710
Middle	10,515	19,104
Upper	5,887	23,882
	29,631	75,373

SALEM COUNTY.

Townships.	Cleared Upland. Acres.	Forest. Acres.
Alloway	14,032	7,757
Elsinboro	4,188	73
Lower Alloways Creek	10,731	2,731
Mannington	1,995	565
Pilesgrove	11,826	974
Pittsgrove	11,088	20,831
Quinton	8,101	7,272
Upper Pittsgrove	20,454	2,596
	82,415	42,799

The total area is 1,785,687 acres, of which 438,298 acres have been cleared, while 1,347,389 are in forest. The areas of the pine-land tracts are:

	Acres.
Hominy Hills	9,000
Manasquan River	17,000
Metedeconk River	19,000
North Branch Toms River	7,000
Toms River	60,000
Forked River-Rancocas	80,000
Burlington Plains	172,000
Atsion River	63,000
Great Egg Harbor River	30,000
Maurice River	26,000
Salem Barrens	3,000
	486,000

Deducting this from the total area leaves 1,300,309 acres fit for tillage, of which more than 800,000 acres still remain in forest. New Jersey is the third State in the Union in density of population, but there is still plenty of room within her borders.

AREAS BY COUNTIES.

COUNTIES.	1. Total.	2. Total.	3. Upland.	4. Tide Marsh.	5. Beach.	6. Total Land Surface.	7. Water.	8. Cleared Upland.	9. Forest.	10. Southeast of Marl Belt. Cleared Upland.	11. Southeast of Marl Belt. Forest.	12. Southeast of Marl Belt. Oak Land.	13. Southeast of Marl Belt. Pine Land.
	Sq. Miles.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.
Monmouth	537.94	341,280	300,999	8,378	1,901	306,278	88,002	211,288	89,711	46,283	64,014	91,949	19,000
Ocean	675 61	432,889	338,998	27,969	6,348	373,310	59,079	48,831	295,167	40,918	294,501	183,414	152,000
Burlington	898.79	575,223	532,929	22,374	989	556,292	18,931	211,232	321,697	25,282	303,307	103,589	225,000
Atlantic	613.49	392,633	307,409	53,325	3,415	364,149	28,484	35,771	271,638	35,771	271,638	263,409	44,000
Camden	225.96	144,613	139,101	2,964	....	142,065	2,548	72,518	66,588	24,212	59,538	68,750	15,000
Gloucester	339.28	217,139	199,901	10,946	....	210,847	6,292	126,319	73,582	52,100	63,211	112,311	8,000
Cumberland	685.36	438,630	274,669	52,661	....	327,330	111,300	101,691	172,978	101,691	172,978	250,669	24,000
Cape May	442.05	282,915	105,004	53,638	5,503	164,145	118,770	29,631	75,373	29,631	75,373	105,004	....
Salem	339.37	219,198	188,138	31,780	....	219,918	29,280	138,081	50,057	32,415	42,799	121,214	4,000
Total	4,807.85	3,077,020	2,887,148	259,035	18,151	2,664,834	412,686	970,857	1,416,791	438,293	1,347,889	1,300,309	486,000

3. Upland as distinguished from tide marsh, but really including all swamps and fresh meadow.
4. Salt marsh fringing the coast inside the beaches.
7. Includes all streams and channels exceeding 100 yards in width, and all bodies of water approximating or exceeding 100 acres.
9. Includes all lots of ten acres and upwards.
12. Obtained by subtracting pine-land areas from total upland areas.
13. Approximate areas.

WATER-SUPPLY AND WATER-POWER.

BY C. C. VERMEULE.

The work of collecting and compiling data bearing upon the flow of the streams of the State has proceeded throughout the year. The purpose of these studies is to enable us to reach reliable conclusions as to the capacity of our water-sheds to supply our cities with water for domestic and industrial consumption, or power for mills and manufactories. An accumulation of interesting facts has been the result of this work, and next May, when our period of observation shall be complete, we shall have sufficient data in hand for our report. Much of our material is at the present time incomplete; more of it will have an important bearing upon the results reached, but of itself is not proper matter for publication in our reports. Our practical readers want conclusions, clearly, conveniently and concisely stated. They have not the time to make their own analyses and deductions from unsifted material. In this progress report we shall give only such results as have sufficient completeness to be of value.

RAINFALL FOR 1890 AND 1891.

In order to properly interpret the gaugings we must know the relation which the rainfall during the period of gauging has to the average rainfall of the region under discussion. From the averages given in the Climatology of New Jersey, published by the Survey in 1888, and from the rainfall records furnished me by the State Weather Service, I have compiled the following comparative tables of rainfall for 1890 and 1891. The yearly rainfalls given are from January to December, and therefore do not agree with the totals for the four seasons, as the winter rainfall includes January and February of the following year. I have deemed it best to use the figures for stations which had the best-established averages, or those made up from the larger series. The stations given fairly represent the characteristics of rainfall of the State from March 1st, 1890, to November 30th, 1891.

RAINFALL AT NEWARK.

Average.	Spring.	Summer.	Autumn.	Winter.	Year.
1843 to '87	11.31	12.92	10.96	11.06	45.95
1890	14.67	15.71	12.53	17.57	54.98
1891	9.67	13.36	7.51	....	48.16

RAINFALL AT NEW BRUNSWICK.

Average.	Spring.	Summer.	Autumn.	Winter.	Year.
1854 to '87	10.98	13.46	10.36	9.51	44.31
1890	13.36	17.04	14.42	16.59	55.76
1891	10.78	11.54	7.23	....	46.66

RAINFALL AT TRENTON.

Average.	Spring.	Summer.	Autumn.	Winter.	Year.
1866 to '80	10.83	15.01	11.71	8.95	47.55
1890	13.65	12.03	12.97	15.09	49.80
1891	9.33	15.40	9.52	....	48.91

RAINFALL AT PHILADELPHIA.

Average.	Spring.	Summer.	Autumn.	Winter.	Year.
1825 to '87	10.62	12.46	10.15	9.80	43.03
1890		8.69	7.93	10.69	....
1891	8.50	11.38	6.17	....	38.39

RAINFALL AT ATLANTIC CITY.

Average.	Spring.	Summer.	Autumn.	Winter.	Year.
1874 to '87	9.56	11.22	10.02	11.75	42.55
1890	14.87	16.56	9.44	13.63	47.90
1891	9.53	11.59	8.53	....	43.14

RAINFALL AT VINELAND AND EGG HARBOR CITY.

Average.	Spring.	Summer.	Autumn.	Winter.	Year.
*1866 to '86	11.31	12.86	11.43	12.67	48.27
†1890	15.13	14.49	15.18	18.96	55.38
‡1891	13.06	18.89	7.94	....	57.51

* Vineland only. † Egg Harbor City only. ‡ Vineland and Egg Harbor City combined.

It may be noted that in the spring of 1890 the rainfall was from 2.4 to 3.3 inches above the average in northern New Jersey, and from 4 to 5 inches in the south. The summer rainfall was also in excess in the north and south, although apparently deficient, or below the average, at Trenton and Philadelphia as much as it was above elsewhere. In the autumn it was in excess in northern New Jersey, nearly normal at Trenton, and deficient in southern New Jersey. All over the State there was a very dry November, the precipitation being less than an inch at most of the stations.

During the winter of 1890–91 there was an excess of from 6 to 7 inches over most of the State; the following spring shows a deficiency of about 1.5 inches in the north and nearly a normal fall in the south. April was quite dry. The summer of 1891 had about the normal precipitation over northern New Jersey, with quite a large excess in the southern part. The autumn was dry all over the State. The deficiency amounts to from 2 to 4 inches. This deficiency was quite uniform for the three months, and streams in northern New Jersey ran very low. Some of the observers report the driest year ever known on their streams. There is evidence of an unusually protracted period of very low water on the Paulinskill, Musconetcong and Ramapo, extending from May through November. There is an almost complete absence of flood flows for this period.

The yearly rainfall in 1890 was from 2.3 to 11.4 inches in excess of the normal. In 1891 it was also in excess from 0.6 to 9.3 inches, the greatest excess being in northern New Jersey in 1890 and in the southern interior in 1891.

The distribution of rainfall is a matter of importance which we shall need to keep in mind also. The Climatology points out the differences so far as the data indicate. An average excess of southern over northern stations of 0.73 inch annually, and of eastern over western stations of 3.74 inches, is then shown. For the last two years in particular, and in all of the records to a greater or less degree, an excess of rainfall is shown by the stations of the southern interior, Egg Harbor City, Vineland and Bridgeton usually showing a much greater precipitation than is indicated by the stations in the vicinity of Mount Holly and Philadelphia; the figures given in the table of flow are composite rainfall, being the averages of several stations which, taken together, are believed to fairly represent the water-shed of the stream under consideration.

EVAPORATION.

We gave quite full studies of this subject in our last report. Under the computation of flow of the Croton we found it necessary to allow a percentage of the excess of rainfall added to the constant ground flow when rainfall was in excess of the evaporation in the dry months. We present herewith some further investigations of the Croton series, with a view to determining more accurately our evaporation constants and variables. First taking the rainfall, flow and loss by years, and eliminating all doubtful figures, where there is evident error in gaugings, we get the following averages:

YEARLY RAIN, FLOW AND LOSS OF RAIN ON THE CROTON—IN INCHES.

Rain.	Flow.	Loss of Rain.
39.41	19.12	20.29
41.06	17.97	23.09
44.42	22.29	22.13
46.92	21.93	24.99
48.47	20.74	27.73
50.56	24.46	26.40

We find in this table no direct ratio between rainfall and flow or loss of rain, but we do find an increase in both columns with increased rain. If we take the loss for 40 inches of rain at 21.6 inches, and then for any excess of rain add half that excess to the evaporation, we get the following results:

COMPUTATION OF YEARLY LOSS OF RAIN—CROTON WATER-SHED.

Rain.	Computed Flow.	Computed Loss.
40.0	18.4	21.6
41.0	18.9	22.1
44.5	20.7	23.8
47.0	21.9	25.1
48.5	22.7	25.8
50.5	23.7	26.8

These computed values range well with the observed values of flow and loss, and seem to point the way to a method of determining the yearly flow from the yearly rainfall. This rule rests on the fact that the evaporation from the ground is practically constant when the rain exceeds 40 inches, and the excess of evaporation is due to the exposure of shallow water on the surface when rainfall is heavy.

On the Sudbury we find the following:

SUDBURY WATER-SHED—YEARLY TOTALS.

	Rain.	Flow.	Loss.
1875–76	40.95	21.45	19.50
1876–77	41.11	22.26	18.85
1877–78	45.41	24.21	21.20
1878–79	47.78	24.43	23.35

These results show an evaporation of 19.17 inches for a rainfall of 41.03 inches; about 3 inches less than the Croton shows for a like rainfall. Adding one-half the excess of rain over 41 inches we get for 45.5 inches, 21.4, and for 48 inches, 22.7 inches of evaporation, which seems to indicate that the above rule holds good for this water-shed also, with a change of constants. With extremely light rainfalls we should, probably, find the evaporation decreases somewhat. In the absence of data to determine how much, we shall be safe to assume that it is constant for lesser rainfalls.

Let us now examine the dry months only, in the same way:

JUNE TO NOVEMBER—CROTON WATER-SHED.

Rain.	Flow.	Loss.
17.25	2.54	14.71
20.86	3.76	17.10
22.28	4.81	17.47
23.94	4.81	19.13
25.71	7.12	18.59
27.30	8.95	18.35

Here also we notice an increase of both evaporation and flow for increasing rainfall, and if we take the normal for 20 inches of rainfall to be 17 inches evaporation, and add to this 25 per cent. of the excess of rain, we have the following:

Rain.	Evaporation.
20.0	17.0
22.0	17.5
24.0	18.0
26.0	18.5
28.0	19.0

10

These results also seem to range well with the observed quantities. It may seem, at first sight, strange that we use only 25 per cent. of excess in the summer months and 50 per cent. for the whole year, but it should be remembered that this percentage represents evaporation from water on the surface in pools, &c., and there is less water so standing during this season, as the ground rapidly absorbs the rain. The constant evaporation for 20 inches of rain for these six months is 17 inches, against 21.6 inches for 40 inches of rain during the whole year. The constant part of the evaporation is much greater, the variable part only being less. It is noticeable that for the smaller rainfall shown, evaporation decreases nearly as fast as the rainfall.

SUDBURY WATER-SHED—JUNE TO OCTOBER.

Rain.	Flow.	Loss.
18.81	2.45	16.36
21.50	3.15	18.35
23.94	3.22	20.72

This series is too short to show more than the general fact already observed—that evaporation increases with the rainfall. Taking the period from May to December, we find a close agreement between the Croton and Sudbury.

CROTON WATER-SHED—MAY TO DECEMBER.

Rainfall.	Flow.	Loss.
23.98	5.42	18.56
28.44	8.01	20.43
30.03	9.98	20.15
33.09	11.77	21.32
40.05	14.69	25.36

It is here evident that for this period the rainfall appears in the proportion of one-third flow and two-thirds loss.

SUDBURY WATER-SHED—MAY TO DECEMBER.

Year.	Rainfall.	Flow.	Loss.
1875	32.95	9.70	23.25
1876	31.88	6.89	24.99
1877	28.25	10.01	18.24
1878	35.84	14.23	21.61
1879	25.52	5.22	20.30

After making proper allowances for rainfall carried over from April, so as to increase the flow in May, we find the Sudbury almost identical with the Croton for this period. The proportion of two-thirds rainfall to evaporation and one-third to flow is apparently quite well established by the records of the Croton and Sudbury from May to December.

CROTON WATER-SHED, DECEMBER TO MAY.

Rainfall.	Flow.	Loss.	One-fourth Rainfall.
15.74	11.81	3.93	3.92
19.72	14.52	5.20	4.93
21.70	16.07	5.64	5.42
25.18	19.03	6.15	6.29

SUDBURY WATER-SHED, NOVEMBER TO MAY.

Rain.	Flow.	Loss.
21.37	20.09	1.28
23.87	21.13	2.74

The difference between the Sudbury and the Croton is evidently almost entirely in a less evaporation in the winter months. It is to be expected, since the winter evaporation is largely from water upon the surface, that it should be proportionate to the rainfall. The last column of the above table of winter flow of the Croton shows how closely 25 per cent. of rainfall agrees with the observed loss of rain.

Applying the above results I am inclined to modify somewhat our monthly constants of evaporation assumed in my last report and adopt the following: January, 0.5; February, 0.5; March, 0.75; April, 1.0; May, 2.0; June, 3.0; July, 3.75; August, 3.75; September, 3.0; October, 1.75; November, 1.25; December, 0.75. These constants are believed to fairly represent the evaporation upon the Croton water-shed for an evenly-distributed annual rainfall of 40 inches. We shall ultimately modify somewhat the methods of determining the variables also, but for the present the above estimates will prove useful in comparing our New Jersey streams and in fixing their constants of evaporation.

PAULINSKILL GAUGINGS.

The record for this stream has been kept throughout the year by Messrs. G. C. Adams & Co., at Hainesburg. The stream has run very low since June 1st. This part of the record not having yet been fully reduced, we give below the results to April 30th only. This gives us a full year of natural periods of flow, such as we used in studying the Croton flow, and enables us to compare with that stream.

FLOW OF THE PAULINSKILL, 1890–91.

Water-shed, 174.8 Square Miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1890.					
February 12th to 28th	1.97	1.58	655	272	437
March	6.15	4.44	1,894	317	672
April	2.81	2.88	996	272	451
May	6.58	3.88	1,219	229	470
June	3.42	2.29	726	146	357
July	5.30	0.71	229	43	108
August	5.21	0.73	597	29	112
September	4.01	1.60	726	111	249
October	5.17	2.31	868	165	352
November	0.69	1.20	423	95	188
December	3.07	0.66	230	63	99
1891.					
January	7.43	4.45	2,884	77	670
February	3.87	4.53	1,894	372	761
March	3.81	3.56	996	293	540
April	2.24	1.64	476	111	258
May	2.26	0.60	146	50	90
June 1st, 1890, to May 31st, 1891	47.48	24.28	Loss of rain, 23.20.		

The year shows a loss of 23.20 inches against 25 inches on the Croton for similar rainfalls. (See table under Evaporation.) From June to November we have rain, 24.30; flow, 8.84; loss, 15.46 inches. The Croton gives for this period: rain, 24.0; flow, 6.0; loss, 18.0 inches, according to our estimates. From May to December we have rain, 33.95; flow, 13.38; loss, 20.57 inches. We have seen that the Croton shows 21.3 inches loss for a rainfall of 33 inches. This is a nearer agreement than we have in the period from June to November, but we find by examination that the flow for this latter period has been increased by storage carried over from May to June, and by November flow from ground water to the amount of about 2 inches. It is evident, therefore, that the loss through the summer months for 1890 was within half an inch of what we have found to be true of the Croton. From December, 1890, to May, 1891, we have rain, 22.78; flow, 15.44; loss, 7.34 inches, which is considerably greater than the loss on the Croton and Sudbury. Fully 2 inches of the December rainfall went to replenish the exhausted ground storage, however, and not to evaporation. Allowing for this fact, we find that the winter evaporation does not exceed that upon the Croton shed. The conclusions reached as to the constant flow during dry months, in our last report, have been verified thus far. The stream shows a marked resemblance to the Croton.

PEQUEST GAUGINGS.

The record has been kept up at Belvidere throughout the year by Mr. I. B. Keener. The results so far as reduced are as follows:

FLOW OF PEQUEST RIVER, 1890–91.

Drainage Area, 158.0 Square Miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1890.					
February 12th to 28th	1.96	1.62	561	286	405
March	6.15	3.97	1,016	290	544
April	2.81	3.34	796	264	459
May	6.58	3.07	584	209	425
June	3.42	2.43	505	100	344
July 1st to 24th	2.02	0.76	319	58	127
August	......	......	......	......	......
September	......	......	......	......	......
October	5.17	2.17	428	145	306
November	0.70	1.47	312	132	208
December	3.07	1.08	327	95	149
1891.					
January	7.43	4.27	1,253	119	587
February	3.87	3.99	842	397	607
March	3.81	3.74	757	312	513
April	2.24	1.82	439	107	260
May	2.09	0.71	154	63	98
December to May	22.51	15 61	Loss, 6.90 inches.		

The loss of rainfall through the winter and spring months must be reduced by 1.5 inches, which went to replenish depleted ground water in December. This gives us a net loss of 5.40 inches, about the same amount shown on the Croton. The general conclusions reached in the last report as to flow from ground storage are sustained by later observations. This flow is at a higher rate than on the other streams of the Highlands, and we have already pointed out the low flood flow which may be observed by comparing the maximum flow in cubic feet per second, of the above table, with the figures for the other streams given in this report.

MUSCONETCONG GAUGINGS.

Messrs. Taylor, Stiles & Co. have volunteered to continue the record at Finesville, which they began for us in February, 1890. This stream is considerably complicated by the storage and division of the waters of the Lake Hopatcong water-shed by the Morris canal, but some valuable facts are brought out by the gaugings, and we are enabled to get a good idea of the character of the flow from this typical water-shed of the southwestern Highland region of the State.

FLOW OF THE MUSCONETCONG, 1890-91.

Drainage Area, 155.8 Square Miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1890.					
February 12th to 28th	1.97	1.41	512	227	348
March	6.15	3.22	1,019	148	436
April	2.81	2.59	632	206	360
May	6.58	2.76	801	166	377
June	3.42	1 32	334	72	184
July	5.30	0.83	265	61	113
August	5.21	0.72	166	61	96
September	4.00	0.83	357	61	117
October	5.17	1.20	334	89	167
November	0.70	0.80	188	72	113
December	3 07	0.97	384	72	130
Total for 1890	44.38	16.65	....	....	....

FLOW OF THE MUSCONETCONG, 1890-91—*Continued.*

Drainage Area, 155.8 Square Miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1891.					
January	7.43	4.69	3,172	87	633
February	3.87	3.66	1,350	385	551
March	3.80	3.25	713	124	440
April	2.24	1.52	334	104	212
May	2.14	0.75	206	72	101
June	1.77	0.48	104	47	67
July	4.33	0.40	104	....	54
August	6.97	0.67	499	....	92
September	1.55	0.31	134	....	42
October	2.68	0.23	72	....	29
November	2.84	0.39	206	....	54
December	4.85	1.35	290	....	184
Total for 1891	44.47	17.70	....	....	....
May 1st, 1890, to April 30th, 1891	50.79	22.55	....	....	....

Gaugings of the Morris canal indicate an average summer flow of 100 cubic feet per second, which is drawn from this water-shed. The winter flow may be taken at 80 cubic feet per second. This is equivalent to a draught of 0.72 inch per month, on the Musconetcong water-shed, for the eight months of navigation, and 0.57 inch per month for the winter months, making a total of 8 inches for the year. For the portion of 1890 shown in the above gaugings this would give 7.25 inches to be added to the flow, giving the following result: Rain, 44.38; flow, 23.90; loss, 20.48 inches. For 1891 we add the full 8 inches, giving rain, 44.47; flow, 25.70; loss, 18.77, and for the year from June 1st, 1890, to May 31st, 1891, we have rain, 46.35; flow, 28.54; loss, 17.81 inches. The storage interferes too seriously to enable us to analyze closer the flow by periods. The dry-month flow is held up somewhat by flow from Lake Hopatcong, but we can make out by close examination a first-month flow of 1.30, a second of about 0.80, and then a gradual decrease to 0.23 in the sixth or seventh dry month.

DELAWARE GAUGINGS.

Additional gaugings have been made at Center Bridge and important data secured which will to some extent modify the estimates of flood flow given in our last report. The flood heights and flood slopes of the river have been better determined from additional and more reliable flood marks. Mr. A. J. Phillips has kept a continuous record of the height of the river, for the use of the Survey, since August. In connection with our gaugings it will enable us to determine the flow since that date. The necessary computations have not yet been completed.

FLOW OF RAMAPO RIVER, 1890–91.

Drainage Area, 159.5 Square Miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1890.					
February 7th to 28th	4 45	3.29	1,913	277	643
March	6.40	4 85	2,020	277	643
April	2.68	3.05	1,032	231	429
May	4.72	2.75	762	170	377
June	4.98	1.25	334	55	176
July	6 06	0.94	338	40	125
August	4.75	0.80	601	41	108
September	4.14	1.51	948	55	209
October	6.95	2 22	839	91	301
November	0.77	1.10	320	80	155
December	4.02	1.77	1,583	80	238
1891.					
January	8.51	6.36	4,552	318	879
February	4.50	5.28	2,130	264	853
March	4.25	5.23	1,686	299	729
April	2.80	2.34	695	143	335
May 1st to April 30th	56.45	31.55	Loss, 24.90 inches.		

These gaugings have been kept up through the courtesy of the Pompton Steel and Iron Company, by Mr. Alfred Richards. The loss here indicated is about the same that the Croton shows for 47 inches rainfall. For a rainfall as heavy as this the Croton would probably give a loss of about 29.5 inches. It is evident, however, at a glance that our rainfall records do not fairly represent this water-shed for the winter months of 1891. The heavy monthly flows in February and March are shown also by the Wanaque, and must be attributed to heavy rain or snow on the upper part of the water-shed, on which area we have no rainfall stations.

From May to December we have rain, 36.39; flow, 12.34; loss, 24.05 inches, showing the proportion of one-third flow and two-thirds evaporation, which we find to be characteristic of the Croton. This stream is the nearest to the Croton of any which we have measured. The geology and topography of the two water-sheds are also the same. The very heavy rainfalls which are indicated by the maximum flows in cubic feet per second, and by the heavy winter flow, probably occur along the eastern edge of the Highlands, in the valley of the Mahwah and the lower Ramapo valley. Strongly indicative of such heavy precipitation are the records of rainfall at South Orange and Paterson. These places lie at the foot of the Watchung mountains, with an exposure similar to that of the valleys above mentioned, save that the rise of the mountains along the Ramapo is much greater. Indeed, the rainfall of January, 1891, was 10.55 at South Orange.

FLOW OF WANAQUE RIVER, 1890–91.

Drainage Area, 101.0 Square Miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
October	6.95	2.49	594	91	217
November	0.77	0.93	126	44	84
December	4.02	1.59	799	44	138
1891.					
January	8.51	6.27	4,943	91	549
February	4.50	5.51	1,107	217	548
March	4.25	5.55	914	217	516
April	2.80	1.92	303	92	174
May	2.96	0.61	77	45	54
December to May.	27.04	21.45	Loss, 5.59 inches.		

The gaugings for this stream have been taken by Mr. James Frazer for the year. The winter flow, from December to May, shows the inadequate character of rainfall records, as did the Ramapo flow. It is scarcely necessary to discuss this record further until we have the complete series.

FLOW OF THE PEQUANNOCK, 1890-91.

Drainage Area, 84.7 Square Miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND. Greatest.	Least.	Average.
1890.					
February	4.45	3.38	686	125	273
March	6.40	4.02	891	155	296
April	2.68	2.70	382	75	205
May 1st to 5th	0.31	0.20	155	74	91
June	....	....	....	....	....
July	....	....	....	....	....
August	....	....	....	....	....
September 27th to 30th	0.58	0.08	90	25	45
October	6.95	3.61	959	25	264
November	0.77	1.42	301	25	100
December	4.02	1.03	437	25	75
1891.					
January	8.51	5.17	2,352	48	387
February	4.50	5.05	1,384	46	276
March	4.25	4.12	683	46	192
April	2.80	1.50	234	46	215
....	....	....	....	....	....

The record for the Pequannock has been kept by Mr. J. H. Furey. While some characteristics are brought out, the series as a whole is not entirely satisfactory, because of unfavorable conditions at the point of gauging. We shall use the results only for what they are really worth in our final analysis. They will not admit of great refinement of deductions.

PASSAIC RIVER.

We have been able to add very materially to our data of Passaic flow, having procured a record of height of the river which, when we have completed the measurements and tedious calculations necessary for its reduction, will furnish a fair record of flow for fifteen years. Gaugings have also been continued at the dam at Little Falls, by the courtesy of the Beattie Manufacturing Company. The data require exhaustive examination, checking and adjustment, a large part of which has already been done, but it is still so incomplete that it is not thought desirable to publish at present. Even the results published in our last report will be somewhat modified by the contemporaneous record which has been alluded to already. It is deemed especially fortunate that we have succeeded in obtaining so much information as to this the most important stream of the State excepting the Delaware. The results for the Passaic will be given in the completed report upon this subject.

FLOW OF THE RAHWAY RIVER, 1890–91.

Drainage Area, 40.4 Square Miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1890.					
February 18th to 28th	2.21	0.99	143	70	98
March	6.95	5.00	1,015	59	175
April	2.61	2.59	292	46	93
May	4.65	2.35	147	50	82
June	4.97	2.95	373	44	106
July	5.72	2.36	292	26	82
August	4.97	3.04	534	32	106
September	4.68	2.19	195	41	79
October	6.79	4.47	781	67	156
November	0.80	3.25	147	94	117
December	4.35	3.82	716	60	134
1891.					
January	8.99	5.90	1,081	82	217
February	4.86	5.75	694	107	223
March	5.08	5.80	458	107	218
April	2.96	3.44	180	94	121
May	3.23	2.30	147	23	80
June 1st, 1890, to May 31st, 1891	61.40	45.27	....	....	....

The gaugings were continued on this stream by Mr. Addison C. Russell. The results seem to show, like the Ramapo and Wanaque, a deficiency in the rainfall records. This stream is similarly situated with those, being along the base of the Watchung mountains and probably affected by irregular, heavy downpours of rain. As we noted last year, this stream shows large ground flows from the masses of drift upon the water-shed. It occupies a ground almost midway between our Highland streams and those of southern New Jersey.

FLOW OF THE RARITAN AT BOUND BROOK, 1890-91.

Drainage Area, 879.0 Square Miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1890.					
February 17th to 28th	1.58	0.98	2,772	1,406	1,938
March	6.26	6.13	17,818	872	4,727
April	2.74	2.26	3,265	874	1,773
May	4.95	1.95	4,060	752	1,489
June	3.97	1.32	2,824	462	1,040
July	5.68	1.18	2,022	498	898
August	5.18	1.58	3,405	498	1,205
September	4.31	1.34	2,823	493	1,064
October	6.74	3.06	7,133	859	2 360
November	0.88	1.30	1,779	781	1,016
December	3.55	2.16	7,526	462	1,654
1891.					
January	7.06	4.92	23,746	420	3.738
February	4.21	3.47	6,056	1,295	2,931
March	4.64	4.47	10,142	1,386	3,404
April	1.83	1.62	3,439	512	1,276
May 1st, 1890, to April 30th, 1891	53.00	28.37	Loss, 24.63 inches.		

This record has been continued throughout the year by Mr. William Fisher. For the year it shows a larger flow in proportion to the rainfall than is shown by the Croton. From May to December we have 35.26 inches rain; flow, 13.89, and loss, 21.37 inches. From December to April the record shows rain, 21.29; flow, 16.64; loss, 4.65 inches. The diagram of flow shows the same flashiness which was indicated last year, and in general corroborates the conclusions then set forth.

STREAMS OF SOUTHERN NEW JERSEY.

The streams of the northern portion of the State show a certain marked individuality in the character of their flow. While there is a general resemblance which will admit of the application of general laws to all which have their sheds upon the same geological and topographical divisions, yet the variation in the steepness, in the amount of natural storage, or in the state of cultivation of the water-shed is always sufficient to bring out peculiarities in each stream gauged. In the case of the southern streams, however, the resemblance is so remarkable that it is found best to treat of them as a group. The variations are only such as are due to difference in size of the water-shed, or some local peculiarity at the point of gauging. So great is the resemblance that it is found best to discuss the gaugings which we have been able to obtain as a whole, and regard these streams as indicative of what we may expect for all of the sand-hill streams of the State. Our longest series of gaugings is the one on the Great Egg Harbor river at Mays Landing. In addition to the gaugings here given, a short series on the Assanpink, and a mass of general notes of flow, as well as several years of personal observation, all indicate the applicability of these results to our southern streams as a class.

FLOW OF GREAT EGG HARBOR RIVER AT MAYS LANDING, 1890–91.

Drainage Area, 215.8 Square Miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1890.					
February 16th to 28th	2.40	0.86	463	322	383
March	6.06	2.39	723	327	447
April	3.37	2.44	734	268	470
May	3.71	1.88	491	270	348
June	2.33	1.27	352	126	244
July	5.13	1.33	302	201	249
August	5.31	1.46	541	97	273
September	6.06	1.05	366	114	203
October	6.30	1.67	346	270	313
November	0.71	1.32	325	142	255
December	4.49	1.52	438	180	284
Total for 1890	45.87	17.19	37 per cent. of yearly rain.		

FLOW OF GREAT EGG HARBOR RIVER AT MAYS LANDING—*Cont.*

Drainage Area, 215.8 Square Miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
1891.					
January	6.07	2.70	867	280	505
February	6.58	3.19	781	508	662
March	6.98	4.15	882	538	778
April	2.44	2.58	650	324	500
May	3 27	1.52	343	222	284
June	3.25	1.45	343	226	279
July	8.93	1.60	377	154	302
August	6.10	1.67	420	220	313
September	1.94	1.41	404	127	273
October	3.64	1.21	347	126	232
November	2 23	1.24	322	186	290
December	4.19	1.74	370	233	325
Total for 1891	55.62	24.46	44 per cent. of rain.		
May 1st, 1890, to April 30th, 1891	56.11	24.12	43 per cent. of rain.		

This series has been continued by Mr. James Blaisdell, at Mays Landing, by the courtesy of the Mays Landing Water-Power Company.

FLOW OF BATSTO RIVER, AT BATSTO, 1891.

Drainage Area, 69.7 Square Miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
January	5.80	....	....	....	....
February	6.24	....	....	....	....
March	6.29	....	....	....	....
April	2.13	2.05	287	92	127
May	2.79	1.44	112	70	86
June	3.59	1.17	126	70	73
July	7.19	1.79	197	59	109
August	6.35	1.46	124	64	88
September	3.08	1.62	226	67	101
October	3.72	1.55	131	52	94
November	2.42	1.11	88	55	69
December	4.12	1.42	116	52	85
April to December	35.39	13.61	38.5 per cent. of rain.		
Year	53.72	....	....		

For this series we are indebted to Mr. Joseph Wharton, the record having been kept by Mr. George Wright. It is especially valuable in enabling us to compare the action of the flow from quite a small water-shed with the larger area on the Great Egg Harbor.

FLOW OF NORTH BRANCH OF RANCOCAS AT PEMBERTON—1890.

Drainage Area, 111.7 Square Miles.

MONTH.	Rain—Inches.	Flow—Inches.	FLOW IN CUBIC FEET PER SECOND.		
			Greatest.	Least.	Average.
March	5.48	3.21	590	161	300
April	2.18	1.93	329	118	192
May	3.20	1.53	189	132	148
June	3.76	1.84	244	129	183
July	5.38	1.37	211	82	132
August	4.49	1.25	144	97	120
Total	24.49	11.13	....	....	....

For this series we are indebted to Mr. Anthony J. Morris, of Pemberton.

COMPARATIVE FLOWS FOR LIKE PERIODS—APRIL TO AUGUST.

	Rain. Inches.	Flow. Inches.	Loss of Rain. Inches.
Rancocas, 1890	19.01	7.92	11.09
Great Egg Harbor, 1890	19.85	8.36	11.49
Great Egg Harbor, 1891	23.99	8.82	15.17
Batsto, 1891	22.05	7.91	14.14

In 1890 there had been large draught upon ground water during this period, which was not replenished at the end of August. In 1891 there was no great depletion of ground water at the end of August. Therefore, the normal loss of rain or evaporation for these months, with a given rainfall, is best shown in 1891.

MAY TO DECEMBER.

	Rain. Inches.	Flow. Inches.	Loss. Inches.
Great Egg Harbor, 1890	34.04	11.50	22.54
Great Egg Harbor, 1891	33.55	11.84	21.61
Batsto, 1891	33.26	11.56	21.70

The first fact which strikes us in these comparative tables is the marked similarity in the flow of the several streams for contemporaneous periods. The Rancocas and the Great Egg Harbor from April to August, 1890, show almost exactly the same percentage of rainfall flowing in the stream—41.6 for the former, against 42.1 per cent. for the latter stream. So with the Batsto and the Great Egg Harbor for the same months in 1891. From May to December, a period which eliminates the effect of depleted ground storage, we find a remarkably constant condition of flow for both years on the Great Egg Harbor, and for the year 1891 on the Batsto.

Turning now to the tables of monthly flow we find the resemblance holding good here also. Here it is noted that the smaller water-shed of the Batsto holds its own with the Great Egg Harbor in the amount of water flowing, if we make proper allowance for the difference in rainfall. So does the Rancocas, the resemblance to the Great Egg Harbor being none the less marked, although the stream is more remote than the Batsto.

Taking the yearly rain, flow and loss as shown by these tables, and computing the flow and loss on the Croton by the rules deduced when we were considering the evaporation on that water-shed, we have the following:

YEARLY RAINFALL, FLOW AND LOSS.

	Rain.	Flow.	Loss.
Great Egg Harbor, Feb. 16th to Dec. 31st, 1890......	45.87	17.19	28.68
Great Egg Harbor, 1891....................................	55.62	24.46	31.16
Great Egg Harbor, May 1st, 1890, to Apr. 30th, 1891..	56.11	24.10	31.99
Croton, estimated..	56.00	26.40	29.60
Croton, estimated..	49.00	22.90	26.10

If we take the evaporation from January 1st to February 16th, 1890, to have been 3 inches, 1890 will show 31.68 inches loss for 48.87 inches rainfall. I am inclined to attach rather more weight to the figures for 1891, and for the year beginning May 1st, 1890. They indicate about 2 inches excess of evaporation over that shown on the Croton water-shed for 56 inches rainfall.

Comparing the periods from May to December, we find an average for the southern New Jersey streams of rain, 33.62; flow, 11.63; loss, 21.99 inches, a result which is remarkably close to what we find on the Croton for these months.

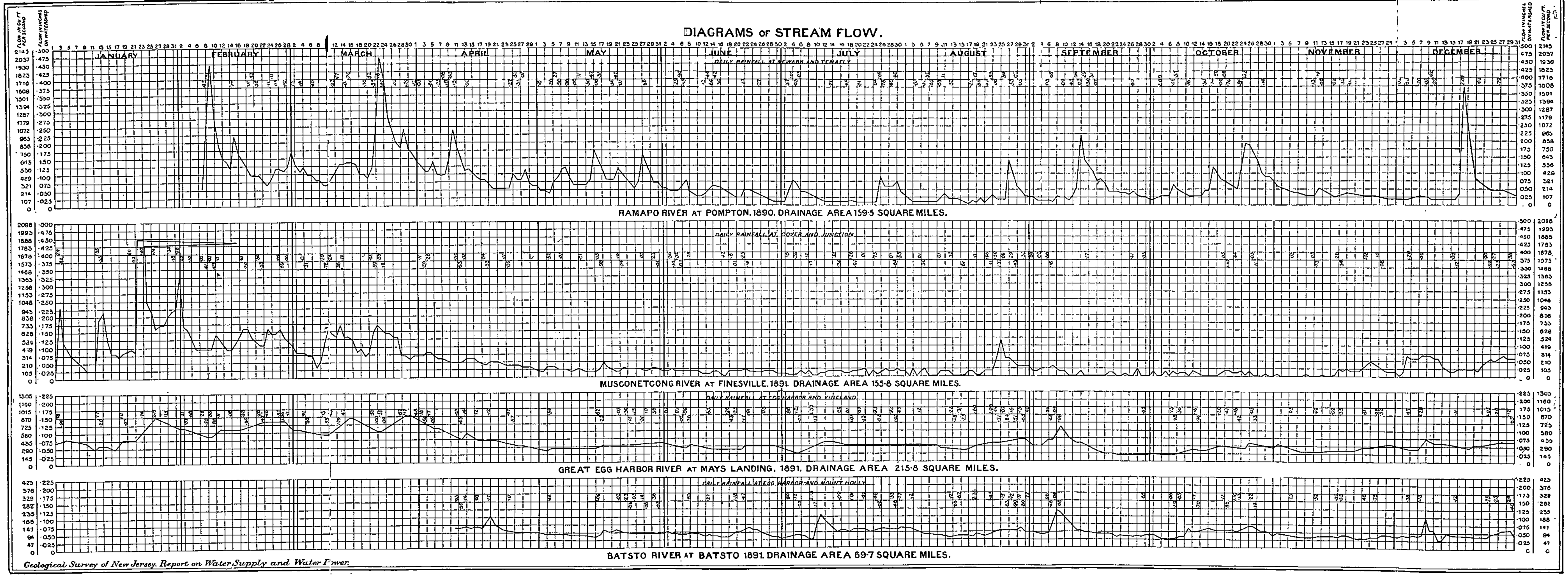
Our observations for the winter months are not yet complete enough to be entirely satisfactory, but they indicate, so far as they go, the following: January to April, rain, 22.2; flow, 12.6; loss, 9.6 inches. This shows an excess of 4 inches over the winter evaporation on the Croton, and seems to establish what we have suggested in our previous report, that the increased evaporation is confined to the winter months. In summer the warmer climate and porous soil would give an increase, but this is offset by less vegetation and by the fact that rain sinks so quickly into this soil that there is very little evaporation from water standing upon the surface. In the winter, however, there is less offset to the conditions favorable to increased loss of rain. From these considerations, and working between observed periods, I am disposed to adopt for our constants of monthly evaporation on southern New Jersey water-sheds the following: January, 1.00; February, 1.00; March, 1.25; April, 1.25; May, 2.00; June, 3.00; July, 3.75; August, 3.75; September, 3.00; October, 1.75; November, 1.25; December, 1.00. These constants are for 40 inches annual rainfall. While we may find cause, as our investigation proceeds, to slightly modify these constants, they are sufficiently accurate to be used with entire confidence for preliminary studies.

To fully appreciate the superior value of southern New Jersey streams for water-power we must examine the records of monthly flow month by month and compare them with those for our northern water-sheds. Such an examination brings out the better-sustained dry-season flow, and the columns of greatest flow in cubic feet per second show how much less liable these streams are to heavy freshets. For example, in January, 1891, the northern streams—the Passaic and its branches and the Raritan—were discharging at their maximum from 27 to 28 cubic feet per second for each square mile of water-shed. The heaviest discharge reached on the Great Egg Harbor for that winter was 4.1 cubic feet per second per square mile. The heavy rains are absorbed by the sandy water-sheds or held in the wooded swamps and fed out gradually to increase the flow for weeks and months. This peculiarity makes it easier to utilize the flow of these streams for any purpose, as less storage is required than upon more flashy streams. It has been my practice in designing storage works for these water-sheds, to estimate that with storage equal to six inches of rainfall upon the water-shed, fifteen inches of rain could be utilized in the driest year. The present investigations as they proceed seem to indicate that this is a very conservative estimate. Storage equal to 3.5 inches would be sufficient to maintain an even flow of one inch per month in the driest year, and only half an inch of storage would yield a steady flow of half an inch monthly. These valuable characteristics of southern New Jersey streams will be more clearly brought out when I have completed my estimates of flow by months for the driest years.

DIAGRAMS OF FLOW.

The accompanying diagrams of flow are intended to bring out the differences between southern and northern New Jersey streams. In my last report a diagram for the Great Egg Harbor, for 1890, will be found. The diagrams of this stream and of the Batsto for 1891, which are shown, accompany this report, are more satisfactory and more truly represent the actual flow. There are a few minor fluctuations in these diagrams, due to opening and closing of sluice gates, which could not be wholly eliminated and must be disregarded. They are not important enough to seriously affect the truthfulness of the presentation, however. The Musconetcong is taken to represent northern streams for 1891, because of its drainage area corresponding fairly in size with the southern streams. It is rather too favorable to northern streams, however, because its fluctuations are diminished somewhat by storage, and because the rainfall was lighter than that for the southern streams. For this reason the Ramapo, for 1890, has been added, and by contrasting this with the southern streams the less variable flow of the latter is seen clearly. The minor fluctuations shown in the diagram of the Musconetcong are produced by holding back the water in mill-ponds.

The rainfall is given in inches for each day. It is made up of the daily means for the stations given. In the tables of flow previously given other stations were included to make up the monthly averages. By referring to the diagram for the Great Egg Harbor, facing page 202, report for 1890, we can see how the heavy rains from December 17th, 1890, are taken up by the ground, and the flow stays at about 400 cubic feet per second until January 21st, 1891. During this period 7.37 inches of rain fell and only 2.10 inches flowed off. Assuming evaporation to have been 1.5 inches, a liberal estimate, we have 3.8 inches absorbed by the earth to replace the draught through the dry period preceding December 17th. The replenishment is evident at about the 17th, and from that date through March the flow



Geological Survey of New Jersey. Report on Water Supply and Water Power.

holds up at the average rate of about 725 cubic feet per second. Notice the marked difference in fluctuations of this stream and the Musconetcong during this period, although the heavier rains are on the southern water-shed. The diagram of the Batsto, while it shows a marked general parallelism to the Great Egg Harbor, still indicates neatly the slightly sharper fluctuations due to the smaller size of its water-shed. On a subsiding flow, the steeper gradients indicate the drawing down of swamp storage, and then when we come to ground flow alone we see how gradually it decreases. Thus, from April 12th, when the swamps had become quite depleted, to May 15th, rains were less than evaporation, yet the flow only fell from .075 to .045 inch daily, showing clearly the capability of yielding a flow of 1.50 inch for the first month from ground water alone.

Studied in this way, these diagrams are capable of unlocking many of the secrets of the flow of these southern New Jersey streams, but even a superficial examination reveals the peculiar steadiness of these as compared with streams like the Croton, Sudbury and others, with which we have been more familiar heretofore.

UNDEVELOPED WATER-POWERS OF SOUTHERN NEW JERSEY.

The agricultural development of the lands of the southern portion of the State must give some incentive to the development of water-power. We called attention to some of the important powers which are already in use, in our last report. Having in preparation for our final report full descriptions of the undeveloped sites and their capacity, the completion of which work will be delayed until our observations are finished, it is not necessary to do more at present than call attention to certain exceptional localities in a general way.

On Maurice river, a little above the head of the Millville Manufacturing Company's pond, and near Vineland, a fall of 20 feet, and probably about 450 net horse-power, could be obtained. Just above this, near the New Jersey Southern railroad, about 15 feet fall and 200 net horse-power might be developed. Several of the smaller powers on both the east and west branches of this river could be advantageously improved, not being at present developed to their full capacity. There are also good small sites on Manumuskin, Manantico and Buckshutem creeks.

As the demand seems to be for large powers, it might be well to concentrate the flow of two or more streams at one point where circumstances are favorable. The power at Mays Landing is susceptible of increase in this way to about 440 horse-power. On Great Egg Harbor river, between Mays Landing and Weymouth, there is still a fall of 11 feet not in use. It should be possible to utilize at least 9 feet fall here, giving about 300 horse-power. The Weymouth site is a good one, and capable of driving a larger plant than the one now there. It was not in use at the date of making the canvass, but I believe steps are being taken to utilize it. It should be good for 325 horse-power, and, if Deep run should be added, 360 horse-power should be obtained on the 13 feet of fall. Just below the mouth of Hospitality branch another site, good for 250 horse-power, might be developed. Near the crossing of the Philadelphia and Sea-shore railroad there is a good opportunity to develop power also. Above this on the main stream the banks are low and only low falls could be secured. On Hospitality branch there are valuable cranberry bogs, which might interfere somewhat with the utilization of several good sites for small powers.

On Wading river, the power at Harrisia (Harrisville) is an excellent one, 225 horse-power being now used on 12 feet fall, with a considerable surplus power wasted. The flow of the east and west branches is concentrated by means of a canal over a mile long. On the east branch, known as Oswego river, there is an unoccupied site at the old location of Martha furnace. The fall is 12.5 feet, and 100 horse-power should be obtainable. Above this the opportunities are not so good, as the stream-valley widens. On the west branch there is a site at the mouth of Tulepehauken creek, where 15 feet fall and 200 horse-power might be had. Smaller powers could be developed at Speedwell and other points farther up stream. At Pleasant Mills the waters of Hammonton creek, the Nescochague, Mechescatauxin and Atsion have been concentrated by a system of dams and raceways, and 150 horse-power is used on 10 feet fall, with a considerable surplus wasted. The Batsto could be added to the other streams, and fully 265 horse-power obtained on 10 feet fall; or the fall could be doubled with little difficulty, and 530 horse-power utilized. At Quaker Bridge, on the Batsto, 15 feet fall could be obtained, and the flow of the Atsion added by a canal, giving 220 horse-power. At Atsion there is a good plant which is not at present in use.

Passing up the coast, the next opportunity which is presented for developing a considerable amount of power is at Toms River. A plant might readily be arranged here to concentrate the flow of all the branches of Toms river on a fall of 30 feet, so as to realize 670 horse-power, and raise the village to the size and industrial importance of Millville within a few years. Transportation facilities are excellent at this point.

Just below the mouth of Ridgeway branch, on Toms river, there is also a very good site. Twenty feet fall and 350 horse-power might be utilized. At White's Bridge 175 horse-power may be developed, and several good sites for smaller powers are to be found on the stream above and on Ridgeway branch.

Metedeconk river offers a site just below the junction of the north and south branches, at Burrsville, good for 200 horse-power on 20 feet fall. There are several good sites of smaller capacity on both branches above.

On Manasquan river, near Allenwood, 20 feet fall and 180 horse-power could be obtained in a good locality. Near Red Bank, on Swimming river, 20 feet fall and 180 horse-power could be had. This, also, is an exceptionally good location.

Turning now to the Delaware or western slope, we find that the streams south of the Rancocas furnish excellent sites for single mills, but offer no opportunity for the development of large water-powers. On the north branch of the Rancocas the power is quite fully developed. At Eayrstown, on the south branch, it would be possible to concentrate the flow from 140 square miles with 30 feet fall, giving about 590 horse-power. This would require the extinguishment of four smaller powers, however. There are good sites for 100 horse-power or less at several points on the branches of the Rancocas.

Crosswicks creek has 60 feet fall between New Egypt and Bordentown, of which 24 feet is utilized. It flows through a narrow ravine and opportunities are good for developing power. Splendid natural facilities exist for utilizing the whole flow of the stream at the crossing of the road from Bordentown to the White Horse tavern, where 30 feet fall could be obtained, and fully 550 horse-power utilized. Four existing water-powers and some other improvements now stand in the way of the utilization of this admirable natural site. About 260 horse-power on 20 feet fall could be obtained at Crosswicks without interfering with any existing improvements of consequence.

As we previously remarked, the estimates of power here given are subject to revision in the final report, but they are based on the performances recorded in actual work of large powers of southern New Jersey and are safe enough for general guidance. It is noteworthy that the few sites here mentioned aggregate over 6,000 net horse-power, or over three-fourths as much as the total utilized power of this portion of the State. Evidently the amount in use is not more than one-third of what may easily be developed. When the large powers which have been indicated shall have been utilized, in how many places shall we have repeated the splendid work which has been done at Millville and Bridgeton, and well begun at Mays Landing? Truly a very great impetus would by this means be given to the industrial development of southern New Jersey.

It will at once be asked if it is more profitable to develop these powers or to use steam. Our answer must be that it has proven directly profitable elsewhere with less favorable conditions than we have at many of these sites, and we have seen how great the indirect advantage has been to the localities where such development has been made. If a more exact answer is required we may estimate that the value of a horse-power, determined from the cost of producing it by steam, and making due allowance for the possibility of selecting more favorable locations when steam-power is used, may be taken safely to average $21 annually in New Jersey. In other words, if we ignore the indirect benefits to be derived in appreciation of property values, &c., and take only the direct money return into consideration, we may spend to develop one horse-power a sum which at six per cent. per annum will yield $21, or $350. There are some industries which need the space and the abundant water to be had in such localities, and can afford on this account alone to locate on these sites. Then there is surplus power above the amounts given in my estimates, for several months of the year, which might be turned to account for certain lines of manufacture. Even without these advantages most of our sites could be developed well within the above money limit.

Turning to the possibilities held out to us by electric transmission, we find that this has passed beyond the experimental stage in Switzerland and in our own country, at Spokane Falls, Aspen and other places. Naturally it has been first applied at localities where coal is expensive and water-power abundant. Let us imagine such an installation which would transmit the power from some of the less accessible of these sites to communities like Vineland, Hammonton or Egg

Harbor City or the larger communities at Camden and Trenton, and rented to large and small manufacturers. The result must be the employment of labor more steadily and to better advantage, the increase in productive capacity of these communities, and the restoration to society of the small manufacturer and the pleasant relations which he sustained with his employes as well as his patrons. The social effects of such a step would go even further and do much to counteract the baleful influences which are at work upon character wherever operatives are herded together in the enormous centers of industry, which are the result of the very rapid movement toward concentration of manufacturing in fewer and larger establishments.

While these may seem to be rather sentimental reasons, all who have the welfare of the State at heart must recognize that the fact that the utilization of our water-power in this way would be a long step toward securing the better housing, more healthful environment and improvement of the condition of our industrial classes, without sacrificing that economy of production which has obtained in large manufacturing plants, is high ground for the encouragement of enterprises of this kind by furnishing information as to their practicability.

Another consideration which is worthy of being kept in view by the community is, that every horse-power of water which runs to the sea unemployed must be made good by the consumption of coal to the amount of three tons annually. No benefit accrues to the workingmen of the State from this coal consumption, or to the State as a whole. The visible supply of the nation's fuel is just so much diminished. Just so much of available energy is wasted. On the other hand, if the horse-power is developed from water-power, $350 is at once added to the wealth of the State, our workmen are employed in the improvement, and the increase of population and indirectly added wealth which are consequences of such development, have been realized at several of our most important industrial centers.

UTILIZED WATER-POWER.

In order to accumulate facts as to the peculiarities of individual streams, so as to be able to make a close application of the results of our researches to each, and furnish information sufficiently explicit to be of direct utility, it was found necessary to inquire of those who were most familiar with the stages of flow and profit by their experience. Naturally the mill-owners and managers were most able to supply a large share of this information, their occupations leading them to observe closely the facts which we most need. It was a simple matter to make in connection with and as a part of such an inquiry, a full canvass of the water-powers of the State. This work has been completed and the results are here given. First we will give a summary by water-sheds in the table on the two following pages. In classing the Raritan as a northern stream we are obliged to include its branches, South river, Lawrence's brook and the Upper Millstone, although they really belong to southern New Jersey.

Classifying the northern streams by entire water-sheds, we have:

	No. of Mills.	Net Horse-Power.
Delaware above Trenton	186	6,658
Wallkill	25	598
Passaic	216	8,924
Hackensack	25	404
Elizabeth	2	36
Rahway	15	356
Raritan	171	5,993

The Passaic stands at the head of the streams, in both total horse-power and horse-power per square mile, the latter being 11.3. This refers to the streams as here grouped, however, for the Musconetcong, taken separately, shows 12.9 per square mile. Of the other Delaware streams, Flat brook shows 2.1, Paulinskill 5.4, and the Pequest 6.1 net horse-power per square mile. The Wallkill has 2.8 and the Raritan 5.4 per square mile. The southern streams should not be expected to show nearly so much power per square mile, as the fall is much less and the country more sparsely settled. Crosswicks creek shows 4.7; the Cohansey, 3.6; Metedeconk river, 3.5; Assanpink creek, 3.4; Maurice river, 2.8; Rancocas creek, 2.3; Great Egg Harbor, 1.4, and Mullica river, 1.0 horse-power per square mile. For the entire State, taking the land-surface at 7,514 square miles, the average is 4.11 net horse-power per square mile.

NUMBER OF MILLS AND NET HORSE-POWER BY WATER-SHEDS AND BY INDUSTRIES.

Streams of Northern New Jersey.

STREAM.	Grist and Flouring Mills.		Saw, Turning, Furniture and other Wood-Working.		Fabrics and Fibres, Woolen, Cotton, Silk, Felt, &c.		Paper.		Rolling Mills, Forges and other Iron Works. Machinery.		Miscellaneous Manufactures.		Total for Each Water-shed.	
	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.
Delaware, main stream and small branches	85	1,056	8	119	4	225	4	487	3	61	7	314	61	2,262
Flat Brook	4	105	2	32	......	......	......	......	......	......	......	......	6	137
Paulinskill	19	614	17	216	2	30	......	......	3	59	3	42	44	961
Pequest	22	735	11	205	......	......	......	......	1	25	......	......	34	965
Musconetcong	16	795	3	47	......	......	3	955	2	155	3	90	27	2,042
Pohatcong Creek	11	243	3	48	......	......	......	......	......	......	......	......	14	291
Wallkill and branches	15	887	6	107	......	......	1	47	1	87	2	20	25	598
Passaic, main stream and small branches	12	820	15	223	27	2,185	3	324	11	661	11	879	79	4,592
Saddle River	15	248	22	202	5	92	1	50	2	25	2	83	47	700
Ramapo	1	10	5	60	2	45	......	......	1	80	......	......	9	195
Wanaque	4	90	5	46	1	110	......	......	......	......	1	25	11	271
Pequannock	5	104	6	218	1	60	2	275	1	12	3	365	18	1,034
Rockaway	7	149	4	40	4	284	1	260	9	312	4	353	29	1,898
Whippany	9	247	7	75	1	70	4	276	2	66	......	......	23	734
Hackensack and branches	8	191	16	168	......	......	......	......	1	45	......	......	25	404
Elizabeth and branches	2	36	......	......	......	......	......	......	......	......	......	......	2	36
Rahway and branches	6	94	3	34	2	128	4	100	......	......	......	......	15	356
Raritan, main stream and small branches	12	846	1	10	2	205	1	25	......	......	5	426	21	1,012
South River	8	339	2	49	1	9	......	......	......	......	4	279	15	676
Millstone	19	532	2	22	1	18	......	......	......	......	......	......	22	572
North Branch	28	751	10	142	1	16	......	......	1	107	6	36	46	1,052
South Branch	50	1,678	12	216	1	12	......	......	4	775	......	......	67	2,681
Total for Northern New Jersey	308	9,070	160	2,279	55	3,489	24	2,799	42	2,620	51	2,912	640	22,969

NUMBER OF MILLS AND NET HORSE-POWER BY WATER-SHEDS AND BY INDUSTRIES—Cont.

Streams of Southern New Jersey.

STREAM.	Grist and Flouring Mills.		Saw, Turning, Furniture and other Wood-Working.		Fabrics and Fibres, Woolen Cotton, Silk, Felt, &c.		Paper.		Rolling Mills, Forges and other Iron Works. Machinery.		Miscellaneous Manufactures.		Total for Each Water-shed.	
	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.	Number of Mills.	Net H. P.
Streams entering Raritan Bay	2	55	....	....	....	....	....	....	....	....	....	....	2	55
Navesink River	6	191	2	61	....	....	....	....	....	....	....	....	8	252
Manasquan River	4	117	5	88	....	....	....	....	....	....	....	....	9	205
Metedeconk River	2	67	5	72	....	....	....	....	....	....	1	120	8	259
Toms River	3	78	8	157	....	....	1	58	....	....	....	....	12	288
Mullica River	5	69	7	134	....	....	2	375	....	....	....	....	14	578
Great Egg Harbor River	7	60	12	152	1	342	1	70	....	....	....	....	21	624
Small streams entering Atlantic Ocean	10	238	14	298	....	....	....	....	....	....	....	....	24	536
Maurice River	8	249	8	148	1	500	....	....	1	60	2	112	20	1,069
Cohansey Creek	8	225	3	50	....	....	....	....	1	100	....	....	12	375
Small branches of Delaware Bay	8	155	5	75	....	....	....	....	....	....	....	....	13	230
Rancocas Creek	12	463	11	165	....	....	....	....	1	135	1	12	25	775
Crosswicks Creek	14	404	7	150	2	65	....	....	....	....	1	30	24	649
Assanpink Creek	5	127	....	....	....	....	....	....	....	....	2	180	7	307
Small branches of Delaware River, Trenton to Cohansey Creek	47	1,317	14	256	....	....	....	....	1	100	2	26	64	1,699
Total for Southern New Jersey	141	3,810	101	1,806	4	907	4	503	4	395	9	480	263	7,901
Total for the State	449	12,880	261	4,085	59	4,396	28	3,802	46	3,015	60	3,392	903	30,870

POWER BY INDUSTRIES.

The power is divided among the several industries as shown in the table. Grist and flouring mills use 39.5 per cent. in northern, and 49 per cent. in southern New Jersey; 42 per cent. of the whole power of the State. The average power of these mills is 28.6. Saw, turning and other wood-working establishments use 10 per cent. north, and 23 per cent. south, or 13 per cent. for the State. Their average power is 15.6 horse-power. The mills classed under fabrics and fibres use 14 per cent. of the power, having an average power of 74.6. Paper mills, being large users of power, are placed under a separate class from fabrics and fibres, to which they really belong. They use 10.7 per cent., with an average of 118 horse-power each. Iron-working mills use 10 per cent., and average 65 horse-power. Miscellaneous manufacturers utilize 11 per cent., averaging 56.5 horse-power each and including a great variety of industries, among which may be mentioned the manufacture of photographic lenses, grinding of soapstone, driving of pumps for supplying water to cities, and of electric-light plants. Paterson, Trenton, New Brunswick, Passaic, Millville, Somerville and Raritan, Lakewood, Wenonah and Nutley have each a water-power pumping-plant for water-supply. Boonton and Lakewood have electric-light plants run by water-power.

INCREASE IN UTILIZED POWER.

Taking the census figures for 1870 and 1880, and comparing them with our own, we have:

	1870. Net H. P.	1880. Net H. P.	1890-1. Net H. P.
Total power in use	25,832	27,066	30,870
Flouring and grist mills	11,108	12,183	12,880
Saw mills, &c		3,903	4,085

This shows a small but steady increase in each decade, amounting in the last to 14 per cent. It does not show the real changes which have taken place, for there has been a steady loss of small, inefficient water-powers, which had to be made good by the construction of larger and better-equipped plants. Many small saw and grist mills have thus been abandoned, the former because of scarcity of timber, and the latter from the competition of large, well-equipped modern mills. Where the stream is of sufficient capacity, these large plants are erected upon the sites of the small mills; otherwise these sites are abandoned and new ones developed.

LARGE WATER-POWER PLANTS OF NEW JERSEY.

Stream.	Location.	Fall in Feet.	Net H. P. in Use.
Passaic	Paterson	66	1,760
Passaic	Passaic	22	1,235
Rockaway	Boonton	101	970
Delaware	Lambertville	9.5 to 18	747
South branch of Raritan	High Bridge	47	730
Maurice river	Millville	22	690
Delaware	Trenton	9 to 17	589
Musconetcong	Riegelsville	20	430
Musconetcong	Warren Paper Mills	48	360
Great Egg Harbor	Mays Landing	10	342
Musconetcong	Hughesville	27	340
Passaic	Little Falls	14	320
Pequannock	Butler	30	260
Rockaway	Old Boonton	30	260
Wading river	Harrisia	12	225

Some of these plants are of larger capacity in proportion to the actual power of the stream than others. Some of them have a surplus of power which is not in use and does not appear in the above figures. Those on the southern streams are much larger for the size of the water-shed and the amount of fall than the northern powers, but notwithstanding this are fully as efficient and reliable, and, indeed, most of them very much more reliable during the dry months.

ESTIMATED VALUE OF UTILIZED WATER-POWER.

The total amount of power in the State is 30,870 net horse-power. If we assume an efficiency of 70 per cent., which is about what is obtained with good wheels, we shall have a gross horse-power of 44,100. In reality more power is required to run the above plants, as the average efficiency is below 70. Taking this power to be worth an average rental of $22.50 per horse-power per annum, or about two-thirds the rate at Paterson, Passaic or Trenton (see pages 219 *et seq.* of last report), we have a total rental of $992,250. Capitalizing this at 10 per cent. would give a value of $9,922,500 for the water-powers of the State. If we add to this the value of the buildings and machinery in the 903 mills using water-power, I do not think the most conservative estimate would make a total of less than $20,000,000 to represent the value of the water-power plants of the State.

In order to fully appreciate the importance of this interest, however, we must consider the great wealth which has been brought to us by the development of these powers. Paterson, now a city of 78,347 inhabitants, with large industrial interests, was created by and has grown up around the water-power of the Society for the Encouragement of Useful Manufactures. Trenton, with 57,458 inhabitants, and another of our most flourishing manufacturing centers, was only a village when the water-power was created, which formed the nucleus of its rapid growth in population and wealth. Passaic, with 13,028; Bridgeton, with 11,424; Millville, with 10,002 inhabitants; Lambertville, Boonton and several smaller towns, owe their being and industrial importance directly to this cause. Little Falls, Butler, Mays Landing and other places show a marked tendency to a similar future, and a majority of the other towns of the State owe their origin to the country grist mill, saw mill or iron forge, driven by water-power, with the little group of houses about, occupied by the employes, and the more spacious and pretentious abode of the owner overlooking all from the most commanding site in the vicinity. To estimate the amount of wealth which the development of water-power has thus indirectly given to the State would be difficult. By comparison the value which has been given for the plants themselves is insignificant.

LIST OF WATER-POWERS.

This list is intended to include every water-power in use in the State, and also such as have been recently used to an important extent, but are now unoccupied. The net horse-power is obtained usually from the capacity of the wheel-plant, taking account of its condition. When this was impracticable it was taken from estimates of the owners or managers, or from the amount of work being done in the mill. The gross horse-power was estimated from the net, and shows the amount of power needed to drive the plant. In estimating it the general efficiency of the wheel-plant, or in cases where the net power was taken from work performed, the efficiency of the whole of the machinery was considered. This gross horse-power, giving the amount of water actually needed to drive the mill, taken with what was learned as to the number of months in which full power could be used, furnishes an indication of the usual flow of the stream, and will be of use when we finally come to compute this flow for each stream.

There are difficulties met with in making such a canvass as this, which render entire accuracy difficult to attain. It is believed that this is a fairly accurate presentation of the interest, however, and it is especially desired that any errors which may be noted by the parties interested shall be sent to the office of the Survey at once, so that we may make the necessary corrections for the full report.

WATER-POWERS OF NORTHERN NEW JERSEY.

Flat Brook and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Flat Brook	Flatbrookville	Sussex	Samuel Gariss	Grist and saw	12	.....	.....	Burned down.
" "	Walpack township	"	Mrs. Charles Haney	Grist	6	30	50	
" "	" "	"	" " "	Saw	6	10	20	
" "	Peters Valley	"	John Kean	Grist	7	17	23	
Big Flat Brook	Sandyston township	"	John D. Snook	Saw	16	22	31	
Branch at Tuttle's Corner	Tuttle's Corner	"	Samuel Smith	"	15	.....	.....	Not in use.
Little Flat Brook	Layton	"	John B. Rosenkrans	Grist	20	28	40	
" " "	Hainesville	"	Washington Lantz	Flouring	20	30	42	

Paulinskill and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Paulinskill	Columbia	Warren	Heirs of Pace Love	Saw	18	.....	.....	Not in use.
"	Warrington	"	E. G. Bulgin	Grist	8	50	100	
"	Hainesburgh	"	G. C. Adams & Co.	"	9	75	110	
"	"	"	" " "	Saw	9	20	83	
"	Paulina	"	A. N. Snover	Grist	7½	30	50	
"	"	"	A. W. Snyder & Co.	Saw	7½	17	24	
"	"	"	A. J. Hill	Grist	9	.....	.....	Not in use.
"	Marksboro	"	George Wale	Photographic lenses	6	17	24	
"	"	"	W. H. Clarke	Grist	9	28	40	
"	"	"	" "	Saw	9	28	40	
"	Hardwick township	"	John Vanstone	Sorghum	4½	.....	.....	Not in use.
"	" "	"	Bert Wintermute	Saw	6½	12	20	
"	Stillwater	Sussex	H. Hopler	Grist	8	20	40	
"	" township	"	James Butler	"	7	20	40	
"	Baleville	"	J. H. Northrup & Co.	Turning	6	20	40	
"	"	"	A. J. Bale	Grist	7	20	29	
"	"	"	" "	Carding	7	20	50	
"	Lower Lafayette	"	Coolver & Huston	Grist	20	40	66	
"	" "	"	" "	Saw	8	10	20	
"	" "	"	" "	Foundry	12	.....	.....	Not in use.

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Paulinskill and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Paulinskill	Lafayette	Sussex	Coolver & Huston	Foundry	11	...	...	Not in use.
"	"	"	O. P. Armstrong	Grist	27	30	50	
Yard's Creek	Hainsburgh	Warren	Mary Pierce	Carding	13	10	20	
Branch at Kalarama	Kalarama	"	Isaac D. Lanterman	Saw	18	7	11	
" " "	"	"	John Painter	Grist	32	24	34	
Jacksonburg Creek	Jacksonburg	"	Mrs. Isaac F. Reed	Distillery	10	10	25	
" "	"	"	Samuel McConachy	Grist	18	15	25	
" "	"	"	J. M. Place	Saw	16	39	56	
Blair's Creek	Blairstown	"	John I. Blair	Grist	20	30	42	
" "	Hardwick Centre	"	John Voss	Saw	12	10	20	
" "	" township	"	Oman McGraft	"	...	8	16	
" "	"	"	Clark Bird	Feed and saw	20	60	86	
Trout Brook	Middleville	Sussex	Casper Losey	Saw	18	10	20	
" "	Stillwater township	"	Betsy Wintermute	Foundry	16	15	21	
" "	"	"	" "	Saw	16	15	30	
Branch at Swartswood Lake	Swartswood Lake	"	John W. Kean	Grist	17	80	42	
" " " "	Stillwater township	"	C. T. Unangst	Grist and saw	85	20	40	
" " " "	" "	"	E. S. Decker	Tannery	18	15	80	
" " Fredon	Emmons Station	"	Richard Vanstone	Saw	18	10	20	
" " "	Fredon	"	William Smith & Bro	Grist	50	21	80	
" " Branchville	Branchville	"	V. H. Cressman	Flouring	22	40	57	
" " "	"	"	William Bell	Woolen	13	...	...	Not in use.
" " "	"	"	V. H. Cressman	Feed	24	41	58	
" " "	"	"	William Space	Woolen	50	...	...	Not in use.
" " "	"	"	William McDonalds	Feed and saw	18	20	33	
" " "	Mount Pisgah	"	William Bell	Saw	14	...	...	Not in use.
" " "	" "	"	" "	Forge	18	80	5	" "
" " "	" "	"	E. A. Ely	Machine shop	12	14	23	
" " "	" "	"	James Perry	Bark	14	10	17	
" " "	" "	"	William Bell, in trust	Lumber	20	...	...	Not in use.

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Pequest River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Pequest	Belvidere	Warren	A. B. Searles	Flouring	17½	128	170	
"	"	"	G. K. & A. McMurtry	Saw	17½	45	60	
"	"	"	Ira B. Keener	Flouring	7	26	87	
"	"	"	Uhler & Lake	Furniture	7	35	50	
"	"	"	E. Van Uxem	Spokes	18	16	22	
"	"	"	Geo. K. & A. McMurtry	Flouring	18	104	150	
"	"	"	Belvidere Agricultural Co.	Agricultural machinery	18	25	86	
"	Bridgeville	"	Mrs. William Mackey	Grist	6	30	60	
"	Butzville	"	David Anderson	"	9	33	44	
"	Townsbury	"	Heirs of Andrew Ketcham	Saw	10	10	25	
"	"	"	J. B. Smith	Feed	12 }	25	50	
"	"	"	John Green	Grist	12 }	25	50	
"	"	"	" "	Saw	12 }	15	30	
"	Tranquility	Sussex	Heirs of E. V. Kenedy	Flouring	5	25	37	
"	Huntsville	"	Geo. V. Northrup	Saw	10 }	15	21	
"		"	" " "	Grist	12 }	30	42	
"	Springdale	"	Seymour Stickles	"	6	20	50	
Beaver Brook	Sarepta	Warren	William Hutchinson					Not in use.
" "	"	"	John R. Buttz	Grist	8	10	15	
" "	"	"	Charles Bartow	"		24	48	
" "	Hope	"	John Sweazy	"	25	48	70	
Honey Run	Sweazy's Mill	"	" "	"		10	15	
Glover's Pond Outlet	Glover's Pond	"	—— Vasbinder	Saw	20	10	15	
Trout Brook	Hope	"	Levi J. Howell	Grist		12	24	
Green's Pond Branch	" township	"	John Parks					Not in use.
" " "	" "	"	Smith Hilderbrant	Cider	9 }	10	20	
" " "	" "	"	" "	Saw	12 }			
Furnace Brook	Oxford Furnace	"	Oxford Iron and Nail Co.	Flouring	28	36	72	
Branch at Vienna	Vienna	"	Charles Barker	"	36	37	53	
" " Petersburg	Petersburg	"	Robert Ayres					Not in use.
" " Warrenville	Warrenville	"	Lackawanna Iron and Coal Co.	Saw	20			" "
" " Johnsonburg	Johnsonburg	"	Elridge Harden	Grist		15	30	
" " Hunt's Pond	Huntsburg	Sussex	George Current	Saw	18	19	88	
" " " "	"	"	Theo. F. Hunt	Grist	30	22	81	

12

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Pequest River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Branch at Alamuche	Alamuche	Warren	Rule H. Drake	Saw	20	21	35	
" " "	"	"	Morris Haggerty	Grist	28	24	40	
" " "	"	"	Joseph Ayres	Saw	26	10	25	
" " "	"	"	Rutherford Stuyvesant	Grist	30	33	72	Not in use.
" " Andover	Andover	Sussex	Heirs of John Seward Wills	Flouring	28	15	25	

Pohatcong Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Pohatcong	Carpenterville	Warren	Isaac T. Riegel	Saw	9	25	36	
"	Springtown	"	Nathan Druckenmiller	Grist	7	12	30	
"	"	"	Thomas Paullus	"	8	12	25	
"	"	"	P. W. Skinner & Bro.	Flouring	8	24	40	
"	Greenwich township	"	John Kenedy	Grist	10	15	37	
"	" "	"	—— Hulsizer	"	10	25	37	
"	Franklin township	"	Levi Cressman	Flouring	7½	17	24	
"	Pleasant Valley	"	New York Life Ins. Co.	Feed	11	24	60	
"	Washington	"	John Neilson	Grist	8	15	25	
"	Karrville	"	William Larrison	Flouring	11	24	31	
"	"	"	William Karr	Wheelwright	6½	8	16	
"	"	"	William Ketcham	Saw	18	15	30	
Hihichehockhi	Stewartville	"	Jacob Shillinger	Flouring	23	30	43	
Brass Castle Creek	Brass Castle	"	Assign. of James Lomerson	Grist	60	45	56	
" " "	Washington township	"	John Smith	Saw	11			Not in use.

Musconetcong River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Musconetcong	Riegelsville	Warren	John L. Riegel & Son	Grist	20	175	250	
"	"	"	" " " "	Paper	20	255	364	
"	Finesville	Hunterdon	Taylor, Stiles & Co.	Machine knives	6	75	107	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Musconetcong River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Musconetcong	Finesville	Warren	I. A. Jacoby	Grist	6½	48	70	
"	"	"	" "		9			Not in use.
"	Hughesville	Hunterdon	Warren Manufacturing Co.	Paper	27	340	487	
"	Warren Paper Mills	"	" " "	"	48	360	514	
"	Bloomsbury	Warren	T. G. Hoffman	Foundry facings	9½ }	80	114	
"	"	Hunterdon	" "	Grist	9½ }	44	62	
"	Asbury	Warren	J. C. Reed and others	"	5½	36	60	
"	New Hampton	"	S. S. Cramer	"	5	30	42	
"	" "	Hunterdon	Martin Wyckoff	"	7	50	70	
"	Changewater	Warren	Bowers Snuff and Tobacco Co.	Snuff	9	35	50	
"	Point Mills	Hunterdon	J. D. Pidcock	Grist	9	25	50	
"	Penville	"	Peter Lance	"	8	50	70	
"	Stephensburg	Morris	John P Sharp	"	8½	55	90	
"	Beattystown	Warren	White & Simanton	"	7	80	60	
"	Lower Hackettstown	"	Zephaniah Hoffman	"	8	86	72	
"	Hackettstown	"	Prost & Co.	"	5	86	60	
"	"	"	Lewis J. Youngblood	"	9½	59	80	
"	Upper Hackettstown	"	J. C Welsh	"	9	36	60	
"	Near Saxton Falls	Morris	Archer Stevens' Sons	Saw	8	12	20	
"	Waterloo	Sussex	Smith Bros.	Grist	18 }	36	60	
"	"	"	" "	Plaster	18 }	40	80	
"	Old Andover	"	Matilda Van Doren					Not in use.
"	Stanhope	"	Musconetcong Iron Co.					" "
"	Lake Hopatcong	"	Morris Canal					" "
Branch north of Port Murray.	Mansfield township	Warren	H. S. Beatty	Grist	22	18		Burned down in June.
" at Hackettstown	Hackettstown	"	James Boyd	Tannery	24	15	37	Not in use.
" " "	"	"	Christopher Morton	"	10	5	10	
" near Drakesville	Drakesville	Morris	Jonathan Coleman	Saw	15			Not in use.
" south of Stanhope	Stanhope	"	Heirs of John Seward Wills	"	22	15	20	
" " " "	"	"	" " " "	"				Not in use.
" at Waterloo	Waterloo	Sussex	John French	"	50	20	40	
Lubber's Run	Lockwood	"	Pope & Appleton	Forge				Not in use.

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Musconetcong River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Lubber's Run	Roseville	Sussex	Robert L. Byerley	Forge				Not in use.
" "	Columbia	"	W. W. & L. F. Sutton	"				" "
" "	Near Columbia	"	Watson McPeek	Saw				" "
" "	Sparta township	"	Lance Goble, Agt	"	20			" "

Delaware River and Small Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Branch at Montague	Montague	Sussex	Jacob C. Hornbeck	Grist	22	12	24	
Vancampen's Brook	Calino	Warren	John Zimmerman	Saw	18	10	20	
" "	Mill Brook	"	Heirs of Bartley Fuller	Grist	22	19	31	
" "	Walpack township	Sussex	David R. Hull	Saw	15	12	24	
Pophandusing Branch	Oxford Church	Warren	John C. Prall	Grist	24	30	60	
" "	" "	"	George Keiser	Tannery	16	10	25	
Buckhorn Creek	Hutchinson's	"	Samuel A. Depew	Saw	12			Not in use.
" "	"	"	" " "	"	20			" "
" "	Harmony township	"	Mrs. Archibald Davis					" "
" "	Roxburgh	"	Isaac Young	Foundry	8	15	20	
" "	"	"	R. M. Bowlby	Grist	45	36	60	
Lopatcong Creek	Phillipsburg	"	W. D. Hagerty	Saw	20	20	80	
" "	"	"	P. W. Skinner & Bro.	Flouring	14	24	84	
" "	"	"	F. G. Warne	Soapstone	18	12	18	
" "	Lopatcong	"	S. C. Purcell	Flouring	8	12	30	
" "	" township	"	John Holden	Grist	20	12	80	Not in use.
" "	Lower Harmony	"	" "	"	22	47	78	
" "	" "	"	William Vanatta	"	9	24	60	
" "	" "	"	Elijah Allen	"	18	12	24	
Branch at Carpenterville	Carpenterville	"	John Reese	"	10			Burned.
Alexsocken Creek	Mount Airy	Hunterdon	Annie Blackwell	"	11	12	80	
Wickecheoke Creek	Locktown	"	Robert Holcomb	"	15	12	24	
" "	Sergeantsville	"	R. G. Johnson	"	25	12	24	
Lockatong Creek	Delaware township	"	Mahlon Strumpel	Grist and saw	24	10	17	
" "	Idell	"	Newbury Hagar	Grist	17	16	82	
" "	"	"	Henry Cook	"	21½	48	80	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Delaware River and Small Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Nishisakawick Creek	Frenchtown	Hunterdon	D. R. Worman	Flouring	20	24	34	
" "	"	"	" "	Grist and bone	24	15	25	
" "	Everittstown	"	Joseph Huff	Grist	24	36	60	
" "	"	"	Joseph Wilson	"	20	......	......	Not in use.
Harihokake Creek	Frenchtown	"	E. R. Case	Saw				
" "	Mount Pleasant	"	Daniel Johnson	Grist	29	27	40	
" "	" "	"	Rev. Joseph Manning	Saw	14	10	25	
Hakihokake Creek	Milford	"	W. & E. T. Thomas	Flouring	30	84	120	
" "	"	"	" " "	Grist	12	36	50	
" "	Little York	"	J. M. Duckworth	"	30	36	60	
" "	" "	"	S. V. Eckel	"	33	35	50	
" "	" "	"	Samuel Kemenhower	Saw	23	12	30	
Spring Mill Branch of Hakihokake	Spring Mills	"	Jacob R. Anderson	Grist	27	25	50	
Delaware & Raritan Canal Feeder	Prallsville	"	Joseph Smith & Co	Flouring	8½	40	57	
Delaware & Raritan Canal Feeder	Lambertville	"	New Jersey Rubber Co	Rubber	15	......	......	Not in use.
Delaware & Raritan Canal Feeder	"	"	" " " "	"	15	100	140	
Delaware & Raritan Canal Feeder	"	"	Caroline Ely	Grist	19	45	64	
Delaware & Raritan Canal Feeder	"	"	F. F. Lear	Flouring	18	60	86	
Delaware & Raritan Canal Feeder	"	"	" "	Saw	18	15	25	
Delaware & Raritan Canal Feeder	"	"	Lambertville Paper Co	Paper	14	96	137	
Lambertville Water-Power Company	"	"	M. Sheppard	Twine	9½	40	80	
Lambertville Water-Power Company	"	"	William Mann Paper Co	Paper	9½	218	310	
Lambertville Water-Power Company	"	"	O'Brien Brothers & Co	"	9½	79	112	
Lambertville Water-Power Company	"	"	James C. Weeden	"	9½	94	134	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Delaware River and Small Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Delaware & Raritan Canal Feeder	Titusville	Mercer	George Agnew	Flouring	26	30	42	
Delaware & Raritan Canal Feeder	"	"	" "	Rubber	26	75	107	
Delaware & Raritan Canal Feeder	Somerset Junction	"	John Howell Borrough's Est.	Grist	18 28	24	84	
Trenton Water-Power Co.'s Raceway	Trenton	"	City Water Works	Pumping	9	20	27	
Trenton Water-Power Co.'s Raceway	"	"	Wm. Kennedy	Sawing and planing	12	40	55	
Trenton Water-Power Co.'s Raceway	"	"	B. W. Titus' Sons	Cotton and woolen	12	25	33	
Trenton Water-Power Co.'s Raceway	"	"	Golding & Sons Co.	Potters' material	14	97	121	
Trenton Water-Power Co.'s Raceway	"	"	A. Thompson & Co.	Flouring	12	19	24	
Trenton Water-Power Co.'s Raceway	"	"	Nelson Thompson	"	12	12	16	
Trenton Water.Power Co.'s Raceway	"	"	Chas. W. Howell	"	13	80	120	
Trenton Water-Power Co.'s Raceway	"	"	S. Zigenfuss & Co.	"	12	70	88	
Trenton Water-Power Co.'s Raceway	"	"	Fisher & Norris	Iron works	14	6	10	
Trenton Water-Power Co.'s Raceway	"	"	Phœnix Iron Works	Machinery	14	40	65	
Trenton Water-Power Co.'s Raceway	"	"	Samuel K. Wilson	Woolen and worsted	12 17	100	135	Partly from Assanpink creek.
Trenton Water-Power Co.'s Raceway	"	"	William Walton	Flouring	17	20	27	
Trenton Water-Power Co.'s Raceway	"	"	Saxony Woolen Mills	Woolen	11	60	75	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Wallkill River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Wallkill	Hamburg	Sussex	Glenn Estate	Forge	......	......	......	Not in use.
"	"	"	W. H. Ingersoll	Flouring	21½	75	107	
"	"	"	" "	Plaster	21½			
"	"	"	Augustus Cochran	Paper	24	47	78	Not in use.
"	"	"	W. H Ingersoll	Saw	24			
"	Lehigh Junction	"	Franklin Iron Co	Forge	......	......	......	" "
"	Franklin Furnace	"	" "	Furnace	......	......	......	" "
"	Sparta	"	James L. Decker	Grist	18	19	31	
"	"	"	" "	Distillery	11	5	10	
"	"	"	James F. Titman	Flouring	21	36	51	
"	"	"	Dr. Andrus	Grist	25	......	......	Not in use.
Branch at Decker Pond	Vernon township	"	Henry L. Sammis	Saw	40	15	30	
" " " "	" "	"	" "		......	......	......	Not in use.
" " " "	" "	"	Thomas L. Babcock	Saw	16	12	24	
Papakating Creek	Frankford township	"	Daniel Wyker	"	12	8	20	
Clove River	Deckertown	"	R. J. Quince	Grist	16	24	40	
" "	North Deckertown	"	Albert Fuller	"	12	25	41	
" "	" "	"	William T. Wright	Lumber	22	20	33	
" "	Clove	"	William Titsworth	Saw	......	......	......	Not in use.
" "	Wantage township	"	John Decker & Mary Decker	Grist	24	24	40	
" "	" "	"	Dr. Charles Cooper	"	35	24	48	
" "	Coleville	"	Theodore C. Marthis	"	16½	20	32	
" "	"	"	Edward Baker's Estate	Spokes	16½	10	25	Not in use.
" "	"	"	J. E. Post	Saw	14			
West Branch of Papakating	Woodbourne	"	Philip Elston	Grist	40	......	......	" "
" " "	Plumbsock	"	Nancy Compton and Emma Stelle	"	20	24	60	" "
" " "	"	"	John Smith	Saw	18	32	52	
Branch at Wykertown	Wykerton	"	Samuel J. Corsen	Grist	40	......	......	Not in use.
Beaver Run	Wantage township	"	James Cox	"	16	12	24	
" "	" "	"	Benj. K. Jones	Foundry	24	37	60	
Branch at Hardystonville	Hardystonville	"	Milton I. Southard	Grist	20	36	60	
" near Ogdensburg	Ogdensburg	"	Augustus Tallman	Feed	18	10	25	
" at Lake Grinnell	Monroe Corners	"	Mrs. Susan Kemble	Grist	8	15	37	
" " "	" "	"	J. C. Wilson	"	12	21	35	
Pochuck	Wawayanda	"	Victor H. Wilder	"	18	......	......	Not in use.

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Wallkill River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Pochuck	Wawayanda	Sussex	Victor H. Wilder	Cheese-box factory	10			Not in use.
"	"	"	" " "	Saw	18			" "
"	"	"	" " "	Furnace	35			" "
"	"	"	" " "	Creamery	8			" "
"	Vernon township	"	Martin Thaddock	Saw				" "
Branch at Glenwood	Glenwood	"	Daniel Bailey	Flouring	28	25	36	
" " "	"	"	Norman McKirk	Saw	15	10	25	
" " Vernon	Vernon	"	Joseph Burroughs	"				Not in use.
" " "	"	"	S. E. Wood	Feed	18	12	24	

Passaic River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Second River	Belleville	Essex	De Witt Wire Cloth Co.	Wire cloth	11	40	80	
" "	"	"						Not in use.
" "	"	"	Hendricks Bros.		12			" "
" "	"	"	" "		20			" "
" "	"	"		Copper	19	100	200	
" "	"	"	National Print Works	Print works	18	25	36	
" "	Bloomfield	"	James Moffet	Brass rolling mills	20	25	40	
" "	"	"	Wheeler Bros.		12			Not in use.
Silver Lake Branch of Second River	Silver Lake	"	Thos. A. Edison	Grist	14			" "
Yantecaw	Delawanna	Passaic	J. & R. Kingland	Paper	22 15			" "
"	Nutley	"	" "	"	17	65	90	
"	"	Essex	Nutley Water Co	Water works	8	10	14	
"	Franklin	"	—— Hilton	Woolen	6	40	80	
"	"	"	Underhill Mfg. Co.	Woolen underwear	12	37	61	
"	Bloomfield	"	E. H. Davey	Trunks and binders' boards	11	45	75	
"	"	"	Thomas Oakes & Co.	Woolen	16	38	54	
"	"	"	A. T. & Joseph Morris	Grist	12			Not in use.

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Yantecaw	Bloomfield	Essex	Estate of Albert Moore	Saw	10	15	30	
Passaic	Passaic	Passaic	Dundee Water-Power and Land Co.	Miscellaneous	22	1,235	1,761	
Weasel Brook	Clifton	"	Richard A. Westervelt	Grist	15	......	......	
" "	Athenia	"	A. R. Post & Co.	Saw	12	12	24	
Saddle River	Garfield	Bergen	—— Zabriskie	Cotton	5	......	......	Not in use.
" "	"	"	C. R. Van Dusen	Grist	6½	42	70	
" "	Lodi	"	Byrne Bros. & Co.	Bleaching and dyeing	7½	......	......	
" "	Rochelle Park	"	D. Romaine	Rubber shoddy	6	58	71	
" "	Arcola	"	Dunlap & Co.	Blankets	4	10	25	
" "	Midland township	"	J. Henry Blauvelt	Grist	7	11	18	
" "	" "	"	" "	Saw	7	10	20	
" "	Paramus "	"	Abram F. Z. Demarest	Grist	6½	12	30	
" "	" "	"	John D. Berdan	"	12	25	41	
" "	" "	"	" "	Saw	12	15	25	
" "	Orvil "	"	Thomas Eckerson	"	6	12	24	
" "	" "	"	" "	Cider and saw	6	5	10	
" "	" "	"	D. A. Blauvelt	Grist	8	15	37	
" "	" "	"	O. J. Victor		7	......	......	Not in use.
" "	Saddle River	"	Abram Dates	Grist	6	10	25	" "
" "	" "	"	William W. Packer	Saw	7	10	25	
" "	" "	"	" "	Foundry	6	15	30	
" "	North Saddle River	"	J. Raymond Ackonback	Grist	4	20	50	
" "	" " "	"	Dr. O. Blyneth	Woolen	7½	20	33	
" "	" " "	"	W. J. C. Ward	Mechanics' tools	8	10	20	
" "	Orvil township	"	John E. Hopper	Saw	8	8	16	
" "	" "	"	Abram C. Hopper	"	8	15	25	
West Branch Saddle River	" "	"	Mary Halstead and Geo. De Baum		......	......	......	Not in use.
" " " "	" "	"	Henry P. Post	Grist	9½	12	24	
" " " "	" "	"	" "	Saw	9½	10	25	
" " " "	" "	"	Martin Tice	Feed and saw	8½	10	25	
East " " "	" "	"	G. J. Hopper	Saw	11	10	25	
Hohokus Creek	Undercliff	"	Abram J. Zabriskie	Saw and silk	6	15	30	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Hohokus Creek	Undercliff	Bergen	Estate of John R. Terhune*	Rubber	14	25	42	
" "	"	"	" " "	Saw	13½	12	24	
" "	"	"	" " "	Turning	13½	10	20	
" "	"	"	McCafferty & Buckley		30	80	110	Not in use.
" "	Hohokus	"	W. D. Rosenkrantz, Agent	Cotton yarn	40	50	70	
" "	Waldrick	"	M. D. White	Saw and bark	18	18	26	
" "	"	"	Martin Margoff	Cotton	10	12	17	
" "	"	"	Charles White	Paper	13	50	70	
" "	Allendale	"	Richard Christopher	Grist	10	13	21	
" "	"	"	" "	Saw	10	8	13	
" "	"	"	A. A. Lydecker	Flouring	10	20	30	
" "	"	"	Jacob J. Smith	Saw	8	10	20	
" "	North Wyckoff	"	John Gardiner					Not in use.
" "	" "	"	G. G. Ackerman	Flouring	9	20	30	
" "	" "	"	John W. Pulis	Grist and saw	11⅓	10	17	
" "	" "	"	John Haubner	Tannery	20			Not in use.
" "	Camp Gaw	"	J. H. Sturr	Grist	13	12	20	
" "	" "	"	" "	Saw	12	12	20	
Branch at Ramseys	Ramseys	Bergen	Abner Benedict	Grist and bark	10	6	17	
" " "	Allendale	"	Charles Christopher	Saw	12	10	20	
" " Wyckoff	Wyckoff	"	P. S. Pulis	Saw and cider	4	4	10	
" " Saddle River	Saddle River	"	Thomas Van Buskirk	Saw	15	18	36	
" " Hawthorn	Hawthorn	"	Alyea Bros.	Grist	13	20	33	
Goffel Creek	"	Passaic		Dyeing	18			
" "	Van Winkle	"	S. P. Van Winkle	Grist	12	20	50	
" "	" "	"	" " "	Cider	10	4	10	
" "	" "	"	Joel M. Johnson		11			Not in use.
" "	Midland Park	Bergen	D. Baldwin	Cotton	16	12	20	
" "	" "	"	Metropolitan Bank of New York	"	24	12	20	
" "	" "	"	G. Morrough's Sons	Woolen	30	23	82	
" "	Wortendyke	"	Metropolitan Bank of New York	Silk	14	12	17	
" "	Wyckoff	"						Not in use.
Branch at Van Winkle	Van Winkle	Passaic	Maria Van Blarcom	Saw	16	10	20	
" " " "	" "	"	Preston Stevenson	"	22			Not in use.

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Branch at Van Winkle	Midland Park	Bergen	Isaac G. Snyder	Paint	16	8	13	
Passaic	Paterson	"	Society for the Establishment of Useful Manufactures	Miscellaneous	66	1,760	2,350	
Haledon Creek	Haledon	Passaic	Henry L. Butler	Carpets	12	10	20	
Peckman's Brook	Jackson Park	"	James Edge	Bolts and nuts	6	8	18	
" "	" "	"	Estate of George Jackson	Scouring	10	20	30	
" "	Little Falls	"	S. Sindle	Grist	19	20	33	
" "	" "	"	" "	Felt	19	20	33	
" "	" "	"	James Van Ness	Dyeing	18	40	67	
" "	Cedar Grove	Essex	F. J. Marley	Saw	18	10	14	
" "	" "	"	" "	Hubs	18	12	17	
" "	" "	"	Elias Van Ness		7			Not in use.
" "	" "	"	Anthony Bowden	Cotton	16	12	20	
" "	" "	"	Andrew J. Wood	Woolen	11			Not in use.
" "	" "	"	J. J. Thatcher	Bronze powder	36	30	42	
" "	Verona	"	American Bronze-Powder Co	" "	13	15	30	
" "	"	"	Montclair Syndicate	Saw	18	20	50	
Passaic	Little Falls	Passaic	Beattie Manufacturing Co.	Carpets	14	320	440	
"	Chatham	Morris	Geo. T. Parrot	Flouring	10	42	60	
"	"	Union	John P. Edwards	Machine	8	50	80	
"	"	"	" "	Paper	8			Not in use.
"	Stanley	Morris	Mrs. William Bonnell	Grist	8	40	80	
"	"	"	Armour Brothers	Paper	7½	52	75	
"	Millington	Somerset	William Leeson	Grist	6⅓	24	40	
"	Logansville	"	Richard Irwin's Estate	Saw	6 5/12	12	24	
"	Franklin	"	F. Van Doren	Flouring	20	40	57	
"	"	"	Edna McMurtry	Saw	13	10	25	
"	Washington	Morris	William Little	Turning	16	62	90	
"	"	"	Abram Brockoven	Saw	10	20	40	
Green Brook	Caldwell township	Essex	Barney Cook and Henry Francisco	Cider	10	8	16	
" "	" "	"	Thomas C. Sindle	Grist	29	30	42	
" "	" "	"	" "	Saw	29	15	21	
" "	" "	"	O. Dorson	Grist	25			Not in use.
" "	" "	"	Sindle & Anderson	Turning	25	15	21	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Green Brook	Caldwell township	Essex	O. Dorson	Saw	12			Not in use.
Ramapo River	Pompton	Passaic	Pompton Steel and Iron Co.	Steel & iron works.	20	80	160	
" "	Oakland	Bergen	Samuel B. Demarest	Silk	4½	20	30	
" "	"	"	" "	Saw	4½	12	20	
Franklin Lake Stream	"	"	James H. Van Blarcom	"	10	30	60	
" " "	"	"	Rev. Eugene Dikovich	"	10			Not in use.
" " "	Crystal Lake	"	H. M. Ranson	"	11			" "
" " "	" "	"	J. B. Ewing	Silk	21½	25	37	
" " "	Franklin Lake	"	Daniel Yeomans	Feed and saw	6	10	20	
" " "	" "	"	" "	Turning	6	10	20	
Branch at Mahwah	Mahwah	"	Winter & Bro	Saw	6			Not in use.
" " "	"	"	Henry Wanamaker	"	6	8	16	
Wanaque River	Pompton	Passaic	H. J. Smith	Silk	15	110	157	
" "	"	"	" "	Electrical fuse	9	25	36	
" "	Wanaque	"	Edward J. Skerrett	Turning	4	12	24	
" "	"	"	Peter J. Brown	Grist	7	24	48	
" "	Midvale	"	Cooper & Hewitt	Old forge site	15			Not in use.
" "	"	"	John Taylor Johnson	" " "	9			" "
" "	Monks	"	Daniel A. Wheeler	Saw and feed	12	28	40	
" "	"	"	Cooper & Hewitt	Old saw-mill site	8			Not in use.
" "	Hewitt	"	" " "	Furnace	82½			" "
West Brook	Midvale	"	Albert Albeglse	Saw	10	8	13	
Ringwood Creek	Boardville	"	Cooper & Hewitt	Old forge site	10			Not in use.
Greenwood Lake Branch	West Milford	"	P. L. La Roe.	Grist	11	18	30	
" " "	" " township	"	Albert Terhune	"	17	20	50	
" " "	" " "	"	Albert S. Terhune	Saw	14	10	16	
		"	" "	"	20	16	26	
Pequannock River	Riverdale	Morris	East Jersey Water Co., Hon. J. F. Post, Lessee,	"	9	30	60	
" "	"	"	East Jersey Water Co., Hon. J. F. Post, Lessee	Bark	8	12	24	
" "	"	"	East Jersey Water Co., Robert Slater, Lessee	Hatters' felt	14	60	87	
" "	Bloomingdale	"	East Jersey Water Co., W. G. Linnen, Lessee	Grist	12	12	30	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Pequannock River	Bloomingdale	Passaic	East Jersey Water Co., M. J. Ryerson's Heirs, Lessees	Grist	15	12	30	
" "	"	"	East Jersey Water Co., M. J. Ryerson's Heirs, Lessees	Turning	15	5	12	
" "	"	"	East Jersey Water Co., M. J. Ryerson's Heirs, Lessees	Saw	15	10	25	
" "	"	Morris	East Jersey Water Co., Bloomingdale Soft-Rubber Co, Lessees	Soft rubber	14	100	143	
" "	Butler	"	East Jersey Water Co.	Paper-mill site	18	......	......	Not in use.
" "	"	"	Butler Hard-Rubber Co.	Hard rubber	30	260	370	
" "	"	"	James C. Reynolds	Paper	15	100	143	
" "	"	"	Pequannock Valley Paper Co.	"	17	175	250	
" "	"	"	Demarest & Co.	Excelsior	18	125	179	
" "	Smith's Mills	Passaic	East Jersey Water Co., H. D. Smith, Lessee	Grist	11	86	72	
" "	" "	"	East Jersey Water Co., Geo. and Thos. Smith Lessees	"	10	......	......	Not in use.
" "	Charlottesburg	"	Cooper & Hewitt	Feed	14	......	......	" "
" "	"	"	" " "	Hardware	19	......	......	" "
" "	New Foundland	Morris	Bigelow Brothers	Saw	9	36	50	
" "	" "	Passaic	J. J. Laroe	Grist	6½	20	30	
" "	Stockholm	Morris		Old forge site	20	......	......	
" "	"	Passaic	A. M. Booth	Pocket-knife works	14	12	24	
" "	"	Sussex	Nancy Riggs	Old forge site	16	......	......	Not in use.
" "	Hardiston township	"	Naval H. Margin	" " "	12	......	......	" "
" "	" "	"	John E Forgerson	Grist	22	24	40	
" "	" "	"	Amos Faber	Old saw	......	......	......	Not in use.
" "	" "	"	Isaac William Arden	" "	10	......	......	" "
Stockholm Branch	Stockholm	"	Mrs. Walter	Tannery	18	5	12	
" "	"	"	Edward Kincaid	Grist and distillery	20	......	......	Not in use.

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

Stream.	Locality.	County.	Owner.	Kind of Mill.	Fall.	H. P. Utilized. Net.	H. P. Utilized. Gross.	Remarks.
Pacack Brook Branch	Stockholm	Sussex	John Lynn	Old forge site	15			Not in use.
" " "	Canistear	"	Ira Day and Adam Smith Estate	" " "	14			Not in use.
" " "	"	"	John Baxter	" " "	14			
" " "	"	"	Isaac Snyder	" saw-mill site	14			Not in use.
" " "	"	"	Ezra Day	" " " "	14			" "
Pine Brook	Westville	Essex	M. N. Crane	Feed and saw	23	20	33	
" "	"	"	Geo. B. Harrison	Grist	20			Not in use.
" "	Caldwell	"	Stephen R. Gould	Bark				" "
" "	"	"	George Budd	Old paper mill	25			Not in use.
" "	"	"	Dr. Charles H. Hunter	Snuff	10			" "
Rockaway River	Montville township	Morris	Heirs of Benj Starkey	Woolen	7	20	50	
" "	" "	"	Albert Zabriskie	Grist	4½	24	34	
" "	Old Boonton	"	M. Fitzgibbons	Straw-board paper	30	260	570	
" "	Boonton	"	H. N. Hubbard	Foundry	23.58	15	25	
" "	"	"	" "	Agricultural machinery	49	25	40	
" "	"	"	Wrought-Iron Paint Co.	Paint	28.7	100	166	
" "	"	"	Boonton Iron and Steel Co.	Rolling mills	81.63	150	250	
" "	"	"	W. C. Boon & Co.	Drop forgings	31.87	30	50	
" "	"	"	O Patterson	Nails	28.82	25	40	
" "	"	"	United States Aluminum Co.	Aluminum	29	160	267	
" "	"	"	Electric Light H and P. Co.	Electric lighting	31.87	43	72	
" "	"	"	Interchangeable Tool Co.	Tools		15	22	
" "	"	"	Lincoln Iron Works	Iron works		23	38	
" "	Powerville	"	Powerville Felt-Working Co. (Limited)	Roofing felt	10	188	270	
" "	Rockaway	"	Wm. F. Brann	Axe factory	8			
" "	"	"	E. D. Halsey	Grist	11	24	40	
" "	"	"	" "	Forge	11	15	40	
" "	"	"		Saw	11	10	20	
" "	Dover	"	Dover Iron Co.	Rolling mills	9½	15	30	
" "	Port Oram	"	Luxembourg Improvement Co.	Hosiery	8	21	80	
" "	Baker's Mills	"	Henry and William Baker	Grist	10	24	48	
" "	" "	"	" " " "	Forge site	7			Not in use.

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Rockaway River	Lower Longwood	Morris	A. A. Wilcox	Forge site	12			Not in use.
" "	Upper Longwood	"	Hon. John Kean, Jr.	" "	15			" "
" "	Woodstock	"	Zophar Tallmage	Distillery	7			" "
" "	Petersburg	"	David C. Wallace	Grist	12	15	20	
" "	Milton	"	Enos Davenport's Estate		7			Not in use.
" "	"	"	Horace Chamberlain	Grist	15 }	20	30	
" "	"	"	" "	Saw	12 }	10	20	
" "	"	"	J. R. Riggs	Old Stanborough Forge	10			Not in use.
" "	Russia	"	" "	Old forge site				" "
" "	Hopewell	"		" "				" "
Montville Stream	Montville	"	Andrew Decker	Grist	21	15	30	
" "	"	"		Print & dye works	25	55	80	
" "	"	"	J. Comley	Novelty works	18	50	70	
" "	"	"		Grist-mill site	10			Not in use.
Dixon Pond Branch	Rockaway Valley	"	C. B. Dixon	Grist	23	15	25	
" " "	" "	"	" "	Old forge site	20			Not in use.
Den Brook Branch	Union	"		Old paper-mill site	12			" "
" " "	Shongum	"	Opennaki Association	Forge site	15			" "
" " "	"	"	A. W. Cutler	Saw-mill site	12			" "
Beaver Brook	Beach Glen	"		Old forge site	10			" "
" "	Meriden	"		" " "	8			" "
" "	Split Rock	"	Cobb Estate	Old furnace site	35			" "
Mill Brook	Mill Brook	"	William E. Teed	Old distillery site	18			" "
" "	" "	"	Adams Davenport	Grist	22	12	24	
" "	" "	"	" "	Saw	16	10	20	
" "	" "	"	Thomas A. Lindsley	Old forge site	30			Not in use.
" "	" "	"	Martin and Isaac Searing	Old saw-mill site	10			" "
" "	" "	"	James M. Bryant	Saw	14	10	20	
Green Pond Brook	Middle Forge	"	U. S. Government	Old forge site	15			Not in use.
" " "	Denmark	"	F. P. Merritt	" " "	30			" "
Hard Bargain Brook	Hard Bargain	"	Stephen Strait's Estate	" " "				
Whippany River	Whippany	"	George Ball	Grist	7	18	30	
" "	"	"	Henry Conger	Cotton	15	70	120	Idle.
" "	"	"	McEwan Brothers	Paper	19	60	100	
" "	"	"	Diamond Mills Paper Co	"	28	100	145	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Passaic River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Whippany River	Monroe	Morris	James A. Muir	Paper	17	66	100	
" "	"	"	J. F. Muir	"	18	...	...	Recently burned.
" "	Morristown	"	Martin & Caskey	Grist	5	18	30	
" "	"	"	Mary Slagle	"	8	18	30	
" "	"	"	Heirs Stephen Vail	Turning	7	30	60	
" "		"	" "	Machine shop	7	60	120	Not in use.
" "	Brookside	"	Aaron Whitehead	Grist	28	38	60	
" "	"	"	M. M. & E. J. Connet	Flouring	30	38	60	
" "	"	"	E. J. Connet	Saw	24	22	35	
Branch at Troy Hills	Troy Hills	"	George B. Smith	Grist	19	15	30	
" " " "	" "	"		Turning	19	6	10	
" " " "	" "	"	" " "	Saw	21	11	19	
" Malapardus	Whippany	"	B. F. Howell	"	15	12	30	
" " "	"	"	" "	Machine shop	15	6	12	
" Speedwell	Morristown	"	Mrs. John Ledgewood	Grist	20	12	30	Not in use.
" " "		"	" " "	Foundry site	12	...	...	" "
North Branch of Whippany	Morris Plains	"	J. H. Branat	Paper	20	50	100	
" " " "	" "	"	F. W. Jaqui	Flouring	27	70	100	
" " " "	" "	"	J. Fletcher Johnson	Cider	25	...	...	Not in use.
" " " "	" "	"	Arthur Thompson	Saw	8	...	...	Old site not in use.
" " " "	Tabor	"	A. W. Cutler	Feed and saw	15	5	10	
Canoe Brook	Millburn township	Essex	Geo. W. Reeves	Saw mill site	15	...	...	Not in use.
" "	Livingston township	"	F. C. Reiley	Grist-mill site	7	...	...	" "
Dead River	Liberty Corner	Somerset	Abram Ten Eyck	Saw-mill site	...	...	...	" "
Branch near Logansville	Logansville	Morris	Van Doren Phœnix	Grist	15	12	80	
Branch at Pleasantville	Pleasantville	"	Joseph Hoar	Saw	10	10	20	
" " Green Village	Green Village	"	Joseph Dixon	"	10	...	...	Not in use.
" " " "	Silver Lake	"	H. M. Olmstead	Flouring	12	52	75	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Hackensack River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Hackensack River	Oradell	Bergen	William Veldran	Saw	4	10	14	
" "	"	"	" "	Grist	4	70	100	
" "	Harrington	"	John J. Bogert	"	4½	25	35	
" "	Rivervale	"	C. O. Colligan	Chair factory	6⅓	20	30	
" "	"	"	" "	Saw	6½	10	20	
" "	"	"	" "	Wheelwrights' supplies	6½	20	30	
" "	"	"	Hiram Bellis	Grist and saw	6			Not in use.
Branch at Overton	Overton	"	John C. Meister	" " "	12	12	30	
" " "	Schraalenburg	"	Cranmond Kenedy	Grist	10			Not in use.
" " "	"	"	Sarah Demarest	"	9	12	24	
" " "	Bergen Fields	"	W. S. Bogert and Henry Cooper	Chair factory	8	8	10	
" " "	" "	"	W. S. Bogert and Henry Cooper	Saw	8	10	20	
" of Trenekill	Harrington	"	Maria Demarest	Grist	6			Not in use.
" " "	Cresskill	"	J. D. Farrington	Saw and grist	12			" "
" " "	"	"	J. R. & V. B. Demarest	Hardware and brass	16	45	60	
" " "	"	"	Hon. W. W. Phelps	Saw	18			Not in use.
" " "	Closter	"	Moses T. Taylor	"	12	8	20	
" " "	"	"	D Bingham	Grist				Not in use.
Pascack Creek	Westwood	"	Jacob R. Hopper	Saw	7	8	20	
" "	"	"	Robert Yates	Grist and saw	7	36	72	
" "	Pascack	"	W. B. Ackerman	Saw	7½	10	15	
" "	Park Ridge	"	George Van Riper	Bobbins				Not in use.
" "	" "	"	Catharine Pretre	Grist	7	12	20	
" "	Montville	"	Garret J. Herring	Bent wagon wood	12	15	30	
" "	"	"	Philip Beckelle	Saw	12	8	15	
Musquapsink Creek	Westwood	"	Isaac D. Bogert	Grist	6	12	24	
" "	"	"	" "	Saw	6	10	20	
" "	Hillsdale	"	Henry C. Storms	"	12	8	16	
" "	Pascack	"	Paul Bates	Grist	18			Not in use.
Bear Brook	Park Ridge	"	John Cummings	"	18	12	24	
" "	" "	"	James Leach	Chair factory	18			Not in use.
Upper Montvale Branch	" "	"	J. H. Wield & Co	Bobbin "	18	23	32	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Elizabeth River and Branches.

Stream.	Locality.	County.	Owner.	Kind of Mill.	Fall.	H. P. Utilized. Net.	H. P. Utilized. Gross.	Remarks.
Elizabeth River	Salem	Union	John Kean	Grist	10	12	22	
" "	Irvington	Essex	William A. Ostrander	"	22	24	35	
" "	"	"	Elias Durran					Not in use.
" "	"	"	Mahlon S. Drake	Rule factory	20			" "
West Branch of Elizabeth River	Salem	Union	John Kean	Saw	18			" "

Rahway River and Branches.

Stream.	Locality.	County.	Owner.	Kind of Mill.	Fall.	H. P. Utilized. Net.	H. P. Utilized. Gross.	Remarks.
Rahway River	Rahway	Union	John Fedder Estate	Grist-mill site	10			Not in use.
" "	Cranford	"	Taylor, Bloodgood & Co.	Woolen	6⅝	28	40	
" "	"	"	John A. Morrough	Grist	8	30	45	
" "	"	"	Elias Vreeland Estate	Saw	5½	18	30	
" "	Milltown	"	J. Edgar Meeker	Paper	7 }	30	50	
" "	"	"	" "	Saw	7 }	10	20	
" "	Millburn	Essex	A. L Henderson	Paper	15	20	30	
" "	"	"	Charles A. Lighthipe	Hat factory site	16			Not in use.
" "	"	"	" " "	" bodies	22	100	170	Not working.
" "	"	"	Diamond Mills Paper Co.	Paper	27	25	40	
Robinson's Branch	Rahway	Union	M H. Acken	Flouring	18½	15	25	
" "	Clark township	"	Martin Fate	Mill site	6?			Not in use.
" "	Willow Grove	"	John Lambert	Grist	22	12	20	
Normahiggin Brook	Branch Mills	"	Silas Miller	"	11	12	22	
" "	" "	"	C T. & A. M. Parkhurst	Paper and feed	16	25	50	
East Branch of Rahway	Maplewood	Essex	H. O. Pierson	Flouring	13	25	35	
" " "	Millburn	"	William Smith	Grist	10			Not in use.
" " "	"	"		Wall paper	15			Not used.
" " "	Springfield	Union	Frederick Crane Chemical Co.	Paper-mill site	15			Not in use.
" " "	"	"	Frederick Crane Chemical Co.	Chemical works	16			Power not used.
" " "	"	"	—— Jennings	Paper-mill site	12?			Not in use.
" " "	Summit	"	William H. Bryant	Saw	10	6	12	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Raritan River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED.		REMARKS.
						Net.	Gross.	
Raritan River	New Brunswick	Middlesex	Norfolk and New Brunswick Hosiery Co.	Hosiery	11	150	215	
" "	Raritan	Somerset	Wm. W. Adair & Co.	Flouring	12½	62	90	
" "	"	"	Rynear Veghte	Paint	14	36	50	
" "	"	"	Raritan and Somerville Water Co.	Pumping station	16	85	110	
" "	"	"	Wm. H. H. Wyckoff	Grist	14	20	35	
South River	Bloomfield Mills	Middlesex	Bloomfield Mills Co.	Licorice and spice	7¼	112	160	
" "	Spottswood	"	A. A. Devoe	Grist	8	24	48	
" "	"	"	" "	Snuff	8	30	60	
" "	Helmetta	"	Geo. W. Helme & Co.	"	8	12	20	
" "	Jamesburg	"	James Buckelew Estate	Flouring	14	80	100	
" "	"	"		Shirt factory	13	125	180	
Tennent's Brook	Old Bridge	"	Perth Amboy City	Mill site	11			Not in use.
Deep Run	Dill's Mills	"	Leonard A. Bampton	" "				" "
" "		"	——— Peters	Saw-mill site				" "
" "		Monmouth	Cor. Hanus	Grist " "				" "
Iresick Brook		"		Mill site				" "
Matchaponix Brook	Spottswood	"	Wm. A. Skinner	Snuff				
" "	Texas	"	Mrs. Amanda Garner	Mill site				Not in use.
" "	Matchaponix	"	Bloomfield Mills Co.	" "	6½			" "
" "	Mount's Mills	"	Perrine Estate	Flouring and saw	8	40	70	
" "	Englishtown	"	Wm. H. Parker	" " "	11	40	70	
McGelliard's Brook	"	"	J. W. Taylor	" " "	10	35	60	
" "	Near Freehold	"	Haight Estate	Flouring	22	45		Not in use.
Milford Brook	Lafayette Mills	"	L. Journee	Grist				" "
Wennock Brook	West Freehold	"	Jas. A. Perrine	Grist and cider	22	20	80	
Manalapan Brook	Black's Mills	"	C. H. Snyder & Son	Flouring	16	63		
" "	" "	"	" " "	Saw	16			
" "	Oakland Mills	"	Jas. S. Parker	Grist	11	36	50	
" "	Smithburg	"	Robt. S. Blaine	Woolen	12	9	13	
" "	"	"	Wm. Hendrickson	Saw	12	13	20	
" "	Charleston Springs	"	J. Segoine	"	11	36	50	
Lawrence's Brook	New Brunswick	Middlesex	City of New Brunswick	Water works	15	216	300	
" "	Milltown	"	Meyer Rubber Co.	Rubber works	7⅔	70	100	
" "	Brookford	"	James Parsons	Snuff		15	25	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Raritan River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Lawrence's Brook	Davidson's Mills	Middlesex	C. C. Beekman	Grist	11	17	24	
" "	Deans	"	Aaron Dean	" and saw	9½	15	75	
Branch of Lawrence's Brook	Baptist Lane	"	Dr. Smith	Cider	14	4	8	
Grog Brook		"	William P. Hageman	Grist	17	16	32	
Branch at Bloomington	Bloomington	Somerset	William Voorhees	"	12	15	25	
Bound Brook	Near Bound Brook	"	J. H. Sebring	Grist and saw	4½	15	30	
" "	New Market	Middlesex	M. Otto	Grist	8	25	50	
" "	New Brooklyn	"	H. J. Baker & Bro	"	9	28	40	
" "	" "	"	Lehigh Valley R R Co.	Water tank and saw-mill	4½	10	14	
Green Brook	Green Brook Road	Somerset	William Holman	Grist	5½			Not in use.
" "	Plainfield	"	Andrew Cadmus Estate	Saw.	5			" "
" "	"	Union	French Bros	Flouring	17	37	52	
" "	"	Somerset	Charles Hyde	Grist	12	35	58	
" "	Scotch Plains	"	Harper, Hollingsworth & Darby	Fur factory	22	54	77	
" "	" "	"	E. A. Seeley	Paper	8	25	50	
Middle Brook	Bound Brook	"	Bound Brook Water Co.	Grist	38½	31	44	
Millstone River	Weston	"	Henry Conger	Hat factory	4¾	18	36	
" "	Blackwell's Mills	"	E. B. Cook	Flouring	4	50	82	
" "	Griggstown	"	Charles Dixon	Grist	4	30	50	
" "	Rocky Hill	"	Isaac Shaw	"	4	40	80	
" "	Kingston	Middlesex	Charles B Robinson	"	3½			Not in use.
" "	Aqueduct	"	The Misses Gray	Flouring	5	25	50	
" "	Westcott's Mills	"		Grist	10			Not in use.
" "	Bergen's Mills	Monmouth	—— Davison	"	11	27	39	
Beden's Brook	Stoutsburg	Somerset	J. Hervey Stout	Grist and saw	10	26	42	
No Pike Brook	Bridge Point	"	Wm. S. Terhune	Grist	6	21	35	
Stony Brook	Princeton	Mercer	Joseph H Brewer	"	8	23	40	
" "	Rosedale	"	A. B. Reeder	"	10	17	30	
" "	"	"	" "	Saw	10	12	20	
" "	Pennington	"	Charles A. Reed	Grist	9	13	26	
" "	Titus' Mills	"	W. W. Titus	Flouring	7	25	36	
" "	Moores	"	Joseph H. Moore	"	8½	25	36	
" "	"	"	" "	Saw	8½	10	20	
" "	Lindvale	"	Robert Crosedale	Grist				

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Raritan River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Beden's Brook	Rock Mill	Mercer	Geo. Anderson	Saw	.....	.....	.....	Not in use.
" "	" "	"	Peter Gray	"	.....	.....	.....	
Bear Brook	Princeton Junction	"	J. H. Grover	Flouring	11	30	50	
Cranbury Brook	Plainsboro	Middlesex	—— Lovett	Grist	8	20	33	
" "	Cranbury	"	John Petty	"	7	12	20	
Rocky Brook	Hightstown	Mercer	G. W. Norton	Flouring	10	28	40	
" "	Etna	"	Charles Keeler	Grist and saw	12	40	57	
" "	Perrineville	Monmouth	Charles Allen	Grist	22	40	50	
Hutchinson's Brook	Ely's Mills	Mercer	S. D. Ely	"	9	40	57	
North Branch	Milltown	Somerset	Heirs of Michael Van Derveer	Flouring	6	36	50	
" "	North Branch	"	Tunison & Beekman	"	4	36	50	
" "	Kline's Mills	"	Jacob Kline	Grist and saw	6	10	20	
" "	Pluckamin	"	Thomas Moore	Grist-mill site	7½	.....	.....	Not in use.
" "	Hub Hollow	"	Ludlow & Bedell	Feed and saw-mill and hub factory	10	35	60	
" "	Mendham township	Morris	Peter Z. Smith	Saw	12	20	30	
" "	Chester township	"	J. Wesley Swackhamer	Grist	9½	29	40	
" "	Roxiticus	"	Aaron Hoffman	Old mill site	6	.....	.....	Not in use.
" "	"	"	Sarah Lidell	Grist	23	25	50	
Lamington River	Burnt Mills	Somerset	N. Welch	"	5	25	50	
" "	Vliet's Mills	"	George Moore	"	9	12	25	
" "	" "	"	" "	Saw	9	10	20	
" "	" "	"	William Rhinehart	Creamery	4	3	6	
" "	Pottersville	Hunterdon	Robert Craig	Flouring	7½	40	60	
" "	"	"	" "	Grist	17	26	35	
" "	"	"	H. M. Sovereign & Son	Foundry and machine shop	16	107	150	
Rockaway Creek	White House	"	William H. Reger	Flouring	9	21	30	
South Branch of Rockaway	Lebanon	"	Isaac P. Hoffman	"	23	25	35	
North Branch of Rockaway	White House	"	Mrs. C. S. Hall	Grist	24	40	80	
" " " "	New Germantown	"	John Lane	"	.....	.....	.....	
" " " "	" "	"	" "	Woolen	.....	.....	.....	
" " " "	Tewksbury township	"	David Reed	Saw	12	10	20	
" " " "	Mountainville	"	Robert Craig	Grist	9	12	24	
" " " "	"	"	Jonathan Potter	Distillery	8	2	4	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Raritan River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
North Branch of Rockaway	Mountainville	Hunterdon	J. N. Wilcox	Grist	22	12	24	
" " " "	Fairmount	"	Frederick Hoffman	Saw	20	10	20	
" " " "	"	"	Geo. B. Sutton	Tannery	15	10	20	
" " " "	"	"	" "	Saw	15	10	20	
" " " "	"	"	Andrew Philhower	Grist	20	25	50	
Cold Brook	New Germantown	"	Peter W. Melick	Flouring	20	24	84	
Pottersville Brook	Pottersville	Somerset	John C. Latourette	Grist	12	7	14	
Black River	"	Morris	Robert Craig	Saw	12	40	60	
" "	Hacklebarney	"	John H. Miller	Flouring	18	58	82	
" "	"	"	" " "	Saw	18	10	15	
" "	"	"	Chester Iron Co.					
" "	"	"	" " "					
" "	Milltown	"	William Cardovin	Carding	9	16	82	
" "	"	"	A. W. Cooper	Grist	17	60	100	
Milltown Branch	"	"	Richard Stevens	Distillery	20	8	16	
Tanner's Brook	Washington township	"	John Castner	Saw	7	10	20	
" "	" "	"	" "	Cider	7	5	10	
" "	Parker	"	Jacob Lauerman	"	11	8	16	
Mine Brook	Mine Brook	Somerset	James Dow	Feed and saw	18	10	20	
" "	Barker's Mills	"	C. Barker	Flouring	85	27	40	
" "	Bernardsville	"	T. G. & J. V. Bunn	Grist and distillery	26	35	50	
" "	"	"	Charles McMichael	Flouring	28	14	20	
Peapack Brook	Schomp's Mill	"	William A. Schomp	Grist	10	14	23	
" "	Peapack	"		"				
" "	Gladstone	"	Lewis Van Doren	Old mill site				Power not used.
Branch below Roxiticus	Mendham township	Morris	S. J. Shurts	Saw	22	10	20	
Burnett Brook	Roxiticus	"	J. R. Nesbitt	Grist	24	25	40	
" "	Mendham township	"	Peter Cramer	Saw	12			Not in use.
" "	" "	"	James Able	Grist and saw	13	20	40	
Indian Brook	" "	"	James H. Lawry	Grist	24	50	82	
South Branch	South Branch	Somerset	Theodore Amerman	Flouring	6½	45	64	
" "	" "	"	" "	Saw	6½	10	20	
" "	Neshanic Station	"	Andrew Lane	Flouring	6' 10"	80	114	
" "	Riverside	"	G. C. Higgins & Bro.	"	5½	75	107	
" "	Three Bridges	Hunterdon	John C Hopewell's Estate	"	5	50	70	
" "	Flemington	"	Kershow & Chamberlain	Grist	5	40	60	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Raritan River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
South Branch	Stover's Mills	Hunterdon	Isaac Stover	Flouring	6	55	80	
" "	" "	"	" "	Saw	6	15	20	
" "	" "	"	" "	Flax	6	......	......	Not in use.
" "	Rowland Mills	"	Ellen Cokesfair	Grist	6	40	60	
" "	Sunnyside	"	L. Cramer	"	9	40	60	
" "	Hamden	"	C. V. Dilley	Flouring	8	40	60	
" "	"	"	M. C. Cramer	Grist	5	20	40	
" "	Clinton	"	E. V. Parry	Flouring	7½	40	60	
" "	"	"	Philip Gulick	Grist	7	40	60	
" "	High Bridge	"	Charles Conover	"	8⅓	23	40	
" "	" "	"	E. Doreland & Sons	Flouring	7½	80	110	
" "	" "	"	Taylor Iron Works	Foundry	14	210	800	
" "	" "	"	" " "	Forge	33	520	750	
" "	Readingsburgh	"	John Hockenbury	Saw	8	......	......	Not in use.
" "	"	"	G. W. Alpaugh	Flouring	14	108	140	
" "	"	"	" "	Saw	8	15	20	
" "	High Bridge township	"	Abram Hoffman	"	5	10	20	
" "	Califon	"	B. Cole	Grist	7⅓	25	40	
" "	"	"	" "	"	6⅔	25	40	
" "	"	"	" "	Feed	8	12	20	
" "	Tewksbury township	"	L H Trimmer	Grist	4½	25	50	
" "	Middle Valley	Morris	H. P. Dufford	"	6	35	60	
" "	German Valley	"	Henry Fleming	"	7	25	40	
" "	" "	"	Henry Weise	Saw	7⅓	15	30	
" "	Naughright	"	Andrew Dufford	Grist	3½	25	40	
" "	"	"	Jacob Naughright	"	5	15	25	
" "	Bartley	"	Wm. Bartley & Sons	Foundry and machine.	10	25	34	
" "	"	"	" " "	Saw	10	21	30	
" "	"	"	J. M. Conover	Flouring	14	33	54	
" "	"	"	Heirs of Joshua Solomon	Old Forge	......	......	......	Not in use.
" "	Mount Olive	"	Richard Stephens & Co.	Flouring	22	40	57	
" "	" "	"	" " "	Saw	33	45	75	
Holland's Brook	Readington	Hunterdon	Peter S. Nevius	Grist and saw	8	12	30	
Neshanic River	Hillsborough township	Somerset	J. E. Adams	Feed and wood	10	28	40	
" "	Clover Hill	Hunterdon	George Rae	Grist	9	36	90	

WATER-POWERS OF NORTHERN NEW JERSEY—Continued.

Raritan River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Neshanic River	Copper Hill	Hunterdon	William Hill	Feed and bone	6	36	60	
" "	Sand Brook	"	H. Moore	Grist	30	21	40	
" "	Grover	"	John C. Carrell	"	26	36	50	
Prescott's Brook	Allertown	"	Geo. Stryker	Grist and saw	14	16	40	
" "	Round Valley	"	Isaac P. Hoffman	Grist	18	24	40	
Hamden Branch	Hamden	"	Fanny Grant	Grist and saw	22	12	24	
Cakepoulin Creek	Sidney	"	Henry Dusenbury	Grist	15	35	50	
" "	"	"	Samuel Stevenson	Paint				Not in use.
" "	Kingstown	"	Archer Taylor	Grist	12½	24	48	
" "	Pittstown	"	William M. Taylor	"	16	12	20	
" "	"	"	Hiram Deats	Foundry and machineshop.	28	20	30	
" "	"	"	E. H. Deats	Saw	21	15	20	
" "	Littletown	"	Daniel Little	Grist	20	15	20	
Midvale Branch	Midvale	"	James Voss		15	10	20	
Beaver Brook	Annandale	"	Joseph Hampton	Grist	24	22	30	
Mulhockaway Creek	Union township	"	I. H. Butler	"	12	12	21	
" "	Pattenburgh	"	W. T. Bird & Bro	"	28	24	48	
Spruce Run	Union township	"	Joseph H. Exton	Saw	20	17	24	
" "	" "	"	" "	Flouring	24	40	57	
" "	Glen Gardner	"	T. Edgar Hunt	Peach baskets	22	35	50	
" "	" "	"	" " "		14			Not in use.
" "	" "	"	G. F. Painter	Grist	20	19	38	
" "	Clarksville	"	T. Frank Cawley	"	18	21	35	
" "	Newport	"	Benjamin Apgar	"	28	20	40	
" "	"	"	Isaiah Bryant	Saw	12	10	17	
" "	"	"	Josiah Apgar	Grist	21	24	40	
Branch at Schooley's Mt.	Schooley's Mountain	Morris	J. V. Stryker	Saw	15	8	20	
Drake's Brook	Flanders	"	D. G. Vliet	Grist	8	18	36	
" "	"	"	S. H. Dorland	Flouring	14	50	70	
" "	Drakesville	"	R. H. Cary	"	15	42	60	
Branch at Flanders	Flanders	"	H. M. Sovereign	Woolen	23	12	17	
" " "	"	"	P. A. Hoffman	Grist	31	33	55	

WATER-POWERS OF SOUTHERN NEW JERSEY.

Assanpink Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Assanpink Creek	Trenton	Mercer	Star Rubber Co	Rubber	12½	100	143	
" "	"	"	Whitehead Bros.	"	7	80	115	
" "	Lawrence Station	"	G. W. Davenport	Flouring and Grist	5	45	50	
" "	Windsor	"	Amos Hutchinson	Grist	10	45	70	
Miry Run	East Trenton	"	E. C. Hutchinson	Flouring	4	11	15	
" "	Mercerville	"	J. Reid	"	5	11	20	
" "		"	H. H. Hutchinson	Grist	12	25	35	

Crosswicks Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Crosswicks Creek	Groveville	Burlington	Wm. McK. Morris, Edw. J. Morris	Cotton factory	7	40	57	
" "	Crosswicks	"	—— Buzbee	" "	9	25	35	
" "	"	"	" "	Saw	9	15	22	
" "	Walnford	Monmouth	Miss S. Hendrickson	Grist	3	32	46	
" "	New Egypt	Ocean	Walter Lamb	Flouring	6	50	70	
" "	Hockamick	Burlington	Levi Parker	Saw	10	40	60	
" "	Brindletown	"	M. Hutchinson	"	12	30	45	
North Run	Cookstown	"	L. D. Woodward	Flouring	13	24	35	
" Branch	Near Wrightstown	"	Mrs. Annie Davis	Grist	12	25	33	
Back Creek	Yardville	Mercer	D. S Hutchinson	Flouring	22	36	55	
Doctor's Creek	"	"	C. Hutchinson	"	10	35	50	
" "	"	"	" "	Saw	10	30	50	
" "	Allentown	Monmouth	J. Darnell & Bro.	Flouring	9	35	50	
" "	"	"	A. Cafferty	"	10	25	36	
" "	Imlaystown	"	Reuben Hendrickson	"	10	25	36	
" "	Red Valley	"	J. Dawes	Grist	10	20	30	
Branch at Crosswicks	Crosswicks	Burlington	—— Buzbee	Plaster	9	30	45	
Cream Ridge Branch	Cream Ridge	Monmouth	—— Kirby	Grist	10	20	30	
Lahaway Creek	Hornerstown	"	E. Emson	"	8	25	36	
" "	"	"	" "	Saw	8	10	15	
" "	Prospertown	"	" "	Flouring	9	35	50	

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Crosswicks Creek and Branches—Continued.

Stream.	Locality.	County.	Owner.	Kind of Mill.	Fall.	H. P. Utilized. Net.	H. P. Utilized. Gross.	Remarks.
Lahaway Creek	Prospertown	Monmouth	E. Emson	Saw	9	15	20	
" "	Lahaway Plantation	Ocean	A. Van Hise	"	5	10	15	
Branch at New Egypt	New Egypt	"	Chas. Cannon	Flouring	20	17	24	

Black's Creek and Branches.

Stream.	Locality.	County.	Owner.	Kind of Mill.	Fall.	H. P. Utilized. Net.	H. P. Utilized. Gross.	Remarks.
Black's Creek	Bordentown	Burlington	M. L. Dunn	Flouring and grist.	12	35	50	
" "	Recklesstown	"	C. C. Stillwell	Grist	13	30	45	
" "	"	"	Chas. E. Wallace	Flouring and grist.	8½	30	45	
Kinkora Creek	Three Tuns	"	David Ashby	Grist	9	17	25	
" "	Columbus	"	—— Kirlin	Saw	5	8	12	

Assiscunk Creek and Branches.

Stream.	Locality.	County.	Owner.	Kind of Mill.	Fall.	H. P. Utilized. Net.	H. P. Utilized. Gross.	Remarks.
Branch at Deacon's	Burlington	Burlington	Edw. & Geo. Riggs	Grist	9	17	25	

Rancocas Creek and Branches.

Stream.	Locality.	County.	Owner.	Kind of Mill.	Fall.	H. P. Utilized. Net.	H. P. Utilized. Gross.	Remarks.
Mill Creek	Charleston	Burlington	M. Pricket	Grist	8	25	35	
North Branch Rancocas	Mount Holly	"	Richard C. Shreve	Flouring	8	71	100	
" " "	" "	"	" "	Saw, sash and blind	7	30	45	
" " "	Smithville	"	Smith Estate	Machinery	7	135	200	
" " "	Birmingham	"		Mill site				Pleasure gr'ds.
" " "	Pemberton	"	Anthony J. Morris	Flouring	7¼	60	80	
" " "	"	"	" "	Saw	7¼	10	20	
" " "	New Lisbon	"	Eayre Oliphant	Grist	9	21	40	
" " "	" "	"	" "	Saw	9	10	20	

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Rancocas Creek and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
North Branch Rancocas	Brown's Mills	Burlington			9			Pleasure gr'ds.
" " "	Hanover Furnace	"	Lawrence Pepper		10			Not in use.
Birmingham Branch	Pemberton	"	Wm. Williams	Grist	8	20	30	
Mount Misery Brook	Mary Ann Furnace	"	Geo. B. Upton	Mill site	8			Cranberry bog.
" " "	Mount Misery	"	" "	" "	8			Not in use.
Lower Mill Branch	Lower Mill	"	Alfred L. Black	Saw	7	15	30	
" " "	Upper Mill	"		Mill site				Not in use.
South Branch Rancocas	Eayrstown	"	Sarah B. Githens	Flouring	8 }	70	100	
" " "	"	"	" "	Saw	8 }	15	20	
" " "	Vincentown	"	John S. Irick	Flouring	8 }	70	100	
" " "	"	"	" "	Saw	8 }	15	20	
Mason's Creek	Union Mills	"	H. Darnell	Grist-mill site				Not in use.
Haynes' Creek	Wilkins' Station	"	Kirby Bros.	Flouring	7 }	50	75	
" "	" "	"	" "	Saw	7 }	12	18	
" "	Medford	"	Jos. C. Hinchman	Grist	11 }	23	33	
" "	"	"	" "	Saw	11 }	15	25	
" "	Ballinger's Mills	"	" "	Grist	24	18	30	
Kettle Run	Taunton	"	" "	Cranberry cleaning	9	12	20	
" "	Braddock's Mills	"	Edw. Braddock	Saw	17	15	25	
Barton's Run	Jennings' Mill	"	Wm. Tomlinson	Flouring and grist	11	23	33	
" "	Milford	"	M. Powell	Grist	10	12	20	
" "	Near Milford	"	Jos. Evans	Saw	9	18	30	
Burr's Mill Branch	Burr's Mills	"	John S. Irick	"		10	15	
Friendship Creek	Friendship	"	Albert Jones	Saw-mill site				Not in use.

Swedes Run.

Swedes Run	Fairview	Burlington	Haines Bros.	Flouring and grist	12	25	37	
" "	Chesterville	"	Wm. Buckman	Grist	9	17	25	

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Pompeston Creek.

Stream.	Locality.	County.	Owner.	Kind of Mill.	Fall.	H. P. Utilized. Net.	H. P. Utilized. Gross.	Remarks.
Pompeston Creek	Parry	Burlington	H. Lippincott	Saw	9	15	22	

Cooper's Creek.

Stream.	Locality.	County.	Owner.	Kind of Mill.	Fall.	H. P. Utilized. Net.	H. P. Utilized. Gross.	Remarks.
North Branch	Marlton	Camden	Hopkins Estate	Grist	12	(8)	....	Not in use.
Cooper's Creek	Haddonfield	"	Jos. G. Evans	"	11	30	43	
" "	Kirkwood	"	Knickerbocker Ice Co.	"	18	50	70	
" "	Gibbsborough	"	—— Lucas	"	8	30	45	
	"	"	—— Blakely	Saw	8	20	33	
Branch at Haddonfield	Haddonfield	"	Hopkins Estate	Grist	22	....	....	Not in use.
Tindale's Run	"	"	Wilson Ice Co.		15	....	....	" "
Branch	Near Ashland	"	Joseph Kay	Grist mill site	24	....	....	" "

Newton Creek.

Stream.	Locality.	County.	Owner.	Kind of Mill.	Fall.	H. P. Utilized. Net.	H. P. Utilized. Gross.	Remarks.
Main Branch	Cuthbert's	Camden	J. J. Schuetzius	Flouring	14	30	45	
" "	Westmont	"	James Flynn	Paint and varnish	15	22	31	

Timber Creek and Branches.

Stream.	Locality.	County.	Owner.	Kind of Mill.	Fall.	H. P. Utilized. Net.	H. P. Utilized. Gross.	Remarks.
North Branch	Laurel Mills	Camden	E. Tomlinson	Grist	12	50	70	
" "	Clementon	"	Theodore Gibbs	"	10	36	60	
Almonesson Creek	Almonesson	Gloucester	John Kennedy	"	18	35	50	
South Branch	Good Intent	Camden	J. Livermoor and others	"	11	22	30	
" "	Grenloch	"	E. S. & F. Bateman	Agricultural implements	14	100	145	
" "	Prosser's Mills	Gloucester	Thos. Boody	Grist	10	25	45	

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Timber Creek and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
South Branch	Turnersville	Gloucester	—— Turner	Saw	10	14	20	
Little Lebanon	"	"	A. W. Nash	Grist	10	36	50	
" "	Near Turnersville	"	J. Prosser	Saw	10	32	45	

Mantua Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Mantua Creek	Near Hurffville	Gloucester	S. O. Bricket	Grist	13	25	42	
" "	Dilkesborough	"	Thos. Reeves	"	15	25	42	
Edwards' Run	Near Mantua	"	Chas. Jessop	"	12	30	42	
" "	" "	"	Samuel Boody	"	12	15	25	
Chestnut Branch	" Barnsboro	"	P. Avis	"	15½	20	28	
" "	Pitman Grove	"	G. W. Carr	Saw, sash and blind	6	30	45	
Wenonah Branch	Near Wenonah	"	The Wenonah Water Co	Creamery	17	4	6	
Monongahela Brook	" "	"		Mill site	10	(15)		Not in use.
Dilkesborough Branch	Dilkesborough	"	W. Jessop	Saw mill	10	15	20	

Repaupo Creek.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Purgey Brook	Tomlin's Station	Gloucester	Simeon Warrington	Grist	13	24	35	

Little Timber Creek.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Little Timber Creek	Near Asbury Station	Gloucester	H. B. Hendrickson	Saw and distillery	10	20	30	

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Raccoon Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Raccoon Creek	Mullica Hill	Gloucester	J. Mount	Grist	12	30	45	
" "	Ewan's Mill	"	D. B. Brown	"	10	20	35	
Swedesboro Branch	Swedesboro	"	B. H. Black	Flouring	18	50	70	
" "	Near Swedesboro	"	David Russell	Grist	15	25	42	

Oldmans Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Oldmans Creek	Harrisonville	Salem	(?)	Grist	16	50	75	
" "	Avis Mills	"	Paul H. Avis & Son	"	12	30	45	
" "	" "	"	" " "	Saw	12	10	15	
Oldmans Creek Branch	Near Harrisonville Station	Gloucester	Geo. Robinson	Grist	16	18	24	
" " "	" " "	"	——— Vanderbilt	"	20	12	20	

Salem Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Salem Creek	Sharptown	Salem	A. Oliphant	Grist	7	20	33	
" "	Woodstown	"	I. L. Davenport	Flouring	10	34	50	
" "	East Lake	"	J. Webster	"	12	40	57	
" "	Richmanville	"	J. McCoster	"	16	30	50	
" "	Paulding	"	Wood Bros.	Saw and plaster	10	30	43	
" "	Daretown	"	Fox Bros.	Grist	14	16	23	
Two Penny Run	Upper Penn's Neck	"		Mill site	7	....	....	Not in use.

Alloways Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Alloways Creek	Alloway	Salem	Diament & Bro.	Flouring	14	56	80	
Deep Run Branch	Near Alloway	"	Wm. Elkin	Grist	12	30	50	
" " "	" "	"	Jacob House	Saw	10	15	22	
" " "	Friesburg	"	C. Dilkes	"	10	15	22	

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Alloways Creek and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Cedar Brook	Near Alloway	Salem	J. Hitchnor	Grist	10	25	36	
Cool Run	" Aldine	"	J. Watson	Saw	12	12	17	
" "	Aldine	"	S. R. Ballinger	Grist	14	35	60	
Daretown Branch	Yorktown	"	David Harris	"	13	20	30	

Stow Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Upper Branch	Maskell's Mill	Salem	Maskell Estate	Grist	9	30	42	
" "	Near Berry's Chapel	"	Mrs. Ad. Sinnickson	Flouring	18	40	60	
Bishop's Run	" Jericho	"	D. Harris	Grist	13	22	30	
Horse Run	Jericho	"	Mrs. Dr. Clark	"	11	25	36	
" " Branch	Near Jericho	"		Saw	12	20	30	
Newport Creek	Roadstown	Cumberland	I. M. Smalley	Grist	16	40	57	

Cohansey Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Cohansey Creek	Bridgeton	Cumberland	R. Lott Estate	Flourinig	16 }	30	45	
" "	"	"	Cumberland Iron Co	Nails and iron pipe	14 }	100	150	
" "	Cedar Grove	"	Robt. Moore, Frank Barker	Saw and grist	8	35	60	
" "	Deerfield	"	D. Harris	Grist	12	25	36	
Mill Creek	Sheppard's Mill	"	H. J. Young	Flouring	14	20	30	
Barrett's Run	Near Bridgeton	"	Cumberland Iron Co	Saw-mill site	...	...	...	Not in use.
Mill Creek	Fairton	"	Theodore Trenchett	Flouring	17½	50	70	
Branch at Bridgeton	East Bridgeton	"	Jonathan Elmer	"	20 }	50	80	
" " "	" "	"	East Lake Woolen Co	Saw	20 }	25	50	
Loper's Run	Bridgeton	"	——— Minch	Grist	18	20	30	
Parsonage Branch	Cedar Grove	"	——— Hand	Grist and saw	8	20	30	

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Cedar Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Cedar Creek	Cedarville	Cumberland	C. O Newcomb	Flouring	12	50	70	
" "	Lummistown	"	Fredk. Lummis	Saw	10	15	20	
" "	"	"	Clarence B. Lummis	Grist	8	15	20	

Nantuxent Creek.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	Net.	Gross.	REMARKS.
Nantuxent Creek	Newport Station	Cumberland	Peter Henderson, Luke Bateman	Grist	13	20	30	

Dividing Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	Net.	Gross.	REMARKS.
Dividing Creek	Near Mauricetown Station	Cumberland	Jas. Reeves	Grist	4½	15	22	
Mill Creek	Dividing Creek	"	Peter Ladew	Saw	7	20	30	

Maurice River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	Net.	Gross.	REMARKS.
Maurice River	Millville	Cumberland	Millville Manufacturing Co.	Water works	22	40	60	These powers are all on one dam and raceway.
" "	"	"	" " "	Flouring	22	40	60	
" "	"	"	" " "	Blacking mill	22	50	70	
" "	"	"	" " "	Foundry	22	60	85	
" "	"	"	" " "	Bleachery	22	100	145	
" "	"	"	" " "	Cotton factory	22	400	575	
" "	Willow Grove	"	C. P. & T. C. Fox	Flouring	5½	52	75	
" "	" "	Salem	Case Brothers	Saw	5	36	70	
" "	Iona	Gloucester	J. L. Buffield	Flouring	6½	13	22	
Manantico Creek	Clark's Mill	Cumberland	(?)	Grist-mill site	6			Not in use.
Manumuskin Creek	Fries' Mill	"	John Fries	Grist	8	12	20	
" "	" "	"	" "	Saw	8	10	20	

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Maurice River and Branches—Continued.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Manumuskin Creek	Cumberland	Cumberland	R. D. Wood & Co	Saw	9	20	40	
Muskee Creek	Leesburg	"	John Russell	"		5	10	
Clear Run	Bricksboro	"	" "	Grist		(12)		Not in use.
Buckshutem Creek	Buckshutem	"			6			Old forge site.
Muddy Run	Bradway Station	Salem	Ackley & Garrison	Saw		25	40	
" "	Union Grove	"	—— Ackley	"		80	60	
" "	Centerton	"	J. R. Fitzhugh	Shoe factory and grist	5½	66	110	
" "	Palatine	"	Estate Geo. Fox	Grist	8	25	45	
" "	"	"	" " "	Saw	8	10	20	
" "	Elmer	"	Robert K. Greenwood	"	5½	12	24	
" "	"	"	W. W. Johnson	Flouring	6½	38	55	
Scotland Run	Malaga	"	A. K. Richmond & Bro	"	6½	25	45	

West Creek.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
West Creek	West Creek	Cape May	Wm. G Nixon	Saw-mill site	6	(20)		Not in use.

Streams in Cape May County.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
East Creek	West Creek	Cape May	Charles Hand	Saw and grist	6	20	28	
Dennis Creek	South Dennisville	" "	—— Ludlam	Grist	5	15	22	
Branch west of Dennisville	Dennisville	" "	—— James	Saw	5	15	22	
Branch at Dennisville	"	" "	—— Edwards	Grist	5	15	22	Tide mill.
Sluice Creek	South Dennisville	" "	Jos. L. Hand, L. D. Smith	Saw	6	15	22	
Fishing Creek	Nummytown	" "	Hildreth Estate	Grist	5	15	22	
Cape Island Creek	Cold Spring	" "	" "	Saw	5	15	25	Tide mill.
Mill Creek	South Seaville	" "	Van Gilder Estate	Grist and saw	6	15	22	

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Great Egg Harbor River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Great Egg Harbor River	Mays Landing	Atlantic	Mays Landing Water-Power Co	Cotton goods	10	312	490	
" " " "	Weymouth	"	Charles R. Colwell	Paper mill	13	70	100	Not in use.
" " " "	"	"	" "	Saw	13	30	60	" "
Tuckahoe River	Head of River	Cumberland	....	Grist and saw	5	....	....	Old tide mill; not in use.
" "	Hunter's Mill	"						
Cedar Swamp Creek	Near Mount Pleasant	Cape May	—— Steelman	Grist and saw	6	10	15	
Branch of Tuckahoe	" Marshallville	" "	R. W. Godfrey	" " "	4½	10	15	
" " "	" "	" "	John Wallace	" " "	4½	10	15	
Stephen's Creek	Estellville	Atlantic	—— Steelman	Grist	6	15	22	
" "	"	"	Estell Estate	Saw	6	15	22	
South River	Monroe Forge	"	John Walker	Grist and saw	....	(50)	....	Not in use.
" "	Richland	"	—— Smith	Saw	6	10	15	
Deep Run	"	"	—— Pancoast	"	5	12	18	
Hospitality Branch	Cedar Lake	"	Binomen Estate	"	5	15	25	
Patcong Creek	Bargaintown	"	Atlantic City W. W. Co.	Grist	5½	15	22	
" "	"	"	" " " "	Saw	6	15	22	
English "	English Creek	"	Baker & Thompson	Grist	9	15	25	
" "	" "	"	" "	Saw	9	10	16	
Gravelly Run	Gravelly Run	"	Judge Abbott	"	5	15	25	
" "	" "	"	—— Tream	"	7	15	25	
Babcock Creek	Mays Landing	"	Charles R. Colwell	Saw-mill site	....	(50)	....	Not in use.

Absecon Creek.

Absecon Creek	Near Absecon	Atlantic	A. Doughty	Grist	5	30	45	
" "	Doughty's Mill	"	" "	Saw	5	30	45	

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Doughty's Creek.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Doughty's Creek	Oceanville,	Atlantic		Mill site	9			Not in use.

Mullica River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Mullica River	Atsion	Atlantic	Jos. Wharton	Grist	9			Not in use.
" "	"	"	" "	Cotton mill	9			" "
Nacote Creek	Port Republic	"	Dr. Pitney	Grist	7	20	30	
" "	" "	"	" "	Saw	7	20	30	
Gloucester Lake	Near Gloucester	"	Gloucester Land Co.	"	10			Not in use.
Hammonton Creek and Atsion River	Pleasant Mills	"	Pleasant Mills Paper Co.	Paper	10	150	200	
Hammonton Creek and Atsion River	Near Hammonton	"	Chas. Weatherbee	Saw	10	20	30	
Batsto River	Batsto	Burlington	Jos. Wharton	Grist	8	12	20	
" "	"	"	" "	Saw	9	20	30	
Muskingum Brook	Indian Mills	"	Jos. Thompson	Grist	14	25	40	
" "	" "	"	A. Woolman	Saw	10	20	33	
Bass River	Bass River	"	The Misses Page	"	8½	30	45	
Wading River	Harrisville	"	Harris & Herrington	Paper	12	225	320	
" "	Speedwell	"	Mrs. Jas. Lee	Old furnace	8	(40)		Not in use.
Governor's Hill Branch	Jones' Mill	"	Jones Estate	Saw	9½	12	18	
West Branch	Near Shamong	"		Old forge site				Not in use.
Oswego River	Martha	"	Harris & Herrington	Saw	12½	(75)		" "
Bull Creek	Herman	"	Johnson Estate	Grist	8	12	18	
" "	"	"	" "	Saw	8	12	18	
Lower Bank Branch	Lower Bank	"	Saml. Weeks Estate	Saw-mill site	8¼	(25)		Not in use.
Ives' Branch	Bridgeport	"	Mrs. Ellen Cramer	Grist and saw-mill site	8	(25)		" "

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Tuckerton Creek.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Tuckerton Creek	Tuckerton	Burlington	W. W. Pharo.	Flouring	7	50	70	
" "	"	"	"	Saw	7	20	35	

Small Coast Streams of Ocean County.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
West Creek	West Creek	Ocean	Chas. Holman	Saw-mill site	6¼			Not in use.
Cedar Creek	Cedar Run	"	—— Holmes	Saw	6	15	25	
Mill Creek	Manahawken	"	S. T. Oliphant	Flouring	8	40	58	
" "	"	"	" "	Saw	8	18	24	
Waretown Creek	Waretown	"	—— Holmes	Grist	8	25	35	
Oyster Creek	Wells' Mills	"	Jesse Estlow & Bro.	Saw	7	20	40	
Forked River	Forked River	"	Holmes Estate	Saw and grist	8½	25	35	
North Branch of Forked River	Near Forked River	"	J. Falkinburgh	Saw	8	25	85	

Cedar Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Cedar Creek	Double Trouble	Ocean	Capt. Geo. Gibberson	Saw	6	40	60	
" "	Dover Forge	"	N. Austen	"	7	30	42	
Middle Branch	Bamber	"	Wm. Harvey	"	9	40	60	
Webb's Mill Branch	Webb's Mill	"	Thos. Hooper Estate	Saw-mill site		(15)		Not in use.

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Toms River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Toms River	Toms River	Ocean	J. Aumack	Grist	6	26	38	
" "	Francis' Mills	"	J. J. Allen	Saw and grist	10	50	80	
" "	Carr's Tavern	"	R. & J. De Bow	Saw	7	22	30	
Jake's Branch	Near Toms River	"	——— Giberson	Box factory	6	20	40	
Davenport's Branch	" " "	"	D. C. Van Scholck	Saw and turning	8	25	35	
Wrangel Brook	Giberson's Mills	"	Estate of Jas. Giberson	Saw	8	15	22	
Union Branch	Manchester	"	J. S. Schultz	Bagging	14	58	80	
Borden's Mill Branch	Collier's Mills	"	E. Emson	Saw	8	15	22	
Branch at Cassville	Cassville	"	A. Van Hise	Saw and planing	8	40	66	

Kettle Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	Net.	Gross.	REMARKS.
Polhemus Brook	Silverton	Ocean	J. P. Haines	Saw	7	(15)	....	Not in use.
Main Branch Kettle Creek	Near Cedar Bridge	"	David C. Clayton, Reuben Irons	Grist and saw	7	17	34	

Metedeconk River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	Net.	Gross.	REMARKS.
Metedeconk River	Burrsville	Ocean	Lakewood Land Co.		9	....	....	Not in use.
North Branch	"	"	Tunis Lane	Grist	8	18	25	
Polipod Branch	Near Bethel	Monmouth	C. H. Lane	Saw	7	12	17	
North Branch	Georgia	"	Dr. Johnson	"	6	12	24	
South "	Lakewood	Ocean	Lakewood Electric Light and Water Co.	Electric light and water works	9	120	170	
" "	Bennett's Mills	"	Harry Appleget	Grist	9	49	70	
" "	" "	"	" "	Saw	9	15	22	
" "	Jackson's Mills	"	Matthew Estate	"	7	18	25	
" "	Near Siloam	"	Thos. Thompson	"	6	15	30	

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Manasquan River and Branches.

Stream.	Locality.	County.	Owner.	Kind of Mill.	Fall	H. P. Utilized. Net.	H. P. Utilized. Gross.	Remarks.
Manasquan River	Squankum	Monmouth	—— Crickett	Grist and canning	9	35	50	
" "	West Farms	"	Henry V. Layton	Grist	10	32	46	
" "	Turkey	"	J. & P. M. Wyckoff	Flouring	8	30	45	
" "	"	"	" "	Saw	8	15	22	
Branch at Herbertsville	Herbertsville	"		"	5	15	25	
" south of Turkey	"	"	Levi G. Irvin	"	10½	20	30	
Mingumhoue Brook	Farmingdale	"	I. Van Note	"	9	18	25	
Branch east of Fairfield	Fairfield	"	Wm. Maps	"	10	20	30	
" at Turkey	Turkey	"	Chas. Hall	Grist	9	20	30	

Wreck Pond and Branches

Stream.	Locality.	County.	Owner.	Kind of Mill.	Fall	Net.	Gross.	Remarks.
Wreck Pond	Near Bailey's Corners	Monmouth	Mrs. Chas. Osborn	Grist	6	10	14	
Great Branch	Bailey's Corners	"	Abr. Osborn	Saw	6	10	14	
" "	Near New Bedford	"	J. W. Border	"	8	10	20	

Shark River and Branches

Stream.	Locality.	County.	Owner.	Kind of Mill.	Fall	Net.	Gross.	Remarks.
Shark River	Shark River	Monmouth	Remsen Estate	Flouring	10	....	....	Not in use.
" "	Near Shark River Station	"	Monroe Shafto	Saw	8	15	22	
" " Branch	" " " Village	"	Bowman Kisner	Grist	10	15	25	

Whale Pond and Branches.

Stream.	Locality.	County.	Owner.	Kind of Mill.	Fall	Net.	Gross.	Remarks.
Whale Pond Branch	Deal	Monmouth	Long Branch Water Co	Flouring	9⅛	18	26	
Cranberry Brook	Poplar	"	Edward Wheeler	Old mill-site (saw)	10	....	....	Not in use.

WATER-POWERS OF SOUTHERN NEW JERSEY—Continued.

Shrewsbury River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Pleasure Bay	West Long Branch	Monmouth	G. F. Baker	Grist	7	....	....	Not in use.
Parker's Creek	Eatontown	"	J. Johnson	"	12	20	30	

Navesink River and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Swimming River	Scobeyville	Monmouth	Van Mater & Muhlenbrink	Grist	10	25	40	
Yellow Brook	Colts Neck	"	Frank Heyer	Saw	13	46	66	
" "	" "	"	Wm. C. Buck	Grist	9½	33	47	
Hockhockson Brook	Tinton Falls	"	S. J. Bennett	Flouring	28 }	35	50	
" "	" "	"	" "	Saw	28 }	15	22	
Pine Brook	" "	"	D. H. Cook	"	8	(15)	....	Not in use.
Colts Neck Branch	Colts Neck	"	Schneider & Gaskell	Grist	21	28	40	
Hop Brook	Edinburgh	"	Estate of Chas. Taylor	"	9	(30)	....	Not in use.
" "	Marlboro	"	Peter D. Stillwell	"	16	25	36	
Willow Brook	Holmdel	"	Thos. Ely	"	15	45	65	

Waycake Creek and Branches.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Waycake Creek	Near Keansburg	Monmouth	A. L. Phillips	Saw and flouring	11	30	45	
Mahoras Brook	Middletown	"	Chas. Allan	Flouring	8	25	36	

Flat Creek.

STREAM.	LOCALITY.	COUNTY.	OWNER.	KIND OF MILL.	FALL.	H. P. UTILIZED. Net.	H. P. UTILIZED. Gross.	REMARKS.
Flat Creek	Near Mechanicsville	Monmouth	Anna Walling	Grist	6½	(20)	....	Not in use.

ARTESIAN WELLS.

The annual reports of the Geological Survey since 1878 have had many notes on the artesian wells in the State, and in that for 1890 a list of the wells and the references to notices in the various reports were given.* The space devoted to the subject annually has scarcely been equal to the development of the artesian well as a means of getting water-supply in the State, but the information, though scanty and fragmentary in its nature, has apparently been productive of good, and the inquiries addressed to the office of the Survey and the demand for its reports on artesian wells, have attested the importance of early publication of all data available from these well borings.

The rapid increase in population, even in the suburban cities and towns and villages, has been surpassed by the growth of public water systems. Already the greater number of the towns in the State are thus supplied, and are no longer dependent upon the common dug well or the driven well for water. The increased attention to sanitary arrangements promotes the growth of public water systems. In the smaller towns and villages, where the cost of aqueducts is perhaps beyond the financial ability of the place, the artesian well is tried. Isolated manufacturing and other establishments which require large volumes of water, or which desire to get it at less cost, are everywhere discussing the problem, and particularly its possible solution, by recourse to boring.

Several firms in the State, and others outside, are engaged much of the time in putting down wells for these parties and for towns. The success which has followed generally is encouraging and suggestive, and there appears to be an increasing number of artesian wells bored each successive year.

The study of the geological structure, particularly of the southern

*Annual Report State Geologist, for 1890, pp. 277–283.

part of the State, has proved to be of great service in finding water-bearing horizons within practicable distance from the surface. A remarkable horizon for water is that at the base of the lower marl-bed, and it furnishes great volumes of water at several places in the coastal plain. A more careful comparative study of the structure and of the known water horizons, will, no doubt, show the existence of other well-defined horizons in the marl series. The artesian wells have, in turn, yielded most valuable data to geology and have verified the conclusions of geological science in a remarkable degree. Much more is hoped for from wells yet to be put down, and it is proper to state in this connection that the complete solution of the problems of geological structure in the southeastern part of the State will come after deep wells have shown the order of succession and the thickness of the several beds. A rich harvest of results is anticipated from the careful study of records from artesian wells in that part of the State. In view of the importance of data from them, the preservation of the records of the nature and thickness, and of illustrative specimens of the various marls, clays, sands, gravels and fossils found in them, is a most important matter. The attention of our well borers is called to this subject at this time, as also that of property-owners who are having wells put down. The value of such data to the geologist is here emphasized. On the other hand, the further study of the geologist and the elucidation of the geological structure will lead to valuable data to aid and guide the practical man in search of good water and of water-bearing horizons.

No systematic attempt has been made this year to collect all of the well data. A few notes of wells which have been visited, or of which information has been furnished to the Survey, are here presented. Mr. Woolman has occupied a part of the field, and has made a special report, beginning on page 223 following.

PASSAIC TOWNSHIP, MORRIS COUNTY.

1. An artesian well was put down several years ago on the Van Wagoner farm, one mile north-northwest of Long hill, by Mr. Oscar Lindsley. The size of bore was three inches in diameter, and the depth 78 feet. The work stopped at that depth, where the rock was struck.

2. In summer of 1891 Mr. Lindsley had a well sunk on his farm, near Green Village, to depth of 152 feet. Size of bore, six inches.

Earth, &c.	22 feet.
Sandstone	130 "

At 138 feet a stream of water with quicksand was met with which rose to a point six feet below the surface.

RUMSON NECK, MONMOUTH COUNTY.

An artesian well was put down last season on Rumson Neck, near the corner of the ridge road and Bellevue avenue, for a water-supply to the residents of the vicinity. The surface at the well has an altitude of 80 to 90 feet above tide-level. The beds passed through in boring were reported by Uriah White to be the following:

		Depth.
1. Top earth	31 feet.	31 feet.
2. Marl	55 "	86 "
3. Shells and sand	6 "	92 "
4. Hard strata	3 "	95 "
5. Gray sand	5 "	100 "
6. Marl or clay	50 "	150 "
7. Sand	40 "	190 "
8. Clay, with thin sand seams	20 "	210 "
	210 "	

A subsequent examination of the specimens which were sent to the Survey office by Mr. White, showed that there was more or less greensand in them to a depth of 95 feet. Below that horizon the specimens show more mica and a gray sand. As the well is about two miles southeast of the line of strike of the tide-level horizon of the lower marl-bed, and the dip of this bed is at rate of 37 feet per mile, the marl would be at about 75 feet below tide-level, or at depth of about 160 feet. The water is obtained from a sand-bed below the lower marl-bed and in the clay-marl series. The pumping capacity of the well is 60 gallons per minute.

Leach Brothers, of Glassboro, report the following wells bored by them in the State in 1891:

"Three at WINSLOW—(1) 135 feet deep, for Geo. Cochran; (2) 145 feet deep, Winslow Inn; (3) 85 feet deep, for Capt. Jewett; flow, 1,200 gallons per hour, each. No marl in these wells.

"Eight wells at PITMAN GROVE, from 60 to 80 feet deep, all above the marl, for the Pitman Grove Association, each one yielding from 1,000 to 2,000 gallons of water per hour.

"One well at SEWELL, for F. J. Anspach, 420 feet deep, pumping 1,500 gallons an hour.

"One at RICHWOOD, for the public school, 65 feet deep, water in red gravel, furnishing 2,500 gallons per hour.

"Five for the West Jersey Railroad Company, at GLASSBORO (these are gang wells), 70 to 80 feet deep, and furnish 6,000 gallons per hour. They are above the marl, as the marl is at 88 feet. At Richwood the marl was found at 78 feet.

"At Pitman Grove the marl was found at 96 feet, and was prospected to a depth of 130 feet, to conglomerate, when the work was stopped and water was taken from the stratum above the marl."

These notes are interesting and suggestive in relation to geological structure. The Pitman Grove well-section corresponds to what would be expected from the known dip of marl-beds to the southeast. But the marl at Glassboro is too high for the horizon of the middle bed and is in position to be the upper bed. As Clementon is the southwestern limit of this bed, so far as known, the identification of the upper bed at this depth in the Glassboro wells extends its limit. The study of a good section at this place appears to promise important facts bearing upon the relations of the Cretaceous marl-beds to the succeeding Tertiary series. A good well-section in the vicinity of Glassboro or Clayton would be productive of valuable scientific results.

WOODSTOWN, SALEM COUNTY.

A well was bored at Woodstown, in December, 1891, by Kisner & Bennett, of Belmar. The site is in the low ground near the creek, where the surface is about 30 feet high above tide-level and near the outcropping middle marl-bed. The strata penetrated in this well are reported to be as follows:

TOTAL DEPTH.	THICKNESS OF BEDS.	BEDS.
4′	4′	Meadow Earth.
16′	12′	Gravel and Limestone.
56′	40′	Greensand Marls. Shells near bottom.
126′	70′	Gray, Coarse Sand. (No water.)
186′	60′	Quicksand, with flakes of Mica.
246′	60′	Black, Sand Marl.
276′	30′	Black, Muddy Quicksand.
296′	20′	Blue Clay—Hard and tough.
340′	44′	White Sand with Lignite, Water-bearing. White Clay. Red Clay.

VERTICAL SECTION OF WELL, WOODSTOWN.

The gray limestone, under the surface earth and gravel, belongs to the middle marl-bed; the total thickness amounts here to 52 feet. The coarse, gray sand and the quicksand are identified as the red-sand bed, though of great thickness. The micaceous quicksand corresponds to the clay which occurs over the lower marl-bed at many localities. The "black, sand marl," 60 feet thick, of the well-section, also appears to be abnormally thick if it be the lower marl-bed. But it is probable that the lower part of this black, sand marl and the "black, muddy quicksand" represent the clay marls which underlie the marl-bed. The white sand corresponds to the laminated sand of the plastic-clay series. At the bottom the red clay is recognized as the top of the plastic-clay series.

This well is, therefore, interesting as a measure of the thickness of the greensand-marl series from the top of the middle bed to the plastic clays. The well-section has a thickness of 336 feet, which corresponds with the 352 feet, the aggregate thickness as determined by a comparison of vertical sections at different localities.*

The wells not noted in previous reports of the Survey, are:

PORT NORRIS, CUMBERLAND COUNTY.

Depth, 78 feet; strata, sand and clay; good water, slightly tinctured with iron; rises 2 feet above the surface; flow, about 1 gallon a minute; four-inch pipe; contractor, Caleb Risley, of Woodbury.

STRAIGHT CREEK, CUMBERLAND COUNTY.

There is a well on the tide meadows, near False Egg Island point, about 100 feet deep. A flowing well of good water.

PORT REPUBLIC, ATLANTIC COUNTY.

Well of Capt. E. W. French, 151 feet deep. Soft water, flowing to surface.

* See "Geology of New Jersey," Newark, 1868, p. 246.

A REVIEW OF ARTESIAN-WELL HORIZONS IN SOUTHERN NEW JERSEY.

With Notes of New Wells in New Jersey, Delaware and South Carolina, and also in Philadelphia, Pa.

BY LEWIS WOOLMAN.

In an article in the annual report for last year (1890), the writer demonstrated that within a triangular area bounded by the ocean, Delaware bay and a somewhat irregular line drawn from the mouth of Forked river southwestwardly to the bay, so as to include within and near its margin Barnegat, Hammonton, Vineland, Bridgeton and Shiloh, there exists beneath and between a succession of impervious beds, mostly clays, a number of porous sands and gravels capable of furnishing by means of artesian wells a plentiful supply of good water that will either overflow or rise more or less nearly to the surface according to the elevation of the same.

These water-yielding horizons, of which four are now known and there are possibly more, are higher stratigraphically than those supplying the artesian wells upon and near the coast from Spring Lake to Sandy Hook.

The first or uppermost of the four horizons underlies Cape May county and probably the southeastern portion of Atlantic county. Its position was deduced from the study of wells at Sea Isle City. Its persistence, with the occurrence, perhaps, of a still higher horizon, has been shown the present year by the sinking of three wells at Milford, Delaware, to depths of 35, 150 and 160 feet, and which tap two water-yielding sources. The extension of these horizons beneath the two States and their equivalency is treated more in detail in the report of the Milford wells. (See page 227.)

The other three horizons are probably continuous, one below the other, under the entire triangular area noted. The upper two of these, or the second and third of the four described, are intimately associated with a series of fine but hard clays, sandy clays and clayey sands, having a thickness, as shown by Atlantic City borings, of over

300 feet, occurring there between the depths of 382 and 697 feet, and ascertained by careful microscopical examination to contain throughout nearly every foot of vertical extent the minute siliceous remains of diatoms, a low order of plant life, each individual form of which is composed of a single cell. As may be inferred, these are entirely invisible without the aid of considerable magnifying power. Practically this series of strata comprises one bed, which may be termed the *diatomaceous clay-bed.*

A reproduction of a microphotograph of these forms magnified 90 diameters is shown upon the accompanying plate.* The species in this deposit are marine. Diatoms when living consist of two valves of pure silica inclosing a brownish gelatinous substance, the valves being connected around their edges by two or more bands, which generally, though not always, fit over one another like the parts of a pill-box.

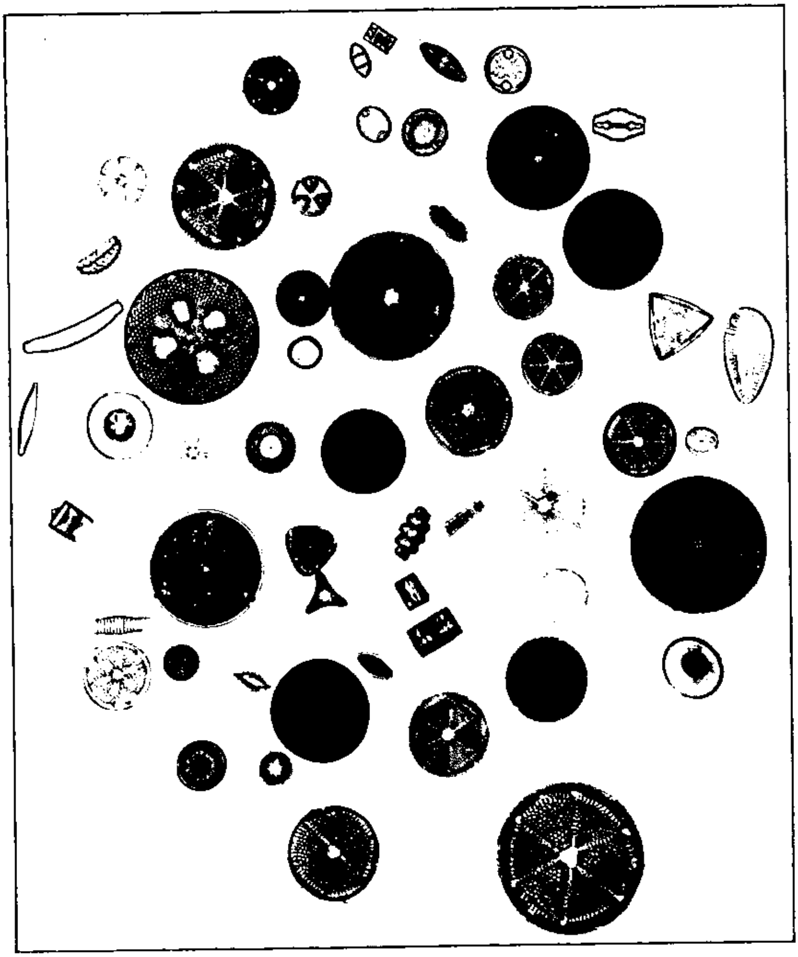
Of course the gelatinous portion in these fossil forms has long since vanished, the siliceous valves only remaining; these are perfectly transparent and are most beautifully, delicately and accurately marked as shown in the plate.

The occurrence of these diatoms is sufficient to identify this bed wherever entered by artesian borings. The two water-bearing horizons connected with it are situated one midway of the bed and the other immediately beneath it. The one occurring midway is found at Atlantic City at the depth of 550 feet and is believed to be the one that supplies the various artesians located along the coast between Atlantic City and Barnegat, and also most of those within the interior and near Port Norris, upon Delaware bay, a distance of twenty or more miles from Cape May. This conclusion is based upon the remarkably uniform increase of depth of the various wells regularly to the southeast directly across northeast and southwest parallel lines drawn through the locality of each well. This increase is twenty-five or twenty-six feet per mile and indicates the dip of the strata, while the parallel lines represent the general trend of the same.

As stated last year, these wells on being sounded each yielded diatomaceous blue clay.

The water horizon immediately beneath the clay-bed is found at Atlantic City at the depth of 700 to 720 feet. Its persistence and

* The plate shows forms found at Beach Haven. Similar forms occur in borings at Barnegat, Atlantic City, Mays Landing, Weymouth and Pleasant Mills, N. J., and at Clayton, Del. They are from the same clay-bed.



DIATOMS.

From Artesian Well Borings, Beach Haven, New Jersey.

Photomicrographed by Fred. E. Ives, from mount made by D. B. Ward, M.D.
Magnified 90 diameters.

availability have been again proved at that place by the sinking thereto the past year of an additional well for the Consumers Water Company. This well has been furnishing an abundant supply of good water for several months. The yield from this stratum is greater than from the one midway of the great clay-bed.

The persistent extension beneath that part of the State towards Delaware bay of the diatomaceous clay-bed, and presumably also of its associated water-yielding strata, is indicated by the occurrence in the State of Delaware of exactly similar micro-fossiliferous clays at outcrops recently visited, with microscope in hand, and samples therefrom carefully examined. One of these is at Malcom's mill, on the headwaters of the Leipsic river, about one mile slightly south of west from Brentford station and three miles nearly south from Clayton. Another is fifteen miles further south, upon one of the head branches of the Murderkill, at Emerson's mills, 3½ miles northeast of Felton. At Malcom's the diatoms are very abundant and are readily seen under the microscope by transmitted light. At Emerson's they are not so plentiful, and being invariably coated with iron pyrites they are opaque, so that their presence cannot be detected except by reflected light, when they present a golden metallic luster and show their coarsest markings in relief.

Further evidence of these clays was obtained at Clayton from a six-inch well bored for the Baltimore and Delaware Bay Railroad Company to a depth of 150 feet, and cased to the depth of about 100 feet, the walls standing apart and intact the remaining 50 feet, which penetrated what was described as a dark, tough, sticky, soapy, clay—a description verified by scrapings personally obtained therefrom, and which proved to be the characteristic greenish-blue clay containing diatoms. The material from the bottom, as shown by portions attached to the end of the sounding apparatus employed, contained greensand grains, indicating marl underneath, as occurs at Shiloh, N. J.

It should be stated that this well was not successful in obtaining water. In consequence of a belief that water-bearing strata had been cased off, since driven wells in close proximity obtain water at depths of 35, 60 and 85 feet, another six-inch well was bored 100 feet east to the depth of 35 feet, and water obtained which rises 20 feet, and yields, on pumping, 1,800 gallons per hour.

Quite probably a point only a few miles northwest of Clayton

15

limits the base or western margin of the diatomaceous clay-bed, while Felton approximately locates the top or eastern outcropping of the same. This indicates a belt some twenty miles wide, in which the slightly-upturned edges of the bed rise to and a little above sea-level, and which belt no doubt extends northeast across New Jersey. In the latter State, except at Shiloh, and perhaps at Hermon, near Greenbank, it has not been found to outcrop, on account of the greater thickness of the superficial gravels and sands, which attain a height of 120 feet and upwards, as against 40 feet in Delaware.

Further proof of the identity, not only of the diatomaceous beds of New Jersey and Delaware, but also of those with similar fossiliferous outcrops long known as occurring at Herring bay, on the western side of the Chesapeake, and also upon the banks, some distance from their mouths, of all the rivers emptying from the west into the Chesapeake, is afforded by the presence of a single specific form of diatom which occurs at the base only of this bed, and has not been found elsewhere in the world, either fossil or recent. It is technically known by the name of Heliopelta, which means sun-shield. It is a beautiful, large, circular disc, having a symmetrically-shaped star in the center. There are several varieties having, respectively, four, five, six and sometimes more rays or points to the star.

It has been found in the Atlantic City wells at the depth of 625 to 675 feet, and not higher, though carefully sought for by several investigators. It occurs also in the base of the well at Clayton, Delaware, and at the following outcrops, which in every instance are upon the western margin, and consequently at the base of the deposit, viz.: At Shiloh, N. J.; Nottingham, Calvert county, Md., and at Petersburg and Bermuda Hundred, Va.

The fourth or lowest of the horizons under notice occurs at Atlantic City at the depth of 1,100 feet, or 400 feet below the diatomaceous clay-bed. It is not certainly known that any other artesian boring has opened this stratum, though possibly the well at Winslow and that at Seaside Park may draw therefrom; but this cannot positively be determined until more facts regarding the strata underlying the diatomaceous clay-bed shall become known through the sinking of additional artesian wells within the southern interior. Its existence, however, need hardly be doubted, and since it furnishes a still more abundant supply of good water than either of the three higher horizons, the greater becomes the desirability of reaching it inland, where its depth is not so great as beneath the beaches.

Facts already presented in this paper and also in previous annual reports respecting wells widely distributed over the Atlantic seaboard and which draw their supply from within Miocene strata are sufficient to show the feasibility of obtaining by means of deep borings a plentiful supply of water at once wholesome and free from the organic impurities almost inseparably connected, at least in thickly-settled localities, with shallow wells. So far as the writer has been able to learn, the amount of water yielded by the different wells referred to has been greater with greater depths of the water-horizons. As bearing upon this some facts may be added respecting wells at Charleston, S. C.

In the annual report for 1880 occurs the record of a well in that city having a depth of 1,970 feet. Recent advices inform that this well has a diameter of tube at the bottom of about 2¾ inches, and is now yielding about 166,000 gallons in 24 hours; also that more recently two additional wells have been bored to depths of 1,945 and 1,950 feet. One of these has a diameter of 3¼ inches and furnishes 245,000 gallons in 24 hours, while the other has a bore at the bottom of 5 inches and delivers 1,186,000 gallons each 24 hours. The value of this water for use in the city of Charleston is further evident from the fact that a fourth well is now being put down.

ARTESIAN WELLS AT MILFORD, DELAWARE.

The past autumn three artesian wells were put down for an electric light and water company, at Milford, Delaware. They reached, respectively, the depths of 35, 150 and 160 feet and each yields an abundant supply of good water.

The wells are situated upon the south bank of the Mispillion creek, near the head of tide-water, which here rises and falls about four feet. The ground slopes gradually toward the stream, the area occupied by the water plant being from two to five feet above high water. Each well has a diameter of six inches. The water overflows from the two deeper ones several feet above the surface, while in the shallow one it just reaches thereto. These facts may be more accurately tabulated thus:

Well.	Size of Casing.	Depth.	Elevation of Surface.	Rise of Water.	Pumping Capacity per hour.
No. 1.	6 inches.	160 feet.	5 feet.	2 feet above surface.	4,000 gals. each.
No. 2.	6 inches.	150 feet.	2 feet.	5 feet above surface.	
No. 3.	6 inches.	34 feet.	5 feet.	Just to surface.	3,000 gals.

Through the courtesy of Charles Barker, Treasurer of the company, the diagramatic record on the following page, prepared by the company's engineer, who carefully watched the work, has been received. A few additional facts learned from another observer who examined the borings from time to time with a single magnifying lens, are placed to the right of the diagram.

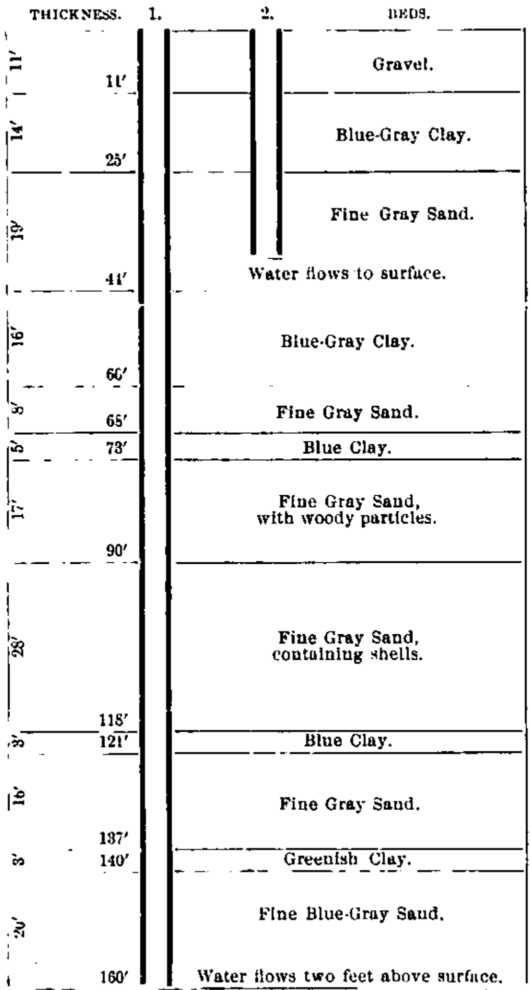
The wells were drilled by J. H. K. Shanahan, of Easton, Md., the hydraulic process being used. Wells No. 1 and No. 2 draw from the same stratum, and were each cased to the depth of about 141 feet, just through the lowermost clay-bed. No. 1 was continued about 20 feet and No. 2 about 10 feet further and a considerable quantity of sand pumped out and replaced with clean, pebbly gravel, to keep back the sand and allow a free flow of water.

The process employed in boring ground the shells noted in the section so thoroughly that only small fragments were obtainable, but by sifting these from a considerable quantity of material left near the wells after their completion, and then carefully looking over the fragments, the following genera were recognized: Arca, Astarte, Natica and two forms of Turritella, the latter being of the same two species that occur so abundantly in the shell marls near Shiloh, N. J.

These facts respecting shell fauna show that the strata at the two localities belong to the same geological period, *i. e.* the Miocene, and determine the position of those in the wells to be, not in the superficial horizontal gravels and sands, but within the underlying series of clays and their interbedded sands, and which are known to have a slight dip to the southeast. Stratigraphically, however, they are not only higher in the Miocene series than the Shiloh deposits, but also somewhat above the 300-feet diatomaceous clay-bed of the New Jersey wells and which also is above the Shiloh beds.

Considering the northeast and southwest strike along the Atlantic seaboard of the Miocene strata, these water horizons should be found in extreme southern New Jersey. If the dip for these beds near Delaware bay be the same as that indicated by the facts connected with the wells along the section from Weymouth to Atlantic City—that is, about 25 feet per mile—then the 140 to 160-feet horizon at Milford must be nearly equivalent to that of 350 to 390 feet supplying the electric-light company's well at Sea Isle City, N. J. (See Annual Report for 1890, page 272.)

It should also be looked for at Cape May at a depth of 475 to 525



NOTES MADE BY JAMES H. BELL.

From about 10 feet to 60 feet, fine sand mixed with lumps of blue clay, which gave the water a decided dirty color.

At 65 and 80 feet, wood, in pieces 1/8 to 1/2 of an inch in size.

At 85 feet, clean gravel, broken shells and fragments of thin stone.

At 110 feet, very fine sand.

At 120 feet, very small snail and broken clam shells, then mostly very fine sand to greatest depth of 160 feet.

At intervals all the way down from 100 feet, fractured clam and snail shells, but all very minute, and except in about a dozen instances requiring a magnifying glass to determine their character, but with this there was no mistaking what they were.

WELL-SECTION, MILFORD, DEL.

feet. A well put down some years since at Cape May Point and abandoned at the depth of about 450 feet was probably discontinued not far above this water horizon.

ARTESIAN WELL AT SEWELL, N. J.

This well was noted in the annual report of 1889, page 86, as having been put down to the depth of 72 feet. It has since been completed by the owner of the property, F. J. Anspach, of Philadelphia, who has cheerfully furnished systematic specimens of the earths penetrated accompanied by descriptive notes, from which the following record has been compiled:

BEDS.	Thickness of Strata.	Total Depth.
Surface layers, as follows: Yellow gravel; Yellowish sand; Yellow, ochrey, sandy clay	17 feet.	17 feet.
Green marl	7 "	24 "
Black marl (= very dark green)	6 "	30 "
Reddish-yellow sand-rock, casts of shells	13 "	43 "
Yellowish sand, with black specks, shown by the microscope to be the greensand grains peculiar to New Jersey marls.	13 "	56 "
Yellowish sand, lighter in color, also containing greensand specks.	16 "	72 "
At this depth, as stated in annual report for 1889, page 86, an abundance of clear water was obtained, and the boring stopped. Time, however, has proved that the water is unsatisfactory, as it precipitates iron oxide upon exposure to the atmosphere. Hence, the boring was resumed.		
Water-bearing sand continued	32 "	104 "
Tough, fine, blue clays and blue sandy clays	180 "	284 "
Notes for this division: At 180 feet, fine, tenacious, sticky clay, containing exogyra. " 264 " layer of sand. " 276 " very sandy clay, with some large pebbles. " 280 " sandy clay, with shells finely comminuted by the drill, and therefore not identifiable. " 284 " fine, tough, sticky clay, containing calcareous stones and lumps of iron pyrites.		
Greenish sand	51 "	335 "
Streak of clay		
Fine, clean, gray sand	7 "	342 "
Coarse, sandy gravel, angular grains, yielded a little water	9 "	351 "
Stiff, white clay	1 "	352 "
Fine, gray sand, with streaks of clay and considerable lignite	23 "	375 "
Layers of white sand and white clay	6 "	381 "

BEDS.	Thickness of Strata.	Total Depth.
White, angular gravel, coarse and gritty, great abundance of good water	14 feet.	395 feet.
White, angular gravel, extra coarse.	10 "	405 "
Fine, white sand	3 "	408 "
Fine sand and coarse gravel, mixed	7 "	415 "
Very coarse, angular gravel, pebbles larger than any above	5 "	420 "

F. J. Anspach kindly writes this additional information: "From the behavior of the tools it is believed this stratum contains bowlders as large at least as cobblestones. The boring was discontinued upon a hard white-clay bottom, which was penetrated by the drill about 12 feet further. The main three-inch casing was driven through the gravel-bed, or to the depth of 420 feet. A brass screen of 60 meshes to the square inch, $2\frac{1}{2}$ inches in diameter and 12 feet long was then secured in the bottom of the well, after which the main casing by means of hydraulic jacks was withdrawn about 12 feet, exposing the screen surface to the water-bearing gravel, thus preventing the fine quicksand and coarser gravel from getting into the three-inch tube. "At first the water was cloudy, the clay being held in supension, but after continued pumping equal to about 40 gallons per minute (the capacity of the pumping cylinder), the cloudiness disappeared and subsequent experiments have proved that there exists at this depth an abundant supply of pure, fresh, soft water, clear, transparent and free from mineral impurities and perfectly satisfactory in every particular. Constant pumping does not lower the water in the three-inch tube and it continues to hold its level of 77 feet below the surface line, which is 82 feet above tide."

WELLS BORED THROUGH PLASTIC CLAYS OF THE NEW JERSEY SERIES IN SOUTHERN PHILADELPHIA.

In Philadelphia, southward from Christian street near the Delaware, there have been drilled at various times during a number of years past a dozen or more wells for sugar refineries, salt works and ice factories. Three contractors who have each made several of the borings agree in stating that a series of thick beds of mottled red, white and yellow clays were passed through, a remnant most probably of the base of the New Jersey plastic clays which the Delaware river in cutting its channel has left in Pennsylvania. Similar clays have been dredged from the bed of the river below Philadelphia and were also encountered beneath the silt in seeking a foundation for the central pier of the pivot bridge across the Schuylkill at Penrose ferry. Specimens of both of these may be seen in the collections of the Academy of Natural Sciences of Philadelphia. Red clay has also been found in cellar excavations near Seventh and Fitzwater. These facts indicate that this bed underlies a triangular area in the southeastern part of the city.

Seven of the wells above noted were put down for one sugar refinery at Morris and Otsego streets. The contractor from memory furnishes the following record for one of these, and states that the thickness of the upper clay-bed varied somewhat, being sometimes not met with so near the surface, in which case the bed was thinner than stated—a fact tending to show erosion of the top of the clay-bed before the deposition of the upper sands. In other respects the record was the same for all the wells:

RECORD.

Alluvium, and then fine yellow sand	....	to 25 feet.
Mottled red and white clay	40 feet.	65 "
White potter's clay mixed with gravelstones	10 "	75 "
Fine running sand, all but quicksand light gray in color	15 "	90 "
Fine-white clay, no gravel	4 "	94 "
White coarse sand	15 "	109 "
Coarse white gravel, with pebbles, some as large as hens'-eggs, and some the size of the fist, hard, gray and white like cobblestones	16 "	125 "

This stratum furnishes the water.

One boring was made through these pebbles to rock at 140 feet.

A microscopical examination of the "alluvium" reveals numerous diatoms of both salt and fresh-water species, showing that the salt water of the bay encroached in the past upon the fresh water of the river and thus commingled the specific forms characteristic of marine and fresh waters.

PASSAIC RIVER DRAINAGE.

BY GEO. W. HOWELL.

Since the report of last year the excavation of rock in the river-bed below the Beattie dam has been prosecuted, and is now near completion. On account of frequent floods the work has been somewhat delayed, but all things considered, fair progress has been made.

The contractors, the Morris & Cumings Dredging Company, of New York, have wholly obliterated the main fall at Little Falls, and the river now runs through a rapid channel eighty feet wide, from the Beattie mill to the pool below the site of the original fall. Work is well along, also, in the twenty-five-foot channel leading from the dam where the gates are to be erected to the main channel below. On the completion of this work, which will probably be early in the present summer, the Beattie Manufacturing Company have agreed to put in the gates which are to pass the flood waters. The ultimate lowering of the entire dam will not be effected till the completion of the necessary work in the river above. The gates, however, will be set at the proper elevation for the final grade.

It has seemed desirable to fully complete the work below the dam before entering on that above, so that the benefit of the gates might be secured in lowering the water above during the prosecution of the remaining work.

After the present contract is completed, the Commissioners will seek to let the remaining work at as reasonable terms as possible. There yet remains to be done the removal of a reef immediately above the dam, which is already blasted, and a larger reef nearly one-quarter of a mile above, on which nothing yet has been done, but which in itself forms a dam entirely across the river. In addition, the plan under which the Commissioners are working, and which was authorized by the Board of Managers of the State Geological Survey, involves the removal of a bar of earth and bowlders at Two Bridges, and a cut-off through the meadow bottom at Pine Brook.

Some of the friends of the enterprise are now recommending the adoption of the old scheme of opening a new channel for the river from Pine Brook to the Deepavaal, a distance of a little more than three miles, while the distance by the river between these two points is from ten to twelve miles. If this plan be adopted, the work in contemplation at Two Bridges and Pine Brook would not be required.

During the coming season a careful examination of the proposed change of route and a comparison of the relative cost of the two plans will be made. If found desirable to effect the change, the matter will be referred to the Board of Managers of the Geological Survey for their action.

Under the present Drainage law the cost of the work is to be assessed wholly on the lands which are classed as flowed lands. In many cases this will be very burdensome, and it is a serious question whether lands or townships adjoining should not also share in the expense. In the minds of many this is especially fitting from a sanitary point of view, as well as from the fact that the taxable value of the lands improved will be considerably increased, thereby in a measure reducing the ratio of general taxes in the adjoining townships and counties.

The State Board of Health has had the matter in consideration, and it is hoped by many that suitable legislation may be secured before assessments on the lands will become necessary, in order that the cost of the work may be more equitably distributed according to benefits received. As the law now stands, no assessments can be made until the final completion of the work.

IRON MINES.

NOTES ON THE ACTIVE IRON MINES.

BY GEORGE E. JENKINS.

SHOEMAKER MINING AND MANUFACTURING COMPANY.

This mine, two miles south of Belvidere, has been in active operation during the year, producing a brown hematite, non-bessemer ore, which analyzes 45 per cent. metallic iron.

BELVIDERE MINES.

During the past year the mining operations among the Belvidere mines have assumed somewhat of their old-time vigor, and much work has been done in this region, most of it, however, being in the way of prospecting. A peculiar feature of the deposits is their location in the crystalline limestone belt. The rock on both the south or hanging-wall side of the deposit, as well as the north or foot-wall rock, is of this character. During the year the following-named mines have been operated:

The LINCOLN BESSEMER ORE COMPANY operated upon the property of Mr. Kaiser for a part of the year, using a separating plant to concentrate the material mined, but the enterprise was not successful, and all mining operations at this date have been stopped.

At the QUEEN MINE, owned by Paul C. Queen, and operated by the Sharon Ore Company, of 52 Broadway, New York City, the work of re-opening has been carried on. Two shafts and an incline are opened upon the deposit, the deepest of which is 155 feet, and the ground has been opened along the direction of the deposit for a distance of 200 feet. The deposit has been ascertained to have a width from hanging-wall to foot-wall of 40 feet, but it is not very regular, and there are no well-defined walls. The ore is of a disintegrated character, carrying much decomposed feldspar, which is removed by washing. Two log washers, driven by steam power, are used for this purpose, and about 60 tons per day of vein material are washed and prepared for shipment. The ore averages 57 per cent. metallic iron, and it is shipped by way of the Lehigh and Hudson railroad to the furnaces in eastern Pennsylvania, where it is used as a low-grade phosphorus ore, some of which passes the bessemer limit. Two sixty horse-power boilers furnish steam for driving two hoisting engines and two steam pumps, which drain the mine of water. About seventy-five men find employment at this mine.

FELLOWS MINE.

R. C. Fellows, the owner of this mine, and the previous operator, leased it on July 1st to the Thomas Iron Company, of Hockendauqua, Pa. Their operations consisted in the sinking of two new shafts, one east and the other west of the old Fellows open-cut workings. The eastern shaft is now 40 feet deep, and has pierced the ore deposit, which is the same in character as that worked upon the adjoining Queen property. The western shaft seems to be upon another deposit, about 200 feet west of the eastern deposit. The depth of the shaft is 50 feet, and 18 feet of this distance is in the ore, which is much harder and more compact than the ore from the eastern shaft. A cross-cut has been driven 14 feet, and strikes a compact sandstone on the south and a limestone on the north.

The work done thus far upon this deposit is mostly in the line of prospecting, and further developments will be noted with interest. The eastern deposit has the same irregularity of width as observed in the Queen mine, and owing to the absence of anything like firm walls, large quantities of timber are necessarily used to keep the ground up while removing the ore.

Two boilers furnish steam for one steam pump and two hoisting engines. The ore has to be washed, and is shipped to the Thomas Iron Company's furnaces as a 58 per cent. magnetic bessemer ore.

About seventy men are employed in and about the mine.

RIDDLE MINE.

G. Riddle, Owner.
The Champion Steel Ore Company, of Trenton, N. J., Operators; Thos. P. Marshall, General Manager; John P. Eckmeter, Mine Captain.

The mine is just east of the Fellows mine. The present company began operations in October, 1890, since which time three shafts have been put down upon the course of the deposit. The deepest working is 118 feet, and at this level 200 feet of drifting has been done in an easterly and westerly direction. The width of the vein has been tested by a cross-cut, driven at right angles to the vein, which is 50 feet in length, striking clay walls on both sides. This vein matter is of a very disintegrated character, requiring careful washing to separate the ore from the accompanying dirt and clay. The ore is of the same character as that produced from the adjoining mines to the westward. It carries about one and one-half per cent. of metallic manganese, and it is sold to the Bethlehem Iron Company for the manufacture of steel.

The mine is equipped with a seventy-five horse-power boiler, and another of eighty horse-power is being put in place. The number of men employed is about twenty-five.

RAUB MINE.

American Zinc and Iron Company, Operators.
Thos. P. Marshall, Manager, Trenton, N. J.

During a part of the year prospecting work only has been carried on, which consisted in the sinking of a shaft 60 feet deep, opening upon a body of ore six feet wide. The ore which has been taken out is very compact, requiring no washing, and is considered a bessemer ore. No ore has been shipped, as the work has been purely in the way of prospecting.

OSMUN MINE.

About one-half of a mile east of the Riddle mine, the Enterprise Mining Company, of 52 Exchange Place, New York City, has been prospecting since January, 1891. A good many test pits, varying in depth from ten to forty feet, have been put down, but no mining of any account has been done. These test holes have yielded six hundred tons of ore, which is in every respect the same as that found in the mines on the western part of this belt of ore. Machinery is now being purchased to be used in proving the ground previously opened by the test pits already noted.

Mr. Caleb Faulkner, of Butzville, is doing some prospecting upon the Robeson tract, which adjoins the Osmun to the southwest. From four to six men have been employed.

OXFORD IRON AND NAIL COMPANY'S MINES.

The two mines spoken of in the Geological Report of 1890 have been operated during the entire year. The opening known as Slope No. 3 is now 660 feet deep on the pitch of the shoot, which is at an angle of 34 degrees. The mine is worked in an easterly and westerly direction for a distance of 150 feet, and the vein varies from a maximum width of 30 feet to the minimum of 10 feet. The ore mined is a non-bessemer, yielding 53 per cent. metallic iron. It is low in phosphorus.

THE WASHINGTON MINE is worked a distance of 100 feet on the course of the vein, and dips to the south at an angle of 70 degrees. The slope through which this mine is operated is oblique to the vein, running down on an angle of 40 degrees, and is now 480 feet deep on this angle. During the year a sink 30 feet deep has been put down and the ore stoped out. One Ingersoll power drill is used for driving headings, all the other work being done by hand-drilling. A boiler capacity of about seventy horse-power furnishes steam for one steam pump in each mine and for the necessary hoisting plant. The ore from both mines is used at the Oxford furnace, but has been stocked at the mine since October, when the furnace was blown out. The ore from the Washington mine runs as high as 65 per cent. in metallic iron, but owing to the sulphur, requires roasting. Ninety-five men are employed.

KISHPAUGH MINE.

Owned and Operated by Ario Pardee.

The work of re-opening this mine, which was begun in October, 1890, has been carried on uninterruptedly during the year. When the work was begun the old Cook shaft was 200 feet in vertical depth. It was continued downward to 350 feet and opened upon the old Kishpaugh deposit in the cap-rock. A drift has been driven eastwardly, along the course of the deposit, for 180 feet, and cross-drifts have developed the vein to be 25 feet wide. At this depth there seems to have been some change in the structure of the surrounding walls as well as in the ore, for, instead of the soft walls encountered in the old mine, they are here found to be much harder and more compact. The ore also bears the same characteristic as to hardness and compactness. The deposit has a dip to the southeast of 38 degrees, and pitches in a southwesterly direction.

A diamond drill is now being used at a point 500 feet southwest of the Cook shaft, in order to test the continuity of the deposit. No ore has been shipped during the year. About thirty men are employed and the mine is well equipped with the best of machinery.

HUDE MINE.

Owned by the Dickerson-Suckasunny Mining Company.
Operated by Ario Pardee, Lessee.

Two tunnels have been driven into the hill, from the north and the south sides. The north tunnel has opened upon a vein of hard, compact, magnetic ore, dipping to the southeast on an angle of 15 degrees. The south tunnel has been driven into the hill far enough to cut three parallel shoots of ore, which dip well to the southeast on an angle of 30 degrees. The mining during the year has been in removing the ore found in these three shoots and taking out the ore from surface workings. The ore is non-bessemer, averaging about 50 per cent. metallic iron, but is high in sulphur and requires roasting. It is used at the Stanhope furnace, to which it is carted by teams. A boiler plant of 75 horse-power furnishes steam for operating the air compressor and hoisting engine. Thirty men are employed.

HURDTOWN MINE.

Hurd Heirs, Owners.

The Glendon Iron Company, who have been the operators of this mine for the past forty years, have continued their operations during the year, and the mine continues to be as productive as ever. It is now 4,300 feet deep, measured on the slope, which goes down on the bed-rock of the shoot. The shoot has an average width of 20 feet, and a height of 36 feet, from cap to bed-rock. Power drills are used to remove the ore, and the mine is thoroughly equipped with the necessary machinery. The ore is used at the Glendon furnaces, in eastern Pennsylvania.

LOWER WELDON MINE.

Weldon Mining Company, Owners.
Copley Iron Company, Operators.

The opening upon the Weldon vein is a single shaft, which is now 270 feet deep, the last 18 feet being a rock sink. It is the intention to continue this shaft till it cuts the shoot of ore which outcrops on the top of the hill, about 500 feet west of the present hoisting shaft. The mine has been worked on the top shaft to a depth of 600 feet, on the angle of the pitch, which is 30 degrees. The vein pinched out during the year, and work is now abandoned in this part of the mine. The lower shoot is still producing, and averages 25 feet from bed to cap-rock, and a width of 4 feet. The ore is a magnetic non-bessemer, yielding 58 per cent. metallic iron, and is used at the Copley Iron Company's furnace. There is a 40 horse-power boiler, which furnishes steam for a Rand air compressor, which supplies air for two Rand drills. The mine is drained by one steam pump. About 20 men are employed.

UPPER WELDON MINE.

Leonard Elliott, Owner.
Richard Hecksher & Sons, Operators.

Since this mine was re-opened by the present operators, over 300 feet of sinking has been done, going through three new shoots of ore, each of which is separated by a bed-rock of from 8 to 30 feet.

The ore-shoots have a height varying from 20 to 60 feet and are from 2 to 9 feet wide. The length of working upon the present bottom of the mine, which is 300 feet vertical depth, is 396 feet. The ore-shoots pitch to the northeast, on an angle of 30 degrees, and dip to the southeast at about 50 degrees.

The ore is non-bessemer, averaging 58 to 60 per cent. metallic iron, and is used at the Swede furnace. The concentrating plant, which was erected a little more than a year ago, has been operated for the whole year, concentrating about 2,000 tons. A granulator and another separator are being added to the plant.

During the past year a great deal of work has been done in straightening and retimbering the hoistway and putting in a new skip road. The mine plant is the same as reported last year. Seventy men are employed in mine and separating works.

OGDEN MINE.

The New Jersey and Pennsylvania Concentrating Company,
Owners and Operators.
Owen J. Conley, General Manager.

During the past two years this company has been engaged in the construction of an extensive plant, for the purpose of concentrating the lean magnetic ore of the old Ogden vein.

The mining operations have been carried on upon the west end of the old Ogden workings, and consist in blasting down the vein, the width of which is 100 feet. All the material is conveyed to the concentrating works by two cable tramways of the Lock-Miller system, which have a span of over 2,000 feet, and are each capable of handling 400 tons of product per day. The material mined is about 20 per cent. in magnetite, and it is concentrated to a 68 per cent. bessemer ore—the phosphorus being eliminated through the process of concentration. The enterprise is, however, only in a state of an experiment, and for this reason no great amount of ore has been shipped. About 200 men are now employed.

AUBLE MINE, NEAR PEAPACK.

John Auble, Owner.
Peapack Mining Company, Operators.

The work done upon this property consists of the sinking of two shafts, one 120 feet deep, and another 80 feet deep, connected by a drift 140 feet long. The vein is small, having a maximum width of three feet, but it is said to be a bessemer. About four men have been employed and 400 tons of ore mined. It is carted to Peapack and shipped to the Carbon Iron and Pipe Company's works, at Parryville.

HACKLEBARNEY MINE.

The Chester Iron Company, the owners and operators of this property, have been employing about twenty men, who have mined principally red ore, but confining their operations all above water-level. The ore is a magnetite of about 50 per cent., some of which is low enough in phosphorus to pass the bessemer limit.

The blue ore is high in sulphur and requires roasting. This is done at the mine in a Taylor gas generator, and about 3,500 tons have been treated during the year. The water-power plant has been reconstructed and furnishes 70 horse-power, with which the air compressor is operated and the ore washed.

A tunnel at the level of the river is being driven into the west hill, and a bunch of ore already discovered at about 50 feet from the entrance. The ore is placed upon the market.

DICKERSON MINE, FERRO MONTE.

Dickerson-Suckasunny Mining Company, Owners.
Ario Pardee, Operator.

This mine, one of the oldest in the State, as well as, perhaps, the most famous, is now to be added to the list of "worked out and abandoned;" for during the year, although a considerable amount of ore has been mined and shipped, the work has principally been in the line of prospecting for new shoots. A diamond drill was employed for this purpose, and several bore holes were put down but no large ore-body was discovered. In November it was decided to remove the machinery and shaft equipment. This has been done, and the workings are now flooded with water.

During the year the Dickerson-Suckasunny Mining Company have been engaged in opening a shaft upon the vein of mixed magnetite and apatite, which crosses their property, and they purpose separating the magnetite and utilizing the phosphorus for fertilizers.

BAKER MINE, MINE HILL, N. J.

Joseph Wharton, Owner and Operator.

This mine was worked up to about July 1st, when it was temporarily closed down. The workings have reached a depth of 500 feet on the underlay, which is about on an angle of 65 degrees. When the mining was stopped, drifts had only just been driven into the new shoot of ore which was discovered during the year. The eastern drift is 30 feet long, and the western drift is about 70 feet, both of which are in ore varying in thickness from 3 to 5 feet. The ore is a non-bessemer, averaging 60 per cent. metallic iron.

HURD MINE AND NEW STERLING SLOPE.

The New Jersey Iron Mining Company, who are the owners as well as the operators of these mines, have continued them in active operation during the year, but most of the mining has been done in opening upon the "old Sterling shoot," through the new Sterling slope.

This new slope is located 75 feet west of the Harvey offset, and continues for 200 feet on an angle of 45 degrees, where it cuts into the old workings. The vein here flattened out to a dip of 20 degrees, but the course of the slope was continued on the angle at which it was started, until it reached a depth of 603 feet. Here a drift was driven into the hanging-wall a distance of 28 feet, where the vein was discovered. During the year a sink has been put down in this ore body 56 feet, and by drifts and "raises" the vein has been worked out to a height of 70 feet above the point at which the vein was first cut into. At the Irondale mines there is no cap-rock to the deposit, the vein outcropping at the surface, but it diminishes very materially in width as the surface of the ground is approached, and work upon the vein is continued until the width becomes so narrow as to be unprofitable in its removal. The principal product of the Irondale mines now comes from this slope, which averages 90 tons per day of a non-bessemer, 60 per cent. ore.

The vein has been worked in an easterly and westerly direction about 300 feet, and the maximum width is found to be 18 feet of clean ore; minimum width, 3 feet; average, 10 feet; dip, 48 degrees; pitches to the northeast.

At the Hurd mine, work has been continued, but only to a small extent, and no new ground has been opened up. The subject of the concentration of iron ore is receiving the attention of the owners of these mines, and during the year a concentrating mill of a supposed capacity of 60 tons per day has been erected. The dry process of separation is adopted, the C. G. Buchanon magnetic separators being used. The original purpose of erecting this mill was to utilize the lean ore which is necessarily culled from the general yield of the vein, and at the same time convert the resulting product into a bessemer ore.

Experiments are being tried with the "Dutch Hill ore" or Erb mine, a lean, magnetic ore, which in its crude condition is low enough in phosphorus to pass the bessemer limit. The results of these trials will be awaited with interest by Morris county mine-owners, for if successful, they will demonstrate a way of utilizing the large deposits of lean ore, heretofore useless except when iron ore is at a very high value.

ORCHARD MINE.

The Estate of J. Couper Lord, Owners and Operators.
Joseph Richards, Mine Superintendent.

The vein upon which this mine is located is probably the same as that upon which the Irondale mines are located, but there is an offset on the western end of the property which throws the vein to the southeast. There are two shafts upon the vein, going down on the foot-wall, the dip of which is 48 degrees to the southeast, but only one of these openings is used for a hoistway. On the course of the vein the mine is worked for a distance of 900 feet, and the vein has an average width of 6 feet, which yields a 59 per cent. non-bessemer magnetite. One year ago a cross-cut on the 700-foot level was driven into the hanging-wall at right angles to the course of the vein, for a distance of 800 feet, the object being to cut the Richard mine vein, but nothing was found excepting a string of ore 20 inches wide, which, being so far south, is probably the eastern extension of the Jackson Hill vein. On the main vein only about 25 feet of sinking has been done during the past year, and operations have been confined to beating away the stope of ore already opened up.

In February, 1891, a survey was made for the purpose of locating a new incline slope, which is to be put down in the foot-wall, running in part through the old workings. This slope will be 773 feet deep, on an angle of 44 degrees and 44 minutes, and an entirely new equipment of both hoisting and pumping machinery is to be put in. The ore is used almost exclusively in the furnaces of eastern Pennsylvania. About 85 men find employment in and about the mine.

The equipment consists of boilers of 250 horse-power, pumping and hoisting engines, air compressor and steam pumps.

MOUNT PLEASANT MINE.

This mine is now operated by the Mount Pleasant Mining Company, who operated upon the Mount Pleasant mine on the property of the estate of J. Couper Lord and on the Baker property.

The extent of the working is now 3,500 feet on the course of the vein, and at a depth of 950 feet on the underlay. The average width is 6 feet, of a rich, magnetic, non-bessemer ore, which is shipped on a strict guarantee of 66 per cent. metallic iron. In July an offset was developed in the bottom of the mine which threw the vein in the foot-wall. After sinking 40 feet the ore body was again discovered, and it continues to be of the same dimensions as where previously worked.

During the past three years much time and money have been spent in the sinking of a "new incline," in part through the old workings and foot-wall, and in equipping the mine with a most excellent and complete mine plant, which consists of the following: Compound condensing Corliss engine, operating four plunger pumps, three of which are 14 inches in diameter, and stroke of 7 feet and $\frac{1}{8}$ inch.

These pumps lift 800 gallons of water per minute, and are run on a speed of six strokes to the minute. Two of the large pumps throw together to surface, and have a lift of 400 feet. The remaining two lift about 350 feet. Four steam pumps clear the bottom workings and have a lift of 300 feet.

The hoisting engine is 175 horse-power, of double cylinder, 15 x 24 inches, which operates two six-feet drums at a maximum speed of 500 feet per minute, and 200 tons per day is the present amount raised, but only one drum is operated. The true capacity is 1,000 tons per day. There are three air compressors, having a capacity of 35 drills, one operated by turbine wheel, all of which supply air for 14 Ingersoll-Sergeant drills, one hoisting engine and three steam pumps. A small locomotive is used underground for shifting the ore cars on the lower level. There are 200 men employed. The ore is placed upon the market, and is used in eastern Pennsylvania furnaces.

RICHARD MINE.

Owned and operated by the Thomas Iron Company.

This mine continues to be the largest producer of any of the Jersey mines, yielding over 84,000 tons annually. The vein is opened and worked for a distance of 2,300 feet along the trend, and in the distance there are three openings. The maximum width of the vein is 25 feet, and the deposit is worked until the width is too narrow for profitable working, which is about 18 inches.

The general average of the deposit is fully 10 feet. The dip is 50 degrees to the southeast. The Thomas Iron Company consume the entire product, and it is shipped as a 60 per cent., non-bessemer ore. The mine plant consists of 900 horse-power boiler capacity, three duplex engines and Rand air compressor, which operates four drills. Steam pumps are used to free the mine of water. One hundred and sixty men are employed.

TEABO MINE.

Glendon Iron Company.

All work was suspended at this mine on January 1st, 1891, and the mine abandoned by its owners, the Glendon Iron Company. The ore which was in stock has been shipped to the Glendon furnaces and the extensive mine plant is now offered for sale.

MOUNT HOPE MINES.

Owned and Operated by the Mount Hope Mining Company.

Work has been continued during the year upon the Jugular vein in the Taylor mine, the Side Hill vein and the Elizabeth vein. Much work has been done in the Taylor mine in retimbering the tunnel level to the present bottom. The two shafts have been entirely reconstructed and tracks and skipways entirely relaid, as well as a new engine placed upon the tunnel level, with which the hoisting is done.

In the Side Hill vein the dip has now changed to a southeast direction, making an angle of about 70 degrees with the horizontal. The vein is now 140 feet long, and all the ore produced is hoisted through the new shaft and then conveyed to the general stock-yard by a gravity road about 700 feet long. The maximum width is 20 feet; minimum width, 5 feet; average, 12 feet. The capacity of this mine is 20,000 tons annually.

In the Elizabeth vein, the pitch is from 25 degrees to 30 degrees to the northeast, and not 65 as stated in the last Geological report. The dip, however, is 65 to 70 degrees. The vein is 140 to 160 feet long, but the mine is only in a state of development, and the exact dimensions of the deposit cannot be ascertained. The ore is from 60 to 65 per cent. metallic iron, and the total product of the three mines is divided into Mount Hope rich reserve ore, running 65 per cent. metallic iron, and low in phosphorus, and Mount Hope standard, which analyzes 58 per cent. The ore is placed upon the market, and used principally by the Thomas Iron Company. About 130 men are employed. The mine plant is the same as reported last year.

HIBERNIA MINES.

The Hibernia mines have all been in operation excepting the De Camp and Scott. In October, 1891, the Lower Wood mine was purchased by the Andover Iron Company, who have been the operators for the past 15 years. The length of the vein is 1,900 feet, but only 1,500 feet of this distance has been operated upon. West of the offset, which is near the skip shaft, no work has been done this year. The vein has a maximum width of 20 feet, and is worked to the minimum width of 4 feet. The average is 9 to 10 feet. The dip is 62 degrees to the southeast, and the workings have reached a depth of 685 feet on this angle. The vertical depth is 584 feet. The mine plant consists of eight boilers of 425 horse-power; one 100 horsepower pumping engine, and two hoisting engines of 50 and 30 horsepower, respectively; four air compressors, capable of furnishing 1,800 cubic feet of free air per minute; six small steam pumps, and the requisite number of drilling machines. The number of men employed is 150, and the output for the year is used at the company's furnace at Phillipsburg, and placed upon the market.

The Glendon Iron Company have worked only the Glendon and Upper Wood mines during the year, although the pumps have been kept at work in the Scott mine. A sink about 125 feet was put down, and the vein found to widen out. The working distance upon this lot is 425 feet.

The Upper Wood has been producing during the entire year. It has a working distance of 950 feet, upon which there are two shafts. The ore is a non-bessemer, 58 per cent. magnetite.

WILLIS MINE.

Mr. Joseph Wharton has continued operations upon this property, which is on the eastern extension of the Hibernia vein. It is worked from the Upper Wood boundary to the eastward for 1,000 feet, where the vein becomes too narrow for profitable working. Along this distance the vein varies in width from four to six feet, giving an average of five feet of clean ore. One hundred feet of a sink has been put down, making the depth of the mine 700 feet on the dip, which is 87 degrees to the southeast.

The walls are very rough and ragged, but generally firm, and therefore not requiring the amount of timbering found necessary in the mines to the eastward. The mine-plant consists of three batteries of boilers of a combined horse-power of 300; three air compressors, which supply air for twelve to fifteen Rand drills; four steam pumps drain the mine, but there is no great supply of water to contend with. The ore is used at Port Oram furnace, to which it is shipped by the Morris County railroad and Central Railroad of New Jersey. One hundred and twenty-five men are employed.

WANAQUE MINE.

Midvale Mining Company, 5 and 7 Beekman street, New York City, Operator.

The work of re-opening this mine was begun in April, 1890. There are three shafts on the vein, the deepest of which is 125 feet. The vein is braced for 1,300 feet, but only about 500 feet has been opened up. The width of the vein is from 10 to 16 feet, but it carries a great deal of rock, from which the ore has to be cobbed. The dip is 85 degrees to the southeast. The ore is very hard,—compact, non-bessemer—yielding 54 per cent. of metallic iron, but is rather high in sulphur. The company intends to crush, roast and concentrate the ore, and two roasters are now being erected for this purpose. Three boilers furnish steam for air compressor and two hoisting and pumping engines. About 8,000 tons of ore have been raised and stocked at the mine. Twenty men are employed.

RINGWOOD MINES.

Owned and Operated by Cooper & Hewitt.

During the year operations have been confined to the Peters mine, where the hanging-wall is being removed so as to expose the ore pillars, which are then removed. By this method the first pillar has been taken out and the stripping of the hanging-wall is still going on.

The output for the year amounted to 20,000 tons, all of which was shipped to Pequest and Durham furnaces.

NOTES ON THE ZINC MINES.

The New Jersey Zinc Company have continued active operations upon their property at Franklin Furnace, putting down a sink seventy-five feet, and finding the vein to be of the same uniform size as it was above.

At Sterling Hill work was stopped in April, the company not having any need of this grade of ore. The ore mined here has not been shipped.

The Lehigh Zinc and Iron Company's mines, which are southwest of the Buckwheat opening, have operated upon the deposit for a length of 500 feet, and the present workings are now 400 feet deep on the dip, which is 58 degrees to the southeast. The maximum width of the deposit is 45 feet, and minimum of four feet. During the year a new equipment has been put up, consisting of 245 horse-power boiler capacity; a hoisting engine of 100 horse-power, having a capacity of raising six tons at the rate of 500 feet per minute. One large steam pump drains the mine of water. One hundred and twenty-five men are employed.

On the Rutherford tract a series of bore holes were put down with a diamond drill in search of the deposit of zinc developed and operated through the "Southwest" opening. The work was begun in November, 1889, and the work was suspended with very satisfactory results in April, 1891. As a result of these borings a new shaft, known as the "Parker Shaft," has been located, and the work of sinking was begun July 14th, 1891. The shaft is 10 feet by 20 feet, outside measurement, and divided into three compartments, 5 feet by 7 feet in the clear. It is at present 200 feet deep, timbered down to a depth of 160 feet by sets placed four feet apart.

The plant consists of a hoisting engine of 50 horse-power; Ingersoll & Sergeant compresser of 100 horse-power; 120 horse-power boiler capacity, and a 90-light Edison dynamo, which is used in lighting both the underground works and the buildings. A switch from the Lehigh and Hudson railroad, one and one-half miles long, is also being built to the mine.

The notes on the active iron mines for 1891, collected by Mr. Jenkins for the Survey, with the mine statistics received from mine-owners and superintendents, exhibit some phases in their history and development which are here summarized:

1. There is a notable and slow decrease in the number of active mines as compared with that of a decade ago. The statistics show that the larger part of the total production comes from comparatively few mines. In 1891, four mines reported an aggregate output of 316,248 tons of ore, nearly 60 per cent. of that of the State. Although there are fewer producing localities, the State production is maintained at nearly a constant rate, and is in excess of every year since 1882. (See page 256.)

2. There is a concentration of production in a few centers and groups of mines, as the Belvidere-Oxford group; the Hurdtown-Ogden range; the Port Oram and Mount Hope groups; the Hibernia range; and the Ringwood group. There are few isolated mines, as the Kishpaugh, Hude, Midvale, at work.

3. A study of the localities shows further that all are accessible by railroad lines, and nearly all have branch tracks to the mines. The necessity for a reduction of expenses in these times of low prices is so important that ore localities remote from transportation lines are considered as practically abandoned or suspended until more favoring conditions may arise.

4. These producing mines are the old and historic ones, whose periods of activity reach back a half century or more. The Kish-

paugh and the Belvidere are exceptions, belonging to the latter half of the present century.

5. The closing of the Teabo and the Dickerson mines marks an important epoch in the history of iron-mining in New Jersey. They have been large producers of good ores, and have been worked steadily and continuously for several decades of years. The Dickerson mine has been distinguished for its long history; its importance in the early days of mining, when forge fires were on every mill stream in the northern part of the State; its large total output; the richness of its ore, and its characteristic shape of ore-body. The occurrence is not fully understood in its geological features, although so well known as a mine. The deposit is not exhausted, although a limit of profitable working at present prices may have been reached. In this respect it is a type of the mines of this region—closed, but not exhausted.

The following notes on its history have been contributed by Frederick A. Canfield, of Dover, one of its owners:

DICKERSON MINE.

Opened 1716; closed 1891, Nov. 16th; period of working, 175 years.

This tract of land on which the Dickerson mine is opened was taken up as a *mining tract* in 1713, by John Reading, surveyor, for Joseph Kirkbride, who left it to his three sons, Joseph, Jr., Mahlon and John, members of the Friends' Society of Bucks county, Pennsylvania.* Jonathan Dickerson, father of Governor Mahlon Dickerson, began to buy interests in the property before 1780. His son, Mahlon, succeeded to his father's interests in 1797, and added to them by purchase until he had acquired all. At his death, in 1853, the property descended to his nephews and nieces, who formed the original stockholders of the Dickerson-Suckasunny Mining Company, the present owner. The mine has been in the possession of the family and its representatives, from whom it was named, for over a century.

*In 1713 (May 12th), Joseph Kirkbride took up a tract of 4,525 acres (see Book A 146, Burlington), which probably included the "Old Mine." February 21st, 1716, John Reading, Jr., took up a tract of 360 acres immediately adjoining the northwest corner of the Kirkbride tract. This tract also probably includes some of the mines on the Dickerson property.

Before the mine came into the possession of Mahlon Dickerson it was worked under a system of forge-rights, whereby certain forge-owners had the right to get the ore needed by them at this mine. The ore was a favorite among forgemen because of the ease with which it was reduced, and because of the fine quality of the iron made from it.

It is safe to say that one hundred forge fires were run with this ore, and it was carted as far as High Bridge in a southern direction, and northward as far as Hamburg, in Sussex county. The forges in Longwood valley, Newfoundland, Stockholm, Sparta, Hurdtown, Chester, Bartley, Whippany, Morris Plains (and it is said that some in Monmouth county) drew their supply from this mine. As money was scarce, the ore was often paid for with bar iron, which was carried on horseback over bad roads. After the Morris canal was opened the ore was sent to Pennsylvania, where it was reduced in furnaces using anthracite.

Governor Dickerson worked the mine in a small way, regulating the production by the demand, and probably mined about 2,000 tons of ore a year. The mine was worked more actively after 1854 until the depression in the iron business, from 1857 to 1860, when the mine was closed, the company having from 25,000 to 30,000 tons of ore in stock which could not be sold at that time. The mine was closed from 1860 to 1862, when the Allentown Iron Company made a lease of the old mine for 15 years at 75 cents a ton royalty. It was worked by this company until 1877. In 1871 the firm of E. Canfield & Co. leased the remainder of the property for six years at a royalty of one dollar per ton; and in 1877 Mr. Ario Pardee (who was in the firm of E. Canfield & Co.) took the entire property and worked it actively until November 16th, 1891. In 1883, owing to the great expense of *securing* the old parts of the mine, and the difficulty in raising the ore to the surface up the long 1,300-foot slope, the owners decided to sink a vertical shaft, which at 550 feet cut the "Side vein" and at 750 feet the "Big vein." The depth of the Big mine is about 1,300 feet.

About three years ago an offset was encountered in both veins which threw the northerly end of the vein about 35 feet to the east. The ore in the vein "inside" the offset seemed to be totally different in character from that in the main part of the vein, and being very stringy and rocky, and getting worse and worse, caused the lessees to surrender the lease and close the mine.

The owners have tested the ground with many diamond-drill holes, which have proved that the ore deposit was not exhausted, although no large bodies of ore were found. The further working could be carried on if it were not for the depressed condition of the iron market. At the present prices for iron the old mine may be regarded as economically exhausted; that is, it will not pay to work it.

It is estimated that about 1,000,000 tons of ore have been taken from the mine. The largest output for any year has been 48,000 tons.

MINERAL STATISTICS.

IRON ORE.

The statistics of the iron mines for the year 1891 are the aggregate output of all of the mines which were worked during the calendar year. Requests with blank forms were sent to mine-owners or mine managers, and the information asked for was received from all of them. The statistics of production thus obtained by the courtesy of the mining representatives forms the basis for more nearly accurate totals for the State than have been obtainable heretofore. The reports received from the several railroad companies which carry iron ore from mines in the State, represent the amount shipped, which differs materially from the total output. The total iron-ore tonnage reported by these carrying companies amounted in 1891 to 449,046 tons. The total output, as ascertained from the mine reports for 1891, amounted to 551,358 tons. These figures are comparable with the total obtained by Mr. Nason in 1890, which were 552,996 tons.

It is notable that the difference is less than 2,000 tons—a decrease. The statistics of last year's report are reprinted here:

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	Annual Report State Geologist.
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	" " "

ZINC ORE.

The production of zinc ore in the State for the calendar year 1891, as reported by the companies working the mines at Sterling Hill and at Franklin Furnace, in Sussex county, amounted to 76,032 tons, 12 cwt., an increase of more than 50 per cent. above the total amount reported for 1890.

The statistics for preceding years are reprinted in the following statement:

1868	25,000 tons†	Annual Report State Geologist.
1871	22,000 tons	" " "
1873	17,500 tons	" " "
1874	13,500 tons	" " "
1878	14,467 tons	" " "
1879	21,937 tons	" " "
1880	28,311 tons	" " "
1881	49,178 tons	" " "
1882	40,138 tons	" " "
1883	56,085 tons	" " "
1884	40,094 tons	" " "
1885	38,526 tons	" " "
1886	43,877 tons	" " "
1887	50,220 tons	" " "
1888	46,377 tons	" " "
1889	56,154 tons	" " "
1890	49,618 tons	" " "

* From statistics collected later.

† Estimated for 1868 and 1871. Later years' statistics are from reports of the railway companies carrying the ores to market.

PUBLICATIONS OF THE SURVEY.

DISTRIBUTION OF PUBLICATIONS.

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 the 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 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 same, as follows:

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

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

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

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

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

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

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

8. Map of the zinc mines, Sussex county; colored. Scale, 8 inches to 1 mile.

A few copies are undistributed.

REPORT ON THE CLAY DEPOSITS of Woodbridge, South Amboy and other places in New Jersey, together with their uses for fire-brick, pottery, &c. Trenton, 1878, 8vo., viii.+381 pp., with map.
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.

ATLAS OF NEW JERSEY. The complete work is made up of twenty sheets, each twenty-seven by thirty-seven inches, including margin, intended to fold once across, making the leaves of the Atlas $18\frac{1}{2}$ by 27 inches. The location and number of each map are given below. Those from 1 to 17 are on the scale of one mile to an inch.

No. 1. Kittatinny Valley and Mountain, from Hope to the State line.
No. 2. Southwestern Highlands, with the southwest part of Kittatinny valley.
No. 3. Central Highlands, including all of Morris county west of Boonton, and Sussex south and east of Newton.
No. 4. Northeastern Highlands, including the country lying between Deckertown, Dover, Paterson and Suffern.
No. 5. Vicinity of Flemington, from Somerville and Princeton westward to the Delaware.
No. 6. The Valley of the Passaic, with the country eastward to Newark and southward to the Raritan river.
No. 7. The Counties of Bergen, Hudson and Essex, with parts of Passaic and Union.
No. 8. Vicinity of Trenton, from New Brunswick to Bordentown.
No. 9. Monmouth Shore, with the interior from Metuchen to Lakewood.
No. 10. Vicinity of Salem, from Swedesboro and Bridgeton westward to the Delaware.
No. 11. Vicinity of Camden, to Burlington, Winslow, Elmer and Swedesboro.
No. 12. Vicinity of Mount Holly, from Bordentown southward to Winslow and Woodmansie.
No. 13. Vicinity of Barnegat Bay, with the greater part of Ocean county.
No. 14. Vicinity of Bridgeton, from Allowaystown and Vineland southward to the Delaware bay shore.
No. 15. Southern Interior, the country lying between Atco, Millville and Egg Harbor City.
No. 16. Egg Harbor and Vicinity, including the Atlantic shore from Barnegat to Great Egg Harbor.
No. 17. Cape May, with the country westward to Maurice river.
No. 18. New Jersey State Map. Scale, 5 miles to an inch. Geographic.
No. 19. New Jersey Relief Map. Scale, 5 miles to the inch. Hypsometric.
No. 20. New Jersey Geological Map. Scale, 5 miles to the inch.

In order to meet the constantly increasing demand for these sheets, the Board of Managers of the Geological Survey have decided to allow them to be sold at the cost of paper and printing, for the uniform price of 25 cents per sheet, either singly or in lots. This amount covers all expense of postage or expressage, as the case may be. Sets of the sheets, bound in atlas form (half morocco, cloth sides, gilt title, maps mounted on muslin, and guarded), are furnished at $13.50 per copy. Application and payment, invariably in advance, should be made to Mr. Irving S. Upson, 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., with cut.

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 map and cuts.

INDEX.

A.

B.

C.

J.

K.

L.

M.

N.

O.

P.

Q.

R.

S.

T.

U.

V.

W.


GEOLOGICAL SURVEY OF NEW JERSEY
J.C. SMOCK, STATE GEOLOGIST.
A MAP OF
NEW JERSEY
To accompany the ANNUAL REPORT of the
STATE GEOLOGIST
FOR
1891.
From original Surveys
by C.C.VERMEULE, Topographer,
based on the
TRIANGULATION OF THE U.S.COAST AND GEODETIC SURVEY.
Scale: 5 miles to an inch
MILES
KILOMETERS
ATLANTIC OCEAN
DELAWARE BAY
LONG ISLAND SOUND
RARITAN BAY
CONN.