GEOLOGICAL SURVEY OF NEW JERSEY

ANNUAL REPORT

OF THE

STATE GEOLOGIST

For the Year 1905

TRENTON, N. J.
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1906

The Geological Survey of New Jersey.

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His Excellency Edward C. Stokes, Governor and *ex-officio* President of the Board, ... Trenton.

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State Geologist.

Henry B. Kümmel.

† Declined reappointment. Succeeded April 1st, 1906, by David E. Titsworth, Plainfield.

* Reappointed April 1st, 1906, for five years.

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To His Excellency Edward C. Stokes, Governor of the State of New Jersey, and ex-officio President of the Board of Managers of the Geological Survey:

SIR—I have the honor to submit my Annual Report upon the work of the Geological Survey for the year 1904. The Administrative Report is accompanied by two papers on scientific subjects. Other papers, in preparation, are so near completion that I recommend that the final printing of the complete report be delayed until they are ready. By this means the results of these investigations can be made public at an earlier date than if they should be held for the 1906 report. I recommend that advance copies of the Administrative Report be printed for use of the Legislature.

Yours respectfully,

HENRY B. KÜMMEL,

State Geologist.

TRENTON, N. J., November 30, 1905.

ADMINISTRATIVE REPORT.

Administration, Publications, Distribution, Library, Collections.—Topography, Field Work, Office Work, Prevention of Floods on the Passaic River.—Geology, Peat, Sands, Building Stones, Trap Rock and Copper Ores, Iron Ores, Stratigraphical Work, Paleontology.—Changes Along the Coast.—Co-operation with the U. S. Geological Survey.—Forestry.

Administrative Report.

By Henry B. Kümmel, State Geologist.

The work of the State Geologist and the members of the Geological Survey is briefly summarized in the Administrative Report. In the accompanying papers there are set forth more in detail the results of investigations along certain lines.

ADMINISTRATION.

Under the head of administration there is included the clerical, editorial and supervisory work incidental to the operations of the Survey. These are naturally the same from year to year, and need not be specifically considered. Laura Lee, Clerk; S. H. Hamilton, James A. Grant, Howard M. Poland and J. F. Kümmel, Assistants, have been employed in this work for varying periods during the year.

Publications.—The Annual Report of the State Geologist for 1904 (pp. 317 + ix, plates XIX, figures in text 18) was issued in June, and promptly distributed to those upon the mailing list of the Survey. It contained the following papers:

Administrative Report.

A Brief General Account of Fossil Fishes.—C. R. Eastman.

The Triassic Fishes of New Jersey.—C. R. Eastman.

The Fauna of the Cliffwood Clays.—Stuart Weller.

The Classification of the Upper Cretaceous Formations and Faunas of New Jersey.—Stuart Weller.

The Talc Deposits of Phillipsburg, N. J., and Easton, Pa.—F. B. Peck.

A Report upon Some Molding Sands of New Jersey.—Henry B. Kümmel, assisted by S. H. Hamilton.

Progress of Work in the Pre-Cambrian Rocks.—A. C. Spencer.

East Orange Wells at White Oak Ridge, Essex County.—C. C. Vermeule.

Forest Fires in New Jersey during 1904.—F. R. Meier.

The Mining Industry.—Henry B. Kümmel.

Early in the year the Boonton, Dover-Stanhope and Chester sheets of the large scale atlas were received from the lithographer and placed on sale. Twenty-one sheets on this scale are now completed and ready for distribution.

In April, Sheet 23, northern Bergen and Passaic counties, with adjoining portions of New York State, and Sheet 28, the region from Trenton to New Brunswick, were issued, and just before the close of the fiscal year (October 31st), Sheet 33, Barnegat Bay and the eastern portion of Ocean County, and Sheet 37, Cape May County, were published. All of these sheets are on the scale of one inch per mile, and take the place of the older sheets, which were somewhat differently arranged. Complete revision of all cultural features and some changes in the topography were made preparatory to the publication of these new editions.

Distribution.—During the year the demand for reports and maps has been active, and the sales of the latter show a marked and gratifying increase over the figures for 1904. This is particularly true in the case of the large scale sheets, the increase being nearly fifty per cent., and the sales exceeding for the first time those of the one-inch maps. This increase has been made in the face of competition of the National Survey, whose maps are much cheaper than the State Survey's, particularly at wholesale, and by numerous map-publishing firms which do not hesitate to appropriate this work bodily in preparing their State and county atlases. That the sales have, therefore, increased at all is indicative of the value which the map-using public puts upon this phase of the Survey's work. Frequent orders are received for large-scale sheets not yet published, and requests made that certain sheets be issued. In response to this demand three new sheets, covering the region from Far Hills to New Brunswick, will soon be printed.

Below is shown in tabular form the distribution of reports and maps for 1904 and 1905:

	1904.		*1905.*	
Annual Report for 1904,			3,279	copies
" " " 1903,	3,691	copies	165	"
" " " 1902,	155	"	71	"
" " " 1901,	73	"	60	"
" " " 1900,	89	"	77	"
" " " 1899,	75	"	60	"
" Reports between 1883-1898,	810	"	715	"
Final Reports, Vol. II,	244	"	238	"
" " Vol. III,	138	"	151	"
" " Vol. IV,	70	"	136	"
" " Vol. V,	217	"	175	"
" " Vol. VI,	876	"	985	"
Other Reports,	461	"	126	"
Total Reports,	6,899	"	6,238	"
Map sheets—				
Scale 1 inch per mile,	1,408		1,245	
Scale 2,000 feet per inch,	1,367		1,942	
Total map sheets,	2,775		3,187	

Library.—The library of the Survey grows steadily, chiefly by exchanges. During the past year the accessions were 48 bound volumes, 150 unbound volumes, 138 pamphlets, 70 maps.

Collections.—During the summer considerable attention was given to the mineralogical and geological collections of the Survey. Some material was of no value and was thrown away. Some was used in making up collections for the use of the schools of the State, and a beginning was made in arranging, labelling and cataloguing the remainder, so that all the specimens of the Survey may be properly recorded in a permanent accession book. This work is not completed, but will be carried on as opportunity arises.

In May the Board of Managers authorized the preparation, from the duplicate specimens of the Survey, of collections of rocks, minerals, fossils and ores for distribution to the High Schools of the State. Thirty collections of 170 specimens each were made up. In each set the first 110 specimens were essentially identical, the balance being duplicates and odd specimens, of which there were not enough to go round. White cardboard trays were provided for all, except the powdered specimens, which were packed in small glass bottles, or cardboard boxes. Printed labels, giving the specimen number, its name, geological period, occurrences in the State and a brief description, were prepared.

The collections were arranged to illustrate the geology of New Jersey. Under each of the main divisions of geologic time, beginning with the oldest, were placed the common rock types, the important ores, the more striking minerals and examples of the common fossils. The character of the collections is well shown by the subjoined list of specimens.

LIST OF SPECIMENS IN THE SCHOOL COLLECTIONS.

Pre-Cambrian.

No. 1. Granite, variety pegmatite.
No. 2. Granite or granitoid gneiss.
No. 3. Gneiss—coarse grained.
No. 4. Gneiss—fine grained.
No. 5. Magnetite-bearing schist.
No. 6. Tailings after separation of magnetite from No. 5.
No. 7. Magnetite after concentration from No. 5.
No. 8. Magnetite showing cleavage.
No. 9. Massive magnetite.
No. 10. Pyrrhotite or pyrite.
No. 11. Graphite.
No. 12. Pyroxene.
No. 13. Biotite.
No. 14. Crystalline limestone.
No. 15. Dike rock in crystalline limestone.
No. 16. Zinc ore, composed of franklinite, willemite and zincite, in limestone.
No. 17. Franklinite after electrical concentration.
No. 18. Willemite, separated from the limestone.
No. 19. Limestone tailings from No. 16.
No. 21. Calcite crystals.
No. 22. Ophiolite.
No. 23. Talc.

No. 24. Hematite.
No. 25. Aragonite.
No. 26. Serpentine.
No. 27. Brucite.
No. 28. Nemalite.
No. 29. Marmolite.
No. 30. Crysotile or Asbestos.
No. 31. Molybdenite.
No. 32. Magnesite.
No. 33. Hydromagnesite.

Paleozoic.

No. 34. Hardyston quartzite.
No. 35. Quartzite.
No. 36. Kittatinny limestone (blue).
No. 37. Kittatinny limestone (pink).
No. 38. Trenton limestone conglomerate.
No. 39. Trenton limestone—cement rock.
No. 40. Ground cement rock.
No. 41. Portland cement clinker.
No. 42. Portland cement.
No. 43. Slickensided rock.
No. 44. Hudson River slate.
No. 45. Hudson River slate (weathered).
No. 46. Eleolite—syenite.
No. 47. Shawangunk (Oneida) conglomerate.
No. 48. Decomposed Shawangunk sandstone.
No. 49. Medina sandstone.
No. 50. Decker Ferry limestone.
No. 51. Rondout limestone.
No. 52. Manlius limestone.
No. 53. Coeymans limestone.
No. 54. Gypidula (Pentamerus) galæata.
No. 55. Esopus (Cauda Galli) grit.
No. 56. Onondaga (Corniferous) limestone.

Mesozoic.—Triassic.

No. 57. Stockton arkose.
No. 58. Lockatong argillite.
No. 59. Brunswick shales.
No. 60. Brunswick sandstone.
No. 61. Baked shales.
No. 62. Trap rock—intrusive.
No. 63. Trap rock—extrusive.
No. 64. Weathered trap rock.
No. 65. Fossil fish.
No. 66. Fossil fish.
No. 67. Calcite crystals.
No. 68. Stilbite crystals.

No. 69. Natrolite crystals.
No. 70. Native copper or copper ore.

Mesozoic.—Cretaceous.

No. 71. Fire clay.
No. 72. Saggar clay.
No. 73. Brick clay.
No. 74. Pyrite balls.
No. 75. Lignite.
No. 76. Merchantville clay (brick).
No. 77. Columbus sand.
No. 78. Greensand marl.
No. 79. Redbank sand.
No. 80. Vincentown limesand.
No. 81. Vincentown limesand.
No. 82. Belemnitella.
No. 83. Exogyra costata.
No. 84. Gryphæa vesicularis.
No. 85. Other Upper Cretaceous fossils.
No. 86. Vivianite.
No. 87. Terebratula Harlani.
No. 88. Terebratella plicata.
No. 89. Ostrea larva.
No. 90. Dinosaur bone (fragments).

Cenozoic.

No. 91. Shark River marl—Eocene.
No. 92. Fossil shell—genus Venus.
No. 93. Miocene fossils.
No. 94. Miocene sand.
No. 95. Cohansey sand—Pliocene (?).
No. 96. Cohansey sandstone—Pliocene (?).

Pleistocene.

No. 97. Pensauken gravel.
No. 98. Fossil shells—Genus, Unio.
No. 99. Striated glacial pebble.
No. 100. Conglomerate (late Pleistocene).
No. 101. Glacial clay.
No. 102. Clay stones.
No. 103. Waterworn pebbles.
No. 104. Infusorial earth.
No. 105. Calcareous marl.
No. 106. Peat.
No. 107. Fresh-water mollusks.
No. 108. Sea sand.
No. 109. Marine mollusks.
No. 110. Sea weed.
Nos. 111 to 170. In part duplicates of the above or other material, no two collections being alike.

Circular letters regarding the collections were sent to more than sixty high schools and academies, and in response to their applications sets have been sent to the following schools:

Westfield, Woodbridge, Kearny, Red Bank, Plainfield, Flemington, Montclair, Phillipsburg, Asbury Park, Long Branch, Bridgeton, Atlantic City, Morristown, Newark, Vineland, Hackensack, Rutherford, New Brunswick, Roselle Park, Belvidere, West Jersey Academy, State Normal School, Montclair Military Academy; total, 23. Seven sets are still undistributed, and can be had upon application and cost of preparation.[1]

Through the co-operation of the State Museum Commissioners it was possible to furnish nine schools with oak cases for the storage and display of the collections. The cases were those used by the Survey for its exhibit at St. Louis. The price of the cases was fixed at $25 per set. The expense of preparing, labelling and packing the collections was $25 each set, and they were furnished the schools at this figure, no charge being made for the original expense of collecting the material.

TOPOGRAPHIC WORK.

The topographic work has continued to be in charge of C. C. Vermeule, with P. D. Staats, W. A. Coriell, G. E. Jenkins, H. E. Jenkins, L. M. Young, G. W. Conover, P. S. Cowdin, A. Atkinson, George Coslett, R. C. Rice and C. E. Bruen as assistants for varying periods.

Field Work.—The field work has embraced the revision of Sheets 33, 37 and a portion of 25, about 930 square miles. On sheets 33 and 37, covering Barnegat Bay and Cape May, respectively, extensive changes were necessary, due to the rapid upbuilding and development of parts of the coast and also to the marked changes in outline of some beaches, particularly in the vicinity of the inlets. On Sheet 25 there were many additions in the way of roads and new towns, and also changes in the topography where the re-survey showed poor sketching originally.

[1]Since writing the above Trenton and North Plainfield have received sets.

Office Work.—The drawings for photo-lithographing the Pluckemin, Somerville, New Brunswick, Dover (in part) and Chester (in part) sheets (370 square miles) were made during the year. So, too, the changes on Sheets 33 and 37 (700 square miles) were transcribed and copy for the engraver prepared. In addition to this, seven sheets (1,630 square miles) were read in proof.

There are now published twenty-one sheets on the large scale and three more are in the hands of the engraver. The greatly increased demand for these maps indicates their popularity and warrants their preparation. The change in arrangement of the one-inch-per-mile maps, and the substitution of a non-overlapping set for the older arrangement, commenced two years ago, has progressed steadily. Ten sheets have been issued to date, taking the place of an equal number now out of print. One or two more will probably be published during the coming year and others as rapidly as the older editions become exhausted.

PREVENTION OF FLOODS ON THE PASSAIC RIVER.

In the Annual Report for 1903, Mr. Vermeule, in reporting upon the great flood in October of that year, suggested two plans for preventing a recurrence of the excessive high water. One of them provided for the construction of a dam at Little Falls, with a permanent opening, of such size that the volume of water passing would never exceed the capacity of the lower channel. The other plan called for a dam with gates, which, except in time of flood, would be kept closed. In this way the low, flat country along the Passaic River above Little Falls and as far as Chatham would be flooded and transformed into a lake and reservoir.

Much interest was aroused by this suggestion, and the matter has been actively taken up by land-owners of that vicinity. The Survey has received many requests for copies of Mr. Vermeule's report, and also for further information regarding the area to be flooded, the depths of water, the character of the shores, the prospective benefits and damages to property and the cost of the dam.

There is a marked interest in this project of the Passaic, not merely because flood control has become an urgent necessity, but for the further reason that incidentally to the control of the floods the river may be very safely utilized for power at Paterson and Dundee, and furthermore that the increased discharge of the river, which may be produced during the dry season from draft upon the proposed storage lake, will in some degree relieve the unsanitary conditions below Little Falls.

A further object which appears to appeal strongly to many of the residents in the Passaic Valley and above Little Falls is one which may, at first sight, seem of less utility than it really is, namely, the enhancement of the beauty of this part of the valley by the addition of a large area of water surface. While at first thought this may appear to be a sentimental consideration, as a matter of fact it is not so regarded by the owners of property, a large majority of whom appear to believe that the proposed lake will add greatly to real estate values in all that part of the valley which overlooks the proposed lake.

Another consideration which has great weight with certain of the people in that vicinity is that the necessity for drainage of 20,000 acres of wet land will be done away with, as this land will all be submerged. This drainage problem is one that was taken up by the Geological Survey some years ago under the Drainage Act, which makes it the duty of the Survey to investigate and report upon such work at the request of the owners of the property to be drained.

The work was started under the law at the request of property-owners in the valley, but for reasons which need not be enumerated, after expending a considerable amount of money, the Drainage Commissioners found it impossible to proceed further. In consequence, matters have been left in a most unsatisfactory condition, financially and otherwise, and it would be considerable relief to many persons if the whole problem could be merged into and eliminated by the proposed storage lake.

In view of these facts and the interest shown by numerous prominent residents of the valley the recent work of the Survey has been directed to procuring data for definite answers to the questions involved. So far as the work has been completed it indicates that the most desirable flow line is at about elevation 190 for a maximum. At this elevation the area of the proposed lake would be 33,536 acres. At this level less than 24 per cent. of the lake would be of a less depth than 10 feet, and not more than 15 per cent. would be 6 feet or less in depth. These figures for shallow flowage compare very favorably with other artificial bodies of water which are sanitary and entirely unobjectionable, and even these amounts of shallow flowage may be materially decreased by moderate expenditure. Consequently it would appear that the objection of shallow flowage is not well founded.

GEOLOGIC INVESTIGATIONS.

Peat Deposits.—The use of peat as fuel is well established in many countries in Europe and to a less extent in portions of Canada, but until recently it was practically unknown in the United States. Sporadic attempts had been made to utilize it, some of them in New Jersey, as was noted by Dr. Cook, in 1868,[1] but these were evidently not profitable, since its use was given up. More recently, however, numerous inquiries have been made of the State Geologist for information regarding the occurrence of workable peat deposits within the State, showing that the attention of capitalists is being directed to the utilization of this material for fuel or other purposes.

Accordingly, the latter part of June, W. E. McCourt began the investigation of the swamps and meadows of the northern part of the State, and the collection of samples of peat. These were sent to Dr. C. W. Parmelee, at New Brunswick, under whose direction laboratory tests have been made to determine the value of this material for fuel and other purposes. The results of these studies have been embodied in a joint paper, which accompanies this report.

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[1] Geology of New Jersey, 1868, p. 699.

Peat is a product due to the accumulation of partially decayed mosses, aquatic plants and grasses with roots, twigs, branches and frequently the trunks of trees. This accumulation is generally found in boggy places, sometimes under water, and frequently it is in the process of growth. In many places, it is of great depth, as much as 60 feet having been recorded in certain foreign localities, while from 5 to 12 feet is very common. Under certain favorable climatic conditions, peat grows. "In the Valley of the Somme, in France, 3 feet grew in 30 to 40 years. On a moor in Hanover a layer of peat from 4 to 6 feet thick formed in about 30 years."[1]

As the result of this examination it appears that many of the swamps of northern New Jersey contain beds of peat of commercial importance. In many cases these lie within easy reach of large centers of population and near to railroads. Probably the deposits of the Pequest Meadows, in Warren County, and the meadows along the Passaic River and its tributaries, in Morris County, are the most important because of their size and location. Already several plants near Danville and Lincoln Park have been established to dig peat either for fuel or fertilizer. When one considers the wide distribution of peat, as shown by the map prepared by Mr. McCourt, the extent of the bogs, their nearness to markets, and the readiness with which the peat can be dug, the value of these deposits is apparent.

To determine the value of these deposits for fuel the laboratory investigation has included a determination of the amount of moisture, the amount of ash, the amount of coke, and the calorific power, that is, the amount of heat which a unit mass will develop when burned. According to different authorities[2] various fuels will give the following tests:

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[1] Sir A. Geikie, Text Book of Geology, 3d Ed., p. 443.

[2] Poole, The Calorific Power of Fuels, pp. 246, 219, 245; also Thorp, Dict. of Applied Chemistry, vol. ii, p. 158.

	Ash per cent.	Calorics.[1]	B. T. U.[2]
Wood—oak,	0.37	4620	8316
Wood—pine,	0.37	5085	9153
Coke—Connellsville, Pa.,	9.74	8020	14436
Coke—average,	....	7050	....
Bituminous—average,	....	7500	....
Bituminous Coal—Pocohontas, W. Va.,	6.65	8751	15739
Bituminous Coal—Clearfield, Pa.,	7.60	7246	13043
Anthracite—Avondale, Pa.,	6.91	7889	14200
Peat—Bohemia,	7.27	3246	5843
Peat—Ireland-dry,	4.00	5700	10260
Peat—Bohemia,	7.72	3774	6793
Peat, with 20 per cent. water,	....	3600	....
Peat, dried,	....	4800	....

Peats from this State show a wide range, as is usual, but a number of very excellent results have been obtained, some giving over 9,000 B. T. U., and a number over 8,000 B. T. U. It is generally accepted that in comparison with coal, the thermal ratio is 1 to 1:8; that is, coal is somewhat over one and three-quarter times as efficient, weight for weight, in generating heat provided total consumption is obtained. As an actual fact, in coal as ordinarily burned, there is a large percentage of waste through incomplete combustion, whereas, it is claimed in favor of peat that this loss is relatively much less. In spite of this, however, it is questionable whether peat is a fuel which will bear transportation for any considerable distance and compete with coal. On the other hand, in the immediate vicinity of the bogs it may be considered a cheap fuel, and, as has been suggested, it may be advantageous to locate electric generating plants on extensive bogs for the cheap generation of light and power, which may readily be distributed for many miles.

Besides the use as raw peat, good results have been had by coking, and saving the products. The gases may be consumed as fuel in the process of coking, the ammonia salts recovered,

[1] A Calorie is the amount of heat necessary to raise the temperature of one kilogram of water from zero to one degree Centigrade.

[2] B. T. U. (British Thermal Unit) is the amount of heat necessary to raise the temperature of one pound of pure water one degree Fahrenheit, at its greatest density.

the acetic acid and paraffin oil saved, and the coke marketed as a fuel of considerable increased value. The calorific value is said to be from 6,500 to 7,000. Peat coke, or charcoal, is now being produced near New Haven, Conn., and marketed for household use in competition with cannel coal. It sells at ten dollars per ton.

Heretofore the chief difficulty in the way of the successful exploitation of peat deposits for fuel lay in the difficulty of eliminating the large amount of water present and the lack of successful machinery for preparing it for market. To a large extent this need has been supplied and various types of machinery are in successful operation in Germany. The difficulty of eliminating the water effectively, cheaply and rapidly is still a real one, but not insuperable. As is shown by Mr. McCourt, at the plant near Lincoln Park, the peat is dug, thrown into a mill in which it is mixed, kneaded and forced out through a die making two bars (4 inches square) which are cut off in small pieces and placed on drying racks for several days. When dry the peat can be handled without soiling one's hands or breaking.

The younger varieties of peat are more or less fibrous, and have a smaller fuel value. When properly treated, however, it is a highly absorbent material, and is extensively used for litter for cattle. "Of twelve varieties examined by Nessler, the power to absorb water ranged from 200 to 800 per cent., while the absorptive power of the straw of summer rye was 315 per cent."[1] Besides this property, it is cleaner than the usual bedding material, retains the ammonia of the urine, and so increases the value of the latter as a manure, and keeps the stables sweeter. Considerable quantities of prepared moss litter are annually imported by this country, and used with great satisfaction by breweries, stock farms, etc. It is sold in New York for ten to fifteen dollars per ton. Peat usually contains a small amount of nitrogen, sometimes reaching 3 per cent. in amount. It is readily apparent, therefore, that its use as a litter is more advantageous than straw, because its manurial value is its own

[1] Storer, Agricultural Chemistry II: 272.

nitrogen content plus that of the ammonia absorbed from the urine.

Peat fibre has also found use in the manufacture of surgical bandages, cloths, paper stock, a superior packing material, especially for perishable goods, and containers of liquids. The peat powder is used for a disinfectant and deodorizer.

For details regarding the location and character of the various peat deposits, as well as the uses to which peat may be put, reference must be made to the full report of Messrs. Parmelee and McCourt.

Sands.—A brief report upon some molding sands was made in the Report for 1904. During the past year additional samples of molding sands were collected, as well as samples of various other grades. During the coming year these will be examined physically and chemically in the laboratory. The occurrence of banks of clean quartz sand in localities of ready accessibility by rail or water is of increasing importance in New Jersey. The demand for good sand for filter work, furnace practice, asphalt and concrete is steadily increasing, while the rapidly growing sand-lime brick industry is creating a new use for large amounts. So, too, sand free from iron is always in good demand at the glass factories. So widespread, however, are the deposits and so low the average price, that cheap shipping facilities are essential.

Building Stone.—In connection with his work as student at Cornell University, Mr. McCourt early in the year carried out an interesting series of experiments on the effect of heat on building stones, and their ability or failure to withstand great and sudden changes of temperature without cracking. Although his results were definite and important so far as they went, yet they were limited to comparatively few specimens, and it was decided to continue them during the coming year. He spent a short time in the field collecting additional specimens and will complete the work and compile the results for publication in a future report.

Trap rock and copper deposits.—Since July 1st, Prof. J. Volney Lewis, of Rutgers College, has had in hand an investigation of the petrology and economic geology of the trap rocks and copper deposits of the Newark formation. This work is supplementary to that previously done by the Survey in the same field. The chief objects in view have been (1) the study of the chemical and mineralogical composition of all varieties of the traps, and their origin, classification, distribution, and uses; (2) the determination of the character and modes of occurrence of the copper-bearing minerals, and their origin and economic importance. The field work was substantially completed before the end of the year, but the microscopic examination of specimens and chemical analysis have still to be made. It is hoped, however, to publish the results of this investigation in the present report.

Iron ores.—The customary canvass was made of the iron mines early in January in order to learn the extent of mining operations during 1904, and the results were published in the report for that year. During the present year a number of old mines have been reopened and it is anticipated that the statistics of ore production for 1905 will show a gratifying increase over those of 1904.

Since the beginning of the Survey in 1864, much attention has been given to the iron-mining industry, and notes regarding the various mines are scattered through the reports of the Survey, many of which are no longer available for distribution. A thoroughly satisfactory discussion of the ores of the State has, however, never been written, although a part of the plans of the State Geologist for some time.

During the past three years the United States Geological Survey has had in the field several parties employed in mapping of the crystalline rocks of the New Jersey Highlands. In the course of this work much information was gathered with reference to the magnetite mines, and special studies were made of many of them to secure data to serve as a basis for an explanation of the origin of the ores.

The time seemed to be opportune for the publication of a summary statement of the facts known with respect to the iron ore deposits of the State, and for a revision of the views held regarding their mode of occurrence, where such revision may be found to be made necessary by recent work. The services of Dr. W. S.

Bayley were therefore secured to write a general report on the iron ores of the State, to be based largely upon the Annual Reports of this Survey. Dr. Bayley has had charge of the Governmen work in the crystalline rocks of the Lake Hopatcong, Somerville, High Bridge, Hackettstown, Easton, and Greenwood Lake areas, and is therefore familiar with the character of the material of the old mines over a large portion of the Highland area, so far as this material is represented in their dumps.

The proposed report will contain a brief summary of the history of iron mining in the State, a description of the chemical character of the ores and of their modes of occurrence, and a brief outline of the life of each of the mines that has contributed to the output of ore during the past 50 years. It will be illustrated by maps of the important ore-producing centers and a general map showing the location of all the mines that have produced ore on a commercial scale and all the mine openings that have yielded ore in small quantities.

Since most of the mines that were formerly active producers have been closed for many years, it is not expected that the report will contain much new information. It will, however, gather into one place all the information that is now scattered through the various Annual Reports of the State Survey and other publications, and present them in convenient form for reference. Although to be largely a compilation it is hoped that the report will satisfy the need for a comprehensive statement of the iron ore resources of the State, which need is becoming more and more strongly felt as the supply of the back issues of the Annual Reports containing notes on the magnetite mines becomes more nearly exhausted.

Stratigraphical work.—During the past field season conferences have been held in the field with various workers on the United States Geological Survey relative to the interpretation of phenomena and the harmonizing of conclusions in New Jersey and adjoining States. In Warren and Sussex counties the questions related to the classification of certain obscure beds, and the origin of the iron and zinc ores. In Monmouth County the classification of certain sands in the vicinity of Long Branch was in question, and the conclusions of the State Survey were finally accepted as correct. The differences in classification of the Cretaceous for New Jersey and Maryland were also adjusted. The minor divisions so completely developed in New Jersey are recognized and will be mapped, but are grouped so as to conform to the larger subdivisions which alone can be identified farther south. This removes the difficulties standing in the way of prompt publication of the geologic folios by the two Surveys.

Paleontology.—During the year Dr. Stuart Weller has continued his studies of the Cretaceous faunas collected during previous seasons. The proper completion of this work necessitates the comparison of our collections with those of the National Survey at Washington, and with similar forms in the museums at Baltimore, Philadelphia, New Brunswick and New York. The final results of Dr. Weller's work will be published as Volume IV of the Paleontology Series.

Mr. Edward W. Berry has made collections of fossil plants from the clays at Cliffwood and vicinity, and also from points along the Delaware from Trenton southward. In presenting his results for publication he has prepared a general account of fossil plants and their value to the geologist, as well as a description of the new forms discovered in this work. Those who do not care to undertake the study of these forms will, nevertheless, find the first part of his report of interest.

CHANGES ALONG THE COAST.

The coast of New Jersey from Sandy Hook to Cape May is of great importance in many respects. It forms the southern approach to New York Harbor, and the large tonnage between New York and all West Indian, Gulf, South and Central American ports passes close at hand. Although from Sandy Hook to Delaware Breakwater is only 134 miles, records of the United States Life-Saving Service show more disasters on this coast than on any other of equal extent in the United States. During the past decade 332 strandings occurred, more than one-half of them within range of the Absecon light at Atlantic City. During a single year (1903-04) nearly two millions of property ($1,999,-745) were placed in jeopardy by accident along this coast, although, owing to the efficiency of the Life-Saving Service, the actual loss was less than $75,000, or only 3.75 per cent. These figures warrant the statement that the New Jersey coast in its present condition is a menace to commerce, notwithstanding the light-houses and life-guards which guard it.

This danger is greatly increased by the absence of any harbors of refuge along the coast, and the shallow, tortuous, shifting channels at the various inlets. The presence of well-defined and fixed channels at Absecon, Barnegat, and other inlets along the coast would go far to eliminating these dangers.

Although certain features of the coast are a menace to commerce, yet other features make it of inestimable value as a place for rest and recreation. It is hardly necessary to emphasize the importance of the summer resorts along the coast. Long Branch, Asbury Park, Ocean Grove, Atlantic City, and Cape May are known from one end of the country to the other. The growth in popularity and wealth of these and other places has been marvelous, and yet it has been accomplished in spite of forces constantly tending to change the outline of the shore, to shift bars and channels and render insecure all titles based upon former position of inlets or coast line. It is difficult for one unfamiliar with the action of waves and currents to appreciate what great changes may be wrought upon the sand beaches during even a single storm or by slow accretion in one locality and equally slow wasting at another. The channels of the inlets are constantly changing in depth and location through certain cycles and the inlets themselves are slowly shifting their position. In the aggregate vast sums of money have been spent to counteract these changes and to protect the beaches from destruction, but in large part to no permanent good. This is in part due to the absence of any concerted action embracing considerable areas and in part to improper plans followed.

In the Annual Report of the State Geologist for 1885, Dr. Cook published many details showing that there had been within comparatively recent geological time a considerable subsidence of the coast, and that the beaches are in general being cut away on the ocean side and by the blowing of sand by easterly winds they are encroaching on the tide marshes behind (west) them. Locally, there has been an eastwardly growth by the current-borne accretion to the beach front, but these are the exception.

During the past summer, Prof. Lewis M. Haupt, who for many years has made a special study of coast changes and wave and current action, gave some attention to recent changes upon the New Jersey coast and prepared for the Survey a paper which accompanies this report. Several features of his report are of special significance. In addition to the recording the successive changes which have taken place at the various inlets, he has put on record a number of instances where remedial works constructed at great expense have utterly failed to accomplish the desired end because of improper design or location. They have been of value as striking examples of the futility of combating the waves and currents on wrong principles, and are warnings of how not to do it. Apart from this the money spent has been worse than wasted, since these failures have in large degree hindered the adoption of other plans based on wider experience.

Professor Haupt furthermore presents good evidence to show that by properly constructed jetties, so shaped and placed as to guide the currents in desired directions, the powerful action of tidal scour may be made effective to remove bars and keep open channels. Results attained elsewhere show that such jetties may be constructed at but a fraction of the cost of works heretofore contemplated, and at expenditures not above the resources of the communities most directly interested.

It is also pointed out that owing to the enormous demands made upon the National Treasury for river and harbor improvement, demands which cannot be fully met for years to come, there is small chance of obtaining National aid for improvement along our coast, since the tonnage is restricted by bars. To a certain extent Congress has established the policy of permitting local interests to undertake improvements of local character, but the way is so hedged about with restrictions that little can be done. There is need for further legislation by Congress, giving more power to State and municipal governments to initiate and carry forward improvements in navigable waters, particularly in those cases which have been reported as not of sufficient National importance to warrant National improvement. Such has been the case with remedial measures at Absecon Inlet and others on the New Jersey coast. As the case now stands the Government engineers have reported adversely for Government aid, and yet local authorities are not free to undertake the work themselves, even in isolated positions, without Governmental approval of plans. Under these circumstances there is much justice in the demand that Congress confer upon localities the right to carry forward improvements in navigable waters, which have been denied National aid, according to local plans and without regard to the approval or disapproval of the War Department. The policy which refuses Government aid, and forbids local endeavor, except under conditions which are prohibitory, when applied to New Jersey, has abandoned the inlets and bays of our coast to the vagaries of the waves and currents, and will make their improvement under existing conditions forever impossible. All persons to whom the fullest development of the State's beaches, bays and inlets is a matter of importance should unite in urging their Senators and Representatives to secure from Congress legislation permitting localities to make such improvements, if desired, at their own expense according to their own plans, and to charge tolls thereon. Such a policy would accord with that under which the enormous railroad systems and most of the waterways were originally built by private capital as commercial enterprises.

CO-OPERATION WITH THE UNITED STATES GEOLOGICAL SURVEY.

Drs. A. C. Spencer and W. S. Bayley, of the United States Geological Survey, have continued their work in New Jersey during the past field season. Dr. Spencer has considered particularly questions relating to the origin of the iron and zinc ores, and in seeking their solution has visited the mines not only of this State but of adjoining regions, even as far north as the Adirondacks. Dr. Bayley has continued the detailed study of the Pre-Cambrian rocks of the Highland belt. It is expected that both the Franklin folio and the Raritan folio will soon be completed and sent to the engraver.

During the summer, on behalf of the State Survey, Mr. Salisbury completed the manuscript and maps of the surface geology for the Philadelphia folio, a large part of which lies within the limits of New Jersey. It was at once forwarded to the Director of the United States Survey, in accordance with the agreement between the two organizations. Considerable work was done upon the Raritan folio also, so that the State's share of the joint work is well in hand.

FORESTRY.

By act of Legislature in 1894, the Geological Survey was charged with the duty of ascertaining the extent, location and character of the wild or forest lands of the State and the advantages of their retention in forest, the relations of forests as climatic factors, and conservers of the rainfall and stream flow, and the forest policy of other States and countries. Reports on these subjects were published in the Annual Reports for 1894, 1895, 1897, and a final report in 1899, accompanied by seven forestry maps. In 1901 the regular annual appropriation of the Survey was slightly increased in order that the forestry investigation might be continued as a part of the regular work of this Department.

It was early recognized, even before the initiation of the forestry surveys, that the prevalence of forest fires particularly in South Jersey was the greatest drawback to the improvement and successful conduct of the forests. At the same time it was found that there was in general a deplorable lack of interest in their prevention, particularly in regions where they were most prevalent, due in part to the widespread belief that they did very little damage and that the forests were not worth saving. It was not altogether easy to combat this erroneous belief through lack of any accurate and systematic calculations of the actual money damage done. Accordingly for a number of years the Survey, through an expert forester, has made a careful examination each season of the forest fires, their extent, severity, character of timber burned and damage done. Detailed statements were published in the Annual Reports for 1902, 1903 and 1904 showing that on conservative estimates the loss by forest fire during those three years was $668,480.00.

It has been shown time and again in these reports that conditions are such that these fires cannot be successfully prevented by private and individual effort. So long as thousands of acres of timberland are swept every year by fire, there is no inducement for the progressive landowner to seek to better his forest holdings, or to practice conservative methods of forestry. With the successful solution of the fire problem in South Jersey, the chief problem of forest protection and forest reproduction will be solved, but it has been the unanimous belief of all those who have given the problem any serious consideration that something more than private effort was necessary.

The last Legislature in a measure recognized this fact and enacted a law establishing a State Forest Reservation Commission with power to acquire land and establish State Reservations for forestry purposes. Although this Commission is not a part of the Geological Survey, it is in a measure closely allied to it, from the fact that the State Geologist is *ex-officio* executive officer of the Forestry Commission. This ensures that the forestry work of the two departments will not conflict but will be in harmony, and that all the results and experience of the Survey in forestry work will be available for the Forestry Commission.

During the past year Mr. F. R. Meier has continued his studies of the white cedar swamps of the State and his measurements of the stand therein. These studies have taken much more time than was anticipated, and the investigation has grown in scope somewhat as it progressed. While this has undoubtedly increased the value of the work, it has made it necessary to revisit some of the earlier regions studied and so has prolonged the time needed to complete it. It is hoped, however, to complete the work in time to have it published with this report.

PART I.

Changes Along the New Jersey Coast.

By LEWIS M. HAUPT, C. E.

Changes Along the New Jersey Coast.

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CONTENTS.

GENERAL CHARACTERISTICS.

Sixty-five per cent. of the boundary of New Jersey is formed of navigable waters. For 319 of the 487 miles, which constitute the boundary, the waters of the Hudson River, Kill van Kull, Arthur Kill, Raritan Bay, Atlantic Ocean, Delaware Bay and lower Delaware River afford waterways navigable by craft of varying draft. On the east, south and west (as far north as

Trenton) the boundaries of the State are marked by tidal waters.

On the east from the northern State line to Bergen Point is the majestic estuary of the Hudson River with depths locally exceeding 150 feet, but limited seaward by bars to depths of 35 feet or less. From Bergen Point to Perth Amboy is the narrow, winding passage of Kill van Kull and Arthur Kill with minimum depths of 9 or 10 feet at mean low water. Still farther south, Raritan Bay with low flat shores, affords access to the smaller ocean-going craft, but is not open to large vessels.

From Sandy Hook to Cape May the open Atlantic forms the boundary and the shore presents somewhat contrasted features. From Monmouth Beach to Bay Head (19 miles) the waves beat against the main land. The projecting headlands have been cut back and the intervening bays have been closed by sand bars until the line of the shore is nearly straight, with sea cliffs up to 40 feet in height. North of Monmouth Beach the main land is protected from the ocean by the sand reef or so-called "beach," which, beginning at the sea cliff to the south, terminates in Sandy Hook and forms a barrier across the mouths of the Shrewsbury and Navesink rivers and in front (east) of Navesink Highlands.

South of Bay Head the coast is marked by a series of sand reefs or beaches from 2 to 8 miles from the main land and separated from it by comparatively shallow bays or lagoons. These beaches are generally less than half a mile in width and are characterized by low hills of wind-blown sand. Low weedy islands and marshy shores distinguish the bays, which communicate with each other by narrow channels called "thorofares" and with the ocean by tidal inlets across the sand reefs. While these inlets are sometimes a mile or more in width, yet they are commonly obstructed on both the ocean and bay sides by submerged bars across which the channel is constantly shifting. Moreover, owing to the waves and tidal currents the beaches are wasting in places, and growing in others; and the inlets as a whole are slowly changing their location, at rates up to 100 feet per year. As will appear later, the changes which have taken place and are still going on at the inlets are of great importance, legally as well as commercially, while the best interests of the State demand that, so far as possible, they be prevented. Barnegat, Little Egg Harbor, Great Bay, Absecon (including Reed's) and Great Egg Harbor are the largest of these bays, and, of the inlets, Barnegat, New, Absecon, Egg Harbor and Hereford are the most important.

On the west from Cape May to Trenton the waters of Delaware bay and river form the boundary. The shores of the bay are low and marshy, and, while the lower river is navigable to ocean-going steamships as far as Camden, the channel is tortuous. Although the head of navigation is at Trenton, yet this part of the river is available for small vessels only, owing to the shallow bars which obstruct the channel.

DANGEROUS CHARACTER OF THE COAST.

Absence of Good Harbors.—In spite, however, of the fact that so much of the State is surrounded by navigable waters, there are virtually but two deep-water terminals, those of Jersey City and Gloucester, access to which is limited by the depth of water across the bar at the entrance to New York Bay at Sandy Hook, and by the more or less obstructed course of the Delaware River. The approach to Perth Amboy is hampered by shoals near the upper end of Raritan Bay and the whole ocean coast from Sandy Hook to Cape May is beset with shoals and is justly regarded as one of the most dangerous sections of the United States, as the record will show.

The very large tonnage plying between New York and southern ports, the West Indies, the Gulf, and Central and South American Republics is annually placed in jeopardy because of the absence of harbors of refuge on this coast, in spite of the urgent demands which have been made on the General Government for many years past. Under these circumstances it would seem desirable that the State should make provision for the opening of a safe refuge for the benefit of her own citizens, that her products may be sent direct to the markets of the world, and supplies be secured at the lowest rates of transportation.

The General Government has, it is true, established a Light-house and Life-saving Service along the Atlantic seaboard, but this does not afford a haven of refuge to prevent casualties so much as a remedy "after the fact" to rescue the lives and property endangered. In this case the office of the light-house is not so much to attract to a safe harbor as to ward off from a dangerous coast. With a disabled vessel, however, on a lee shore, it is not always possible to heed the warning which so often comes too late.

That these statements are not mere idle platitudes may possibly be forcibly impressed by some eloquent statistics taken from the last report of the Superintendent of the Life-saving Service for 1904.

Record of Marine Casualties in the Decade (1895–1904).—It is an appalling fact that, although the run from Sandy Hook light to the Delaware Breakwater is but about 134 miles, there are believed to be more disasters on this stretch of water than on any other of equal length in the United States. The maximum is reached in the vicinity of Absecon Beach, where there are 53 casualties reported at its southern end, at Great Egg Inlet, in the decade, and 40 at or near its northern end, in the same period, although this is but 52 miles from the Delaware Breakwater and 82 from the Sandy Hook anchorage, neither of which are available. In fact, within the 23-mile range of the first-order light at Atlantic City, the total number of casualties in 10 years is reported to have been 170, as compared with 83 within the range of the light at Fire Island, or with 25 casualties in the dreaded Cape Hatteras District. The total number of strandings on the New Jersey coast for 10 years, excluding the Delaware and Raritan bays, was 332, so that more than one-half of them occurred within the range of the Absecon Light-house, thus impressing the urgent necessity of opening a channel across one of the three most important bars on this part of the coast for the sake of humanity, as well as for its direct benefits to the State and Nation. Of the 53 casualties at Great Egg Inlet, 10 concurred in 1899, 13 in 1900 and 10 again the year following. The greatest number in any one year at Atlantic City was in 1903, when there were 7 wrecks at or near the inlet.

Moreover, the report shows that the pecuniary value of the property jeopardized in the single year (1903-4) in this district reached the large aggregate of $1,994,795, which was 47 per cent. of the value of all the casualties on the entire Atlantic and Gulf Coast of the United States. It is a glowing tribute to the efficiency of the service that, of the large total risked, only $73,985 was actually lost. Between August 6th, 1903, and June 19th, 1904, there were 12 casualties in the vicinity of Absecon Inlet, embracing all classes of vessels from naptha launches to the Steamship Craigneuk, of Scotland, 2,215 tons, laden with sugar from Matanzas, Cuba, and bound for New York, valued at $400,000, which was on the bar off Brigantine for 6 days. With a well-defined fixed channel across the Absecon bar most, if not all, of these accidents might have been avoided.

Sanitary and pleasure resorts.—From the foregoing statistics it appears that the coast is a menace to commerce, notwithstanding the presence of its light-houses and life-guards. Yet long before they existed it was the home of a considerable industry in shipbuilding and in whaling, as well as in the manufacture of iron, for at the date of the settlement of Pennsylvania by William Penn, in 1682, he founded a smelting furnace in New Jersey and the State was even then exporting, amongst other things, whale-oil, whale-fins and furs to England. Prior to the Revolution it was the center of the shipbuilding industry of the colonies, where many a staunch clipper was fitted out for the maintenance of our commerce; but all these have yielded to the course of events which has destroyed these industries and almost closed the harbors.

IMPORTANCE OF COAST RECREATION.

There is some compensation for these losses, however, in the fact that these beaches have of late years been patronized because of their recuperative tonics of fresh air and salt water, so that sections which were the abode of wild cattle, birds, fish and insects, are now transformed into centers of art and refinement, ease and luxury. So great is this transition that the value of property in some sections has increased many thousand-fold, and large sums are being expended to recover more territory from the voracious ocean.

Development.—In 1833 the Gazetteer of the State gave an account of the then known resorts, in which it was said concerning Long Branch that the "Inducements to invalids, the idle and the hunters of pleasure to spend a portion of the hot season here are many. * * * During the season a regular line of stages runs from Philadelphia, and a steamboat from New York, to the boarding houses here, of which there are several; Wardell's, Renshaw's and Sear's are the most frequented. Many respectable farmers also receive boarders"—Tuckerton, which had about 40 houses and 4 taverns, was "frequented by many persons in the summer season for the benefit of sea bathing." May's Landing had "3 taverns, a considerable trade in cord wood, lumber and shipbuilding." Tom's River had "some 60 frame dwellings, 2 taverns, 6 stores, and built many schooners and sloops." It had an annual export of more than $200,000 worth of timber and cord wood. "Sommers' Point was a port of entry in 1833 and was much resorted to for sea bathing in the summer and for gunning in the fall." No other resorts are mentioned, except Cape May, which "is 104 miles by post-route from Philadelphia, and is a noted and much-frequented watering-place, the season at which commences about the first of July and continues until September. There are here 6 boarding houses, 3 of which are very large." Of the 8 places which in 1833 might be termed summer resorts, only Long Branch and Cape May had boarding houses exclusively for guests.

In speaking of the site of Atlantic City, Heston's Hand Book says: "Call it a sand patch, a desolation, a swamp, a mosquito territory, where you cannot build a city, or if you could no one would go there." As late as 1855, land sold there at $17.50 per acre. To-day $30,000 per lot is asked.

To emphasize better the great change which has taken place along this coast in the past 70 years it may be well to give a list of the various places which are now recognized as summer resorts on this coast, beginning at the northern end on Raritan Bay:

Port Monmouth,
Atlantic Highlands,
Navesink Park,
Oceanic,
Seabright,
Little Silver,
Shrewsbury,
Branchport,
Oceanport,
Low Moor,
Monmouth Beach,
North Long Branch,
Long Branch,
Hollywood,
West End,
Elberon,
Deal Beach,
Allenhurst,
Interlaken,
North Asbury Park,
Asbury Park,
Ocean Grove,
Ocean Park,
Bradley Beach,
Neptune City,
Avon (Key East),
Belmar (Ocean Beach),
Como,
Spring Lake,
South Atlantic,
Longport,
Ocean City,
Somers' Point,
Sea Isle City,
Avalon,
Peermont,
Navesink Beach,
Red Bank,
Fairhaven,
Sea Girt,
Manasquan,
Brielle,
Point Pleasant,
Bay Head,
Mantoloking,
Chadwick,
Lavellette,
Ortley,
Berkley,
Seaside Park,
Tom's River,
Island Heights,
Manahawken,
Harvey Cedars,
Barnegat City,
Peahala,
Beach Haven,
Bonds,
Sea Haven,
Tuckerton,
Leed's Point,
Island Beach,
Brigantine,
Atlantic City,
Chelsea,
Ventnor,
Anglesea,
North Wildwood,
Wildwood,
Hollywood,
Sewell's Point,
Cape May,
Cape May Point.

From Seaside Park to Barnegat Inlet, 10 miles, there are no resorts, and from Barnegat to New Inlet, 22 miles, only one of importance, a condition of affairs due in part at least to the relative inaccessibility of this part of the coast.

Accessibility.—Just as in 1833, the earlier development of Long Branch and Cape May, as summer resorts, depended upon their comparatively easy accessibility, so, at this later day, rapid and safe train service has been a most potent factor in the upbuilding of the modern popular resorts of this coast. Thus the opening of the Camden and Atlantic Railroad transferred the prestige of Cape May largely to Atlantic City, and the northern coast lines have distributed the patronage of Long Branch far to the southward. It is merely a question of time and rates as to the location and rapidity of growth of these centers of recreation. With additional rail and trolley communications, and with ferries across the various inlets, the entire coast line of New Jersey may be made the most attractive territory in the world, and one of the most profitable as a source of revenue to the citizens of the State. The creation of deeper and safer channels across the outer bars, so that the ports may be made accessible to the world by merchant vessels and yacht-men, will also add greatly to their welfare and stimulate traffic overland. A broad boulevard connecting the famous Rumsen Road, at Shrewsbury Neck, with Cape May, by means of bridges and ferries, would be a most valuable and popular improvement.

The opening of competing railways to Atlantic City has not injured the revenues of the first railroad built in 1853 in any manner, but has greatly improved the service and increased the traffic by extending its area of patronage far beyond Philadelphia. Sixty years ago it took 10 days to travel from Pittsburg to Absecon Island; to-day only as many hours are required. A similar, direct route across the State, from Camden to Sea Girt through Lakewood, saving 22 miles, would prove of great service in opening up the beautiful North Jersey Coast to patrons from the South and West, as it is no farther in an air line from the Delaware, at Camden, than is Atlantic City. The increase in values at this latter place during the past 26 years has been enormous. The property valuation is now over $50,000,000, which, on the basis of 900 acres, would give the average value of the realties at $55,555 per acre. The resident population has increased in the same time from 6,000 to nearly 40,000, while the transient lists may often exceed 200,000 persons.[1] If uniformly distributed over the 900 acres of the city the average would therefore be 222 per acre, or more than double the safe sanitary

[1] During the last week of July, 1905, the railroad statistics reported 210,000.

limit, so that during the busy season the density may exceed 300 per acre as in the tenement districts of overcrowded cities, and the sanitary advantages of the resort be thus defeated by its very popularity.

Moreover, the rapid growth of the population, and the great increase in the patronage of the Jersey coast, points to the early absorption of the available space, for its capacity is in fact limited and is growing less, while the demand for retreats is expanding. The population of this country will have doubled by 1935. If the available length of the beaches be taken at 120 miles and their average width at one-half mile, there will then be only 38,400 acres, and at 8 lots to an acre, and 5 persons to a family, or 40 per acre, the capacity of the entire coast would not suffice to provide homes for the population of New York City at the date of the last census. The importance of conserving the area of the beaches is therefore self evident.

The sources whence the coast resorts derive their patronage may be seen from the following brief exhibit as to the least time required and distance to be traversed to reach them by rail from the great centers of industry.

		Time.	*Distance.*	*Time. per Mile.*
Philadelphia to	Atlantic City, ...	60 min.,	60 miles	—1.0 minutes.
"	Cape May, ...	110 "	82 "	—1.34 "
"	Sea Girt, ...	123 "	82.5 "	—1.5 "
"	Long Branch, ...	151 "	94.2 "	—1.6 "
"	Point Pleasant, ...	125 "	71.5 "	—1.7 "
"	Wildwood, ...	119 "	78.4 "	—1.5 "
"	Ocean City, ...	120 "	67 "	—1.8 "
"	Sea Isle City, ...	94 "	66 "	—1.5 "
"	Beach Haven, ...	133 "	76.4 "	—1.7 "
"	Seaside Park, ...	90 "	59.3 "	—1.5 "
New York to	Long Branch, ...	75 "	49.6 "	—1.5 "
" "	Sea Girt, ...	104 "	61.3 "	—1.7 "
" "	Point Pleasant, ...	107 "	64.2 "	—1.7 "
" "	Seaside Park, ...	154 "	76.4 "	—2.0 "
" "	Bay Head, ...	145 "	65.7 "	—2.2 "
" "	Atlantic City, ...	195 "	150 "	—1.9 "

Atlantic City is to Philadelphia what Long Branch was to New York before the opening of the great hostelries on Manhattan and Rockaway beaches on Long Island. The communications from New York to Atlantic City and from Philadelphia to Asbury Park or Long Branch are still far from direct. They might be improved with great profit to the transportation companies and convenience to their patrons.

Sea Girt and Point Pleasant are now nearer in time and distance to New York than to Philadelphia, but they could be made the peers of Atlantic City with more direct lines of communications and special train service, such as the lower coast resorts enjoy. Such accommodations would also tend to develop more rapidly the entire stretch of over 50 miles, extending from Absecon to 'Squan, to the great advantage of the State.

From this general review of the transportation possibilities of the entire ocean frontage of New Jersey, it would seem justifiable to make timely provision for the protection of her littoral territory and the fixing of her boundaries, so that definite titles may be conveyed and be guaranteed to prospective purchasers. The necessity for such provisions will become more evident after a consideration of the changes which are taking place along the seaboard as hereinafter set forth.

PHYSICAL CHANGES ALONG THE COAST.

The Geological Survey has, at different times, collected such information as was available from reliable sources, by personal itineraries along the coast, and has embodied it in the reports of the State Geologist, notably in the year 1885, when the testimony of the keepers of the Life Saving Service and others was published as to the changes which had been taking place, based upon their personal observations for many years. From these data the general conclusion was reached that there is an extensive wear along the east side of the beaches of the New Jersey coast effecting a change in their position, which in many cases has amounted to a lateral movement exceeding the width of the beach. This movement is still going on with undiminished activity, and although there have been local accretions they are so limited in extent that "it is accepted as a rule that on the east shore the loss is absolute while the gain is but relative."

The location and extent of some of these changes will be shown by a reference to the maps of the Geological Survey and other comparative charts submitted as a part of this report.

Traditions, as recorded by the "oldest inhabitants," are, however, conflicting, especially in suits over disputed boundaries, and the many surveys and maps which have been consulted are found to be lacking in essential data as to dates, scales, definite land marks or points for orientation and occasionally in the recorded bearings or in the omission of distances, so that recourse has been had only to the most reliable surveys found in the archives of the State and general Government. These will remove all uncertainty as to actual changes in the recent past and point out the remedies to be applied to reclaim and hold the valuable territory which the littoral forces are submerging.

The Inlets Rapidly Closing.—Not only are the beaches being driven back by the sea, but the harbors which were accessible to coasters, within the memory of men now living near them, are being closed by the traveling drift. A glance at the maps of the Survey will show that most of the mouths of streams emptying into the ocean have been closed and the salt water estuaries are now converted into marshes or fresh water lakes. It is also suggestive as to the direction of movement of the obstructing sand to observe that from Sandy Hook to Bay Head the longer axis of these lakes is inclined to the northward at their outer ends, whilst below the latter point the beach is separated from the main land by broad bays and marshes having a sandy cordon with numerous inlets which are in general drifting to the south. A most remarkable topographic feature of the coast is the 70-mile terrace extending in a straight line from Barnegat to Cape May, and forming the western escarpment to the salt marshes which cover some 300,000 acres of land reaching from 2 to 6 miles seaward.

The present condition of the inlets will be more clearly shown by arranging them in their geographical position and indicating the distance in statute miles from the point of Sandy Hook, which is now about 1¼ miles northwest of its position in 1764, when the light-house was built. The dates when the inlets closed cannot be ascertained with any degree of certainty, save as maps of certain dates show them to be opened or closed. Some are purely legendary.

LIST OF EXTINCT AND EXISTING INLETS ON THE NEW JERSEY COAST.

Miles.	DESIGNATION.	CONDITION.	Depth.	REMARKS.
0.	Point of Sandy Hook, ...	Open, ...	30 ft.	New York Entrance.
7.	Navesink River, ...	Closed, ...	0	Permanent, by R. R., '56.
8.5	Shrewsbury River, ...	"	0	" "
14.	Whale Pond, ...	"	0	By Nature.
15.	Elberon Brook, ...	"	0	" "
15.5	Brook (no name), ...	"	0	Seepage to beach.
15.7	Brook (no name), ...	"	0	" "
17.	Deal Lake, ...	"	0	" "
17.7	Sunset Pond, ...	"	0	" "
18.2	Wesley (Long Pond), ...	"	0	" "
19.	Goose Pond, ...	"	0	" "
19.7	Duck Creek, ...	"	0	" "
20.2	Shark River, ...	Open at times, ...	3 ft.	Shifting Bar, no nav'n.
20.7	Silver Lake (Perch Pond), ..	Closed, ...	0	....
21.7	Three Corner Pond (Como),.	"	0	....
23.2	Fresh Pond (Spring Lake),..	"	0	Tributary of Wreck Pd.
24.	Wreck Pond (Sea Girt Inlet),	"	0	Drainage to Ocean.
25.5	Newberry's Pond (Stockton Lake), ...	"	0	Once mouth of Squan R.
26.2	Squan River,*	Open, ...	3 ft.	Shifts north and closes.
30.	Metedeconk River Inlet, ...	Closed about 1755, ..	....	East of Herring Inlet.
33.	Kettle Creek Inlet, ...	"	....	....
38.	Cranberry Inlet, ...	Open 1750; closed about 1812, ...	....	Opposite Tom's River.
49.	Barnegat Inlet, ...	Open, ...	7 ft.	Shifting to the south.
68.2	Old Inlet, ...	Closed about 1874, ..	....	Keith's Line began at point.
72.	"New Inlet" (Great Bay), ..	Open about 1790, ...	11 ft.	Shifting.
73.	Ben's Hill, Shell Gut and others, ...	Closed and indefinite,	....	....
75.7	Brigantine Inlet, ...	Open, ...	7 ft.	Shifting to the south.
80.2	Wading Inlet, ...	Closed in 1882, ...	....	Accretions due to wreck.
82.2	Absecon Inlet, ...	Open, ...	8 ft.	Channel shifting.
85.7	Dry Inlet, ...	Closed, ...	....	....
90.	Old Inlet, ...	Closed, ...	....	About 1841?
91.5	Egg Harbor Inlet, ...	Open, ...	11 ft.	Shifting.
99.5	Corson's Inlet, ...	"	4.0 "	Shallow and shifting.
107.	Townsend's Inlet, ...	"	3.5 "	" "
115.4	Hereford Inlet, ...	"	6.5 "	" "
120.2	Turtle Gut Inlet, ...	"	3.5 "	" "
122.5	Cold Spring Inlet, ...	"	5.0 "	" "

* Between 'Squan river and the head of Barnegat Bay there are four ponds, formerly known as Cook's, Foreman's (Little Silver lake), Eakin's (Old Sam's), and Johnson's (Twilight lake), which are disconnected from the coast by sand dunes. From Bay Head, where no changes are reported to have taken place since 1865, the character of the coast changes to one having inland bays protected by low beaches, while the direction of the drift also appears to change to the southward. The present peninsula, reaching to Barnegat Inlet, 19 miles south, still known as Island Beach, was formerly broken into several islands by inlets, now closed.

From the above exhibit it appears that in the 26 miles north of Manasquan Inlet, where the uplands drain directly into the sea, there are to-day but two open river mouths and these are practically not navigable, save at high water to shallow sloops, and there are 16 lakes or creeks which are closed.

In the stretch of about 100 miles south of 'Squan, there are 10 inlets open, and records of 9 others which have been closed. In all 25 are reported closed and 12 open. The relative permanency is greatly in favor of the part of the coast having the large tidal reservoirs in the rear of the inlets and the importance of maintaining the free ingress of the tide cannot be too strongly emphasized if these inlets are to be maintained. If the throat of the bays and lakes is congested by contraction works the tidal pulsations are reduced and deterioration follows until finally the effluent streams become so feeble that the mouth closes.

Changes in the Beaches.—Furthermore in the Geological Survey Reports for the years prior to 1885[1] will be found additional data as to others physical changes which have been taking place as reported by the Coast Guards and residents, during the periods of their personal knowledge.

These records show that the encroachments of the sea are causing serious losses in certain places with but slight gain in others, and that the beaches are driven back and submerged in accordance with the prevalent movements on all alluvial formations subject to the action of the littoral forces. The rate and volume of this movement varies greatly, but it is least where there are no breaks in the continuity of the shore line and greatest where the inlets are widest. In certain localities where wrecks have interrupted the action of the forces and created neutral areas, there have been deposits and growth of the beach, and in others, where the wrecks have been stranded between high and low water line, there has been erosion. Accidental illustrations of these effects may be seen from the accompanying photographs showing that whilst one wreck may invite deposit another may cause erosion under apparently similar conditions of exposure.

[1] 1868 and 1882.

On closer analysis, however, it will appear that in the case of the "*Mark Gray*" which went ashore about 100 yards off Sea Side Park in 1902 (see Plate I, Fig. 1) the distance from the low-water line was sufficient to create a protected area or lee which rapidly shoaled and formed a spit reaching from wreck to shore so long as the protection remained, but when the year following a severe northeaster broke up the wreck and carried it away the shore line returned to its original condition almost immediately.

In Plate I, Fig. 2, the wreck north of 'Squan River was so far ashore as to cause the waves to break directly on the beach which was badly cut out by their recoil and undertow. In cases where spur-jetties ("groynes") have been extended across the strand the drift has been arrested and impounded on the windward[1] side, in consequence of which there has been erosion of the beach on its leeward side so long as the jetties remained intact. For it must always be borne in mind that the permanence of the beach at any point is due to the balance between deposition and erosion. If by any means the amount of sand supplied to the beach at any point by the waves and currents be diminished so that the loss exceeds the gain, the beach begins to recede at that point. From this it often happens that protection and growth of the beach at one point necessitates attack and loss at another.

In short the beach is the resultant between cut and fill as affected by the forces causing the movement of the material. On exposed, projecting salients, even if rocky, there will generally be loss, while in the protected coves or bights of bays the pulverized product will be deposited. Plate II, Fig. 1, shows well the general operation of a spur-jetty or groyne placed across the strand to intercept the traveling sands which here are manifestly northward, as indicated by the banking up of the drift on the "windward" or south side and the angular wave movement to the northward. Another instance of similar action is shown in Fig. 2.

To resist these attacks of the sea many different forms of

[1]In respect to the movements of the waves.

Fig. 1. Effect of a wreck at Sea Side Park in building out the shore.

Fig. 2. Effect of a wreck at Squan River in causing erosion of the shore.

Fig. 1. Spur jetty or groyne at Long Branch.

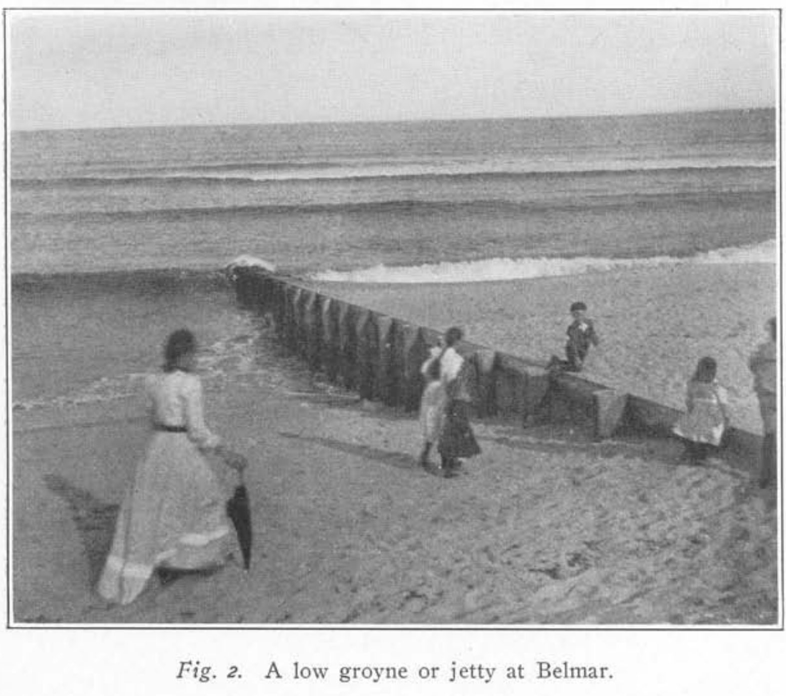

Fig. 2. A low groyne or jetty at Belmar.

walls, bulkheads and jetties have been constructed by riparian owners with varying results, which will be briefly referred to as illustrations of "how not to do it," since the local experiences are of greatest value in the application of the best remedial designs.

The rate of cutting varies from zero, on the continuous beach, to 120 feet per annum on the southerly spits of some of the inlets, as will be seen from a reference to the reports of the Captains of the Life-Saving Stations, given in the Annual Report for 1885, which is summarized as follows:

STATEMENTS OF KEEPERS OF THE LIFE-SAVING STATIONS.

Sta. No. 2. One mile north the beach has grown out 200 feet in 5 years, and the deposits have extended to one mile south, where they were from 300 to 350 yards in about 30 years.

From a point about 1⅓ miles north of Highlands to about 1 mile south of it the beach has washed away and remade again and again since the settlement of the country.

Sta. No. 3. The shore has washed away about 200 feet in 20 years, and at Seabright it is rapidly encroached upon.

Sta. No. 4. At Monmouth Beach the wear of late has been from 5 to 10 feet per year. Half a mile south of the pier at Long Branch the beach is wearing away rapidly. At West End it is partially protected by bulkheads and other defenses of greater or less efficiency, and the wear is, in a measure, arrested.

Sta. No. 5. South of this station bulkheads are in course of erection.

Sta. No. 6. The wear immediately north of Deal Lake has been 1,000 feet in 20 years.

Sta. No. 7. The Shark River Inlet shifts from time to time to the northward, periodically closing up and reopening to the southward.

Sta. No. 8. At Spring Lake the bank wears away faster since the dunes have been levelled off.

Sta. No. 9. Near Sea Girt the wear occurs chiefly in winter and the growth in summer. Squan Inlet works northward and closes up periodically. In the last 50 years the whole beach has been washed away and redeposited. The shore northward to Shark River has worn away about 50 feet in 30 years.

Sta. No. 10. There has been no permanent change in 20 years. Herring Inlet, at the mouth of Metedeconk River, closed about 130 years ago.

Sta. No. 11. No very permanent change and no prevailing currents.

Sta. No. 12. In the past 35 years the shore has grown out 200 feet. The drifting sands have covered up the meadow for a considerable distance east of the railroad.

Sta. No. 13. No permanent change has taken place at Tom's River Station within 35 years. A slight depression probably marks the site of old Cranberry Inlet, which is said to have opened in 1750 and closed in 1812. Other inlets have opened opposite Tom's River at various times.

Sta. No. 14. Below Seaside Park, on Island Beach, now a peninsula, there is no material change on shore within 16 years.

Sta. No. 15. No change has been noticed within the past 10 years.

Sta. No. 16. The beach is constantly making to the west, due to the wear of the shore at the rate of about 50 feet in 40 years. Near the south end the beach is flat and of recent formation. It appears to be working westward.

Barnegat Inlet is working south without material change of width. The old light house (built 1834) has been destroyed.

Sta. No. 17. At the northeast end of Long Beach the wear is about 600 feet in the past 5 years, and threatens the Oceanic Hotel. It is caused by the flood tide. The beach is working westward.

Sta. No. 18. The beach at Loveladies Island is working westward, and the sea washes over it just north of the station.

Sta. No. 19. At Harvey's Cedars no permanent change has occurred lately.

Sta. No. 20. At "Ship Bottom" Station the beach has worn away 75 yards within the last 12 years. Confirmed by the Coast Survey.

Sta. No. 21. At Long Beach the keeper reports no change in 40 years, but the Coast Survey shows a growth of 70 yards in 42 years. For a distance of 2 miles north no change, and for 3 miles south a growth of 105 to 170 yards diminishing to the point.

Sta. No. 22. The beach at Bond's has worn away 50 yards since 1870, but prior to that date the Coast Survey maps show a growth of 25 yards since 1839. The shore up to Beach Haven shows wasting. The old inlet worked south and closed up about 1874. Since when the spit has grown to the southward ¾ mile in 15 years.

Sta. No. 23. Beach low and flat, frequently overflowed and growing to south.

Sta. No. 24. The beach has worn away 100 yards in 8 years at the point, and abreast of the station the rate has been 50 yards during the same period. The Coast Survey charts indicate a wear of about 100 yards for a length of two miles in 10 years. The southwest end has worn about 75 to 100 yards in 8 years, and Brigantine Inlet has widened over half a mile by the wear of both points.

Sta. No. 25. The wear of the north point was from 75 to 175 yards per year for the past 5 years, while that of the east shore was from 4 to 16 yards per year. The inlet wears most on south side.

Sta. No. 26. North of this station the wear is estimated at 75 yards in 20 years. South of the station the old wrecks have caused a growth of 10 yards per year for the past 25 years. The former inlet, 1½ miles south, closed up in 1882 or 1883. Beyond that the shore is wearing rapidly, 75 to 100 yards in 18 months.

Sta. No. 27. The point at the south side of Absecon Inlet has worn away 400 yards in 20 years, and along the east shore the wear has been nearly a half mile in 30 years. The building of jetties since about 1878 has stopped the wear and recovered much of the lost beach at the point.

Sta. No. 28. The shore abreast of the station has grown out a little. Below the station it has worn away.

Sta. No. 29. This station is near the point where the shore is wearing away at the rate of 20 feet per year. The "New Inlet" which existed here has been filled in by the drift, and the outer beach is being rapidly reclaimed by inexpensive sand fences.

Sta. No. 30. At the Ocean City Station the wear was 100 yards in 8 years. The point of Peck's Beach, which at one time wore rapidly away, is now growing out. It has subsequently extended a half mile.

Sta. No. 31. The south end of Peck's Beach has worn away at the rate of 200 yards in 15 years. The island is low and flat.

Sta. No. 32. At the southern end of Peck's Beach, renders no report.

Sta. No. 33. The shore has worn away about 18 yards in 10 years. The shore up to the inlet is quite flat, and probably wears away faster. Forty years ago the north point was heavily wooded, but it has worn away about one mile during that time. The wear along the whole beach is said to be about uniform.

Sta. No. 34. Near Townsend's Inlet the dunes are growing higher, as well as the beach, although it has worn away 6 to 8 feet on west shore.

Sta. No. 35. The dunes are 40 feet high, and are moving westward and engulfing the trees. The rate of this movement is 20 yards in 12 years. The old thoroughfare on the inside has been closed by sand washed over the beach half a mile southwest of the station.

Sta. No. 36. At Anglesea, previous to 1878, the shore wore away rapidly southeast of the lighthouse, but since then little wear has occurred. In 1883 it began to grow out, and has made about 150 yards. Between Anglesea and Holly Beach City the wear has been about 5 feet per year for 15 years, and much timber has been destroyed. Northwest of the light the shore wears about 20 feet per year.

Sta. No. 37. There is little or no wear as far as the end of the point, which has extended one-quarter of a mile in 15 years. It is low and is frequently overflowed.

Sta. No. 38. Is wearing away fastest on the northeast side, half a mile from Turtle Gut Station, where it has lost upwards of a quarter of a mile in 40 years. The south end has grown considerably and Cold Spring Inlet has widened.

Sta. No. 39. Sewell's Point wore away rapidly until it was protected by jetties, which have, however, produced no growth. The wear from the end of the beach to a point half of a mile west of the station has been about 30 yards in 10 years. For a half mile beyond this there has been a growth of nearly 30 yards in same time, and beyond this a stone wall protects the shore. No change.

Sta. No. 40. For about 1½ miles east of station the wear has been nearly the same as on Poverty Beach. West of the station the wear has been 30 feet per year for the past 8 years, except where the shore is protected by jetties. The evidences of wear are numerous.

Deductions from Record.—From these statements it will be seen that there are certain definite stretches of erosion, others of stability and others of deposit. It will be noted also that

Fig. 1.

Vicinity of the Navesink Highlands; Ratzer Map, 1769.

at the northern end of the coast, where the highlands abutted directly on the sea, the greatest changes have occurred as the bluffs which rise from 10 feet at Sea Girt to 40 feet at Deal Beach, are exposed to the direct undermining action of the breakers.

The first five miles, composing Sandy Hook, is evidently a region of deposit, since even up to the time of the Ratzer surveys of 1769 (Fig. 1) the Highlands of the Navesink, rising to an elevation of 240 feet, were open to the full force of the Atlantic (if the evidence of the map can be relied upon) and supplied the material for the peninsula which jutted out from its base. This is indicated by the absence of salt marshes north of Navesink River which then apparently debouched directly into the ocean. Since that time the drift from the bluffs to the southward has gradually overlapped the foot of the Highlands and closed the mouth of the Shrewsbury and Navesink rivers, thus serving as an effectual cover and protection for the highlands which are no longer attacked by the waves from the east. Sandy Hook is now dependent for its supply of drift upon the bluffs composing the beach front from Monmouth to Bay Head. Here it is evident that the coast has been receding under the attack of the waves. This is indicated by the position of the 10-fathom line which is here 3 miles or more off shore and is much indented, indicating a rough or furrowed bottom, and suggesting movements along the bottom at right angles, rather than parallel, to the shore. On the other hand, south of Bay Head, where the main land is protected by the sand reefs (beaches) the 10-fathom line approaches to with 1½ miles of high-water mark, and retains that position as far south as Lavalette City. Moreover, the map of Lieutenant Ratzer also indicates that the coast line at the mouth of the Shrewsbury River was then about a mile farther out to sea than it is to-day. This gives an average rate of waste of 38 feet a year, near Station No. 4, where it was recently said to be from 5 to 10 feet, but the beach is now largely defended by bulkheads. At Station No. 6, near Deal Lake, the wear was 1,000 feet in 20 years or at the rate of 50 feet per annum. This section of the coast (Monmouth to Bay Head) would seem, therefore, to be the source from which the Sandy Hook drift is mainly derived. Inasmuch as the persistent growth of the Hook, particularly of its submerged portion, is a continual menace to the entrance of New York Harbor, the arrest of this shore drift would manifestly aid in the securing and maintenance of deeper channels at that important highway of commerce.

The next section of the coast reaching from Station No. 10, at Bay Head, to No. 16, at Barnegat Inlet, is one of comparative stability, where the losses and gains nearly counterbalance, and as the coast line is straight and makes but a slight angle with the meridian, being about south 10° west, the movement is uniform and slight. The old inlets, notably Herring's and Cranberry, which formerly existed, are now closed. At Barnegat (Fig. 2) the movement has been southward at the rate of over a half mile in 50 years or more than 50 feet per annum. Here the old light-house, built in 1834, was destroyed by this southerly movement and the new one, erected in 1858, was threatened as early as 1886. Between 1880 and 1885 the wear on the southern point of the inlet was about 120 feet a year, while between 1840 and 1874 it was 70 feet a year. The channel across the bar is tortuous and shifts so constantly that the location of the buoys is omitted from the sailing charts. There are no "improvements" in aid of navigation and the ruling low-water depth is about seven feet.

At Barnegat Inlet the alignment of the coast changes some 20° to the westward, bearing almost in a straight line south 30° west for 22 miles, to Little Egg Harbor, near Station No. 23. This island, known as Long Beach, is relatively permanent, wasting at a few points and gaining at others until the southern end is reached, when the accumulation becomes large. Still farther south the deposits on the inner islands increase as the drift moves southward and becomes more extensive below Absecon Inlet where it has almost filled the bays between the outer coast and the inland terrace. The general trend of the coast continues with its island-beaches as far as Cape May. In these 40 miles there are 7 inlets, still open, but having shallow entrances and limited tidal basins which are filling steadily from the material carried into them by the flood tide. These inlets are also subjected to the same general laws as to their movements as those farther north. In fact the bars are more extensive and the depths less because of the smaller size of the inner basins and the frequent shifting of the channels.

THE LEGAL ASPECT OF THE PROBLEM.

Many of the ancient grants and charters to territory along the seaboard were based upon the existing landmarks as determined by the position of inlets or other natural water courses.

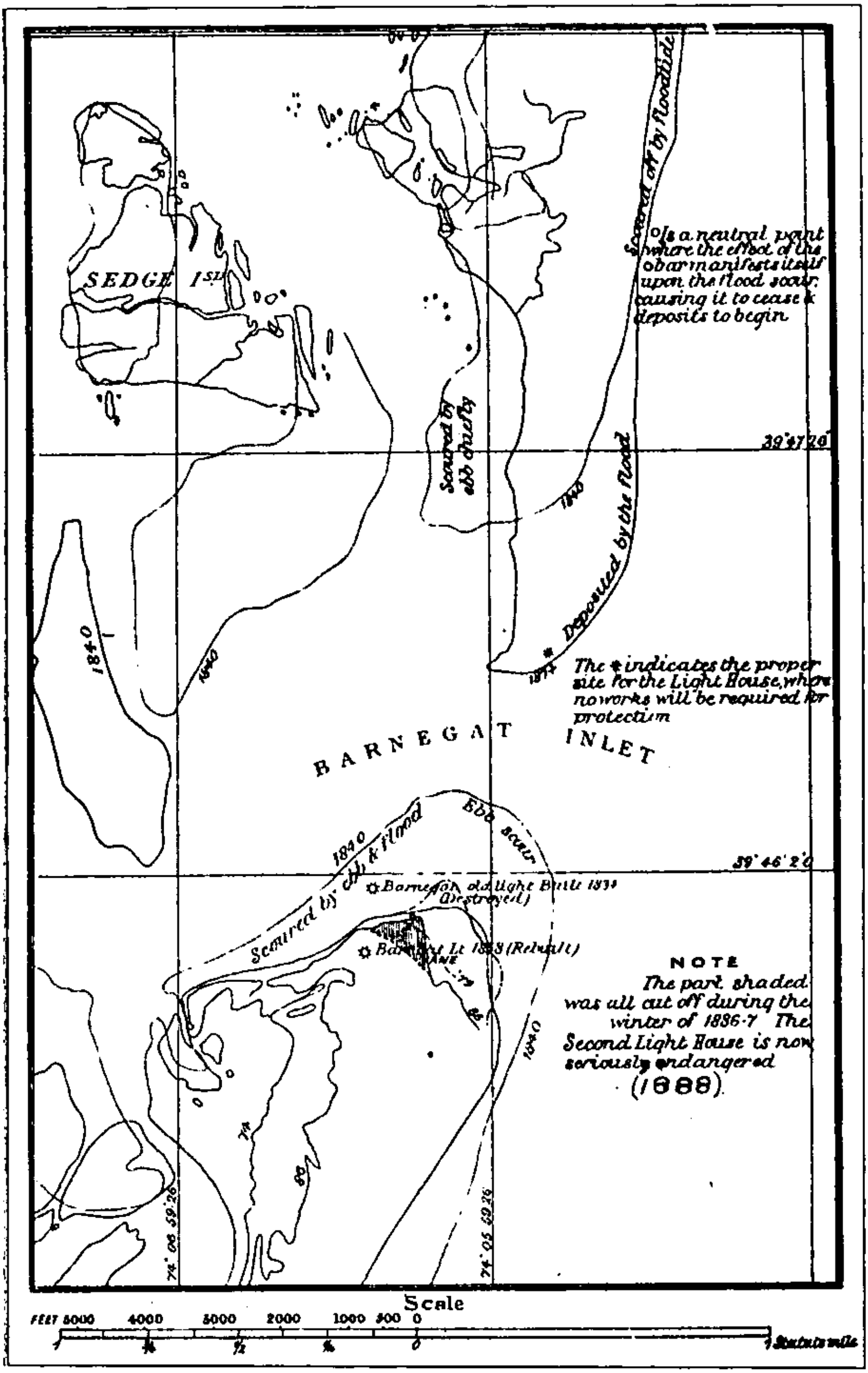

Fig. 2.

Map of Barnegat Inlet showing changes up to 1888.

Fig. 3.
'Squan Beach to Absecum; Ratzer's Map, 1769.

As has been seen these are subject to constant changes due to the ever varying forces operating on mobile materials, so that in the absence of permanent monuments or fixed channels much confusion has arisen, giving rise to expensive litigation.

Thus the beginning corner of "Keith's Line" separating East from West New Jersey was at the northerly point of Little Egg Harbor Inlet, as shown on the map of Sellers and Fisher (1676), as well as on the survey made by Ratzer, in 1769 (Fig. 3). On this chart the point of the beach is placed in latitude 39° 32′, which is the present position of Life-Saving Station No. 22, as shown on the Geological Survey Chart of 1885, on which the beginning corner is located on the beach one-quarter of a mile to the south of the station, while the point of the island is 3.9 miles below. On the United States Coast and Geodetic chart of September, 1904, the distance from the Life-Saving Station to the point of the inlet is 4.64 miles (Latitude, 38° 29′ 11″). From these data it appears that the progression of this spit to the southward has been at the average rate of 168 feet per annum in the period from 1769 to 1885 and about 200 feet per annum subsequently.

A title based upon so great mobility of its initial landmark would have little validity. This was illustrated in the case of the boundary line between Atlantic and Burlington counties, which was in litigation about 1885, when much valuable testimony was taken as to the uncertainty of the position of the inlets and beaches. The "corner" in question was defined to be, "The next inlet in the south side of Little Egg Harbor's most southerly inlet and thence along the sea coast to the line of partition between East and West Jersey." Had this last course contained even an approximate distance the nameless inlet might have been identified and the numerous disputes over property, oyster and fishing rights, have been avoided. This deed was dated as far back as 1709, or beyond the memory of any living person.

Again in a suit for title to the beach front at Hempstead, Long Island, the Supreme Court has recently ruled, "That old maps of the beach on Long Island are but slight evidence of the condition of the beach or the location of the inlets at a period fifty years earlier, even though correct at the time made. It is a fair presumption that the constant shifting in the various inlets of Rockaway Beach on Long Island, shown to be going on at the present time, was going on in 1725." From this it would appear that such a description as is contained in the deed of "A beach lying on the south side of the Island at a place called Rockaway" is not one that would convey title to a definite tract of land subject to the action of such physical forces as prevail on alluvial coasts.

In view of the recorded changes which have taken place between Absecon and Egg Harbor inlets, in recent years, and particularly since the incorporation of Atlantic City, in 1854, it may be expedient to recur to the legal aspect of the charter as the basis upon which this great development has taken place, by quoting the Act which was approved March 3d, to take effect May 1st, 1854. It reads as follows:

"BE IT ENACTED *by the Senate and General Assembly of the State of New Jersey,* That all that part of Absecom Beach lying and being in Atlantic County, in the State of New Jersey, beginning in the Atlantic ocean, as far as the jurisdiction of the State extends, at a point on a line with the south side of California street; thence easterly along the boundary line of the State to a line at right angles with the east side, at high water, of Absecom Inlet; thence westerly along the east side of said inlet, to a point opposite and at right angles with the west bank of Clam creek; thence southerly along the west bank of said creek to its first prominent fork, and thence on a line parallel with Atlantic street to the intersection of the aforesaid line on the south side of California street, thence along said line to the place of beginning.

"And all the freemen, citizens of the State, residing within the limits aforesaid, be and they are hereby ordained and constituted and declared to be, from time to time and forever hereafter, one body corporate and politic in fact and in name, by the name of Atlantic City." * * * * *

Thus by a description based solely upon natural boundaries, without a known or accessible point of beginning or a permanent corner, without a course or a distance and with no well-defined contents, this tract of land on a shifting island is set apart as constituting the site of one of the most popular seaside resorts in the world.

The vagueness of this description will become more manifest by reference to the chart Plate V showing the changes which have taken place here within a comparatively few years. It would seem to be of great importance to establish some permanent landmarks to define the limits of the City's jurisdiction.

DETAILED CHANGES AT THE INLETS.

The changes of greatest importance, from the standpoint of commerce, are those which are taking place at the inlets. Even the most casual examination shows that these are constantly shifting their positions, changing in depth and in some cases filling up completely. From time to time efforts have been made to control these changes in some instances, but little has been accomplished, although that little is of value as a guide for future efforts at improvement.

As each inlet is a special problem a brief description of the most important will be given a *seriatim.*

Shark River.—Shark River is the only stream of any importance between the Shrewsbury River to the north and Manasquan River at the south. It spreads out over a broad extent of flat land, forming a shallow bay connected with the ocean by a narrow passage the mouth of which is constantly shifting and is sometimes closed for weeks together. The following account[1] taken from the "State Gazette," of August, 1877, describes the conditions prevailing at that time:

Shark river, at Ocean Beach (now Belmar), has been closed to the sea all the summer by the northeasterly storms of the spring. It has been steadily filling up all the season, until the fresh water began to have a bad effect upon the beds of famous Shark river oysters, and the clams, crabs, etc., with which it abounds. The fishermen and oystermen have been anxious to get it open and have the tides pour in the accustomed volume of salt sea-water. Several efforts have lately been made to that end, but without success, until Saturday evening last, when an opening was made through the wide ridge of sand that separated the accumulated water of the river from the sea, and at low tide it began to tear away the sand. In the course of a short time it had torn away and carried into the ocean thousands of tons of sand and formed a deep and rapid current, which swept through the ever-widening gap with terrific force. It created a turbulent and swift current far out into the ocean, and was a really magnificent spectacle. Shark river widens out into a large

[1] Quoted by Woolman & Rose, in their History of the New Jersey Coast.

bay fully two miles wide a short distance back from the ocean, and as this had risen fully three feet, the vast quantity of water that had to escape may readily be imagined. It took from Saturday night to Monday forenoon for the river to fall to its normal level.

This account, written within a few days of the opening, did not give the sequel, which was that the littoral drift rolling northwardly speedily closed the mouth of the cut as before and since. The closure of this large salt-water bay, converts it into a stagnant fresh-water basin and kills the marine life so that it becomes necessary for the health of the neighborhood to admit the salt water by reopening the channel across the spit of sand which separates the bay from the sea. Various efforts have been made by means of sand catches, fences and piling to compel the currents to maintain a fixed channel, but with only temporary benefit. In 1881 the United States Government caused an examination and report to be made at this inlet concerning which it was said:

"The bar on the outside is dry at low water, and is slowly working to the northward in a manner characteristic of similar ones along the coast." * * * "The average rise and fall of the tide at the inlet is 1.4 feet." "The rise and fall of the tide in the ocean at this point is about 4 feet. At the railroad bridge, about 500 feet inside, it is 0.7 feet. The velocity of the current in the inlet is 5 miles per hour. The conclusion seems to be warranted that the flood current is considerably stronger than the ebb."[1]

As there is no commerce it was not deemed advisable to attempt any improvement of this inlet.

From the relative tidal fluctuations, as quoted, it will be observed that the contraction of the entrance by the extensive spit of sand, as in 1889, very materially interferes with the filling of the inner basin by the tides, while the short duration of the flood and its increased velocity as compared with that of the ebb causes a rapid movement inward of the beach sand, which is immediately dropped on the extensive middle ground flat, just inside the inlet.

On September 5th, 1889, a sketch was made of this inlet to illustrate the extent and direction of its movement. (See Fig. 4.) The year before it was reported to have been closed, and the residents of Ocean Beach, now Belmar, cut a channel across the

[1] See Report of Chief of Engineers for 1881, vol. i, p. 731.

southern end of the spit, 700 feet south of the mouth, a year later. This opening was maintained by the currents for a few months, but as it progressed northward to the position shown in Fig. 4 it grew smaller and soon after closed. The row of piling indi-

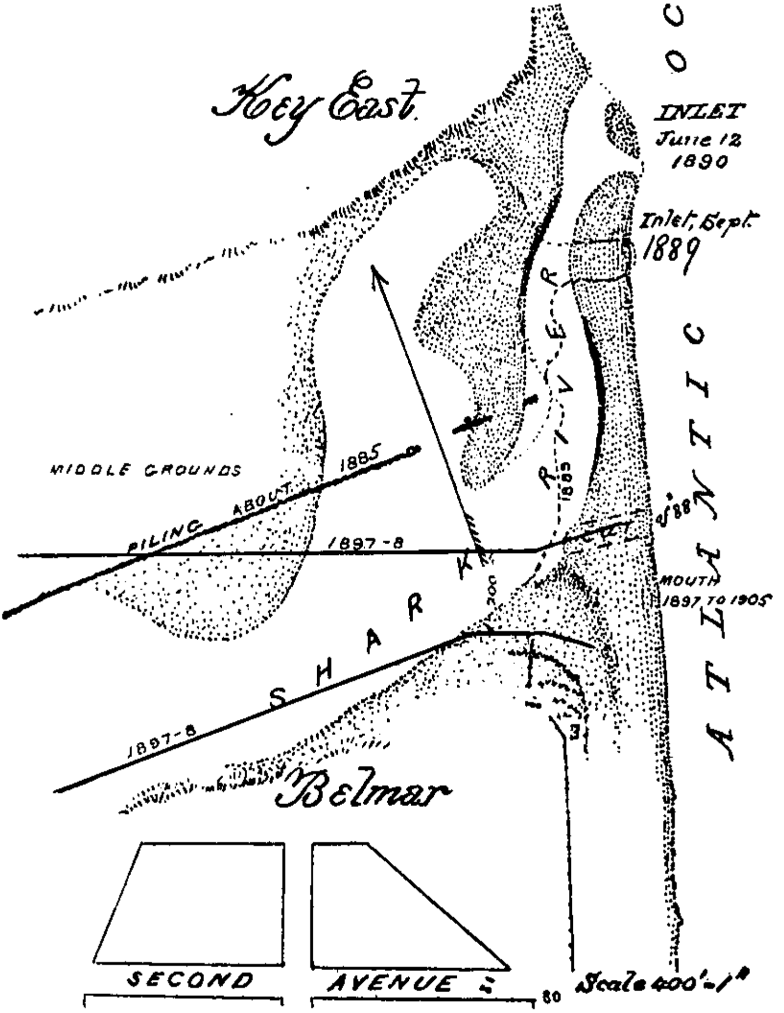

Fig. 4.

The mouth of Shark River, showing various positions of the Inlet.

cated on the cut was placed by the proprietors of Key East (Avon) on a straight line through the mouth, in or about 1885, with the expectation of confining the sand movements and reclaiming land, but it was buried in a few years and was practically useless. Finally, by the coöperation of the Board of Chosen Freeholders of the County with the Councils of the Boroughs of Belmar and Avon, some $12,000 were expended in building the bulkheads of 1897-98 as indicated on Fig. 4, in an attempt to fix permanently the inlet between them. They were too low and converged toward the sea end, thus creating a narrow neck 200 feet wide. As a result the flood tide was throttled and by the internal expansion of area for the incoming currents, large deposits of the sand were made in the channel and over the tops of the bulkheads. Large shoals formed in the pocket on the north side of the south bulkhead gradually congested the throat, as shown in Fig. 1, Plate III, taken from a point in mid channel at low water. The breach on the outer end of the south bulkhead and the eastern remnant of the north bulkhead is also shown in Fig. 2, Plate III. The sand which has been driven from the south over the south bulkhead by waves and deposited in the channel has forced the current against the north bulkhead and made in it an extensive breach and a scouring away of the Avon bank for several hundred feet, so that at this date, August, 1905, the channel is forming to the northward of both of these structures and the outer bar is bare at low water[1]. The works are therefore no longer holding the channel in a fixed position, and immediate relief is demanded, but the cost of permanent work is too great for the local resources.

The mouth of Manasquan River.—The fishing interests of this inlet were so important as to warrant the Government in making an effort to improve the bar and in 1879 an appropriation of $12,000 was made, followed by others which aggregated $39,000 up to 1882. It was reported that "The uncertainty of condition at the entrance operated as an effectual bar to the growth of commerce." The official report of 1898, after the two jetties were built, states, "The condition of the river was worse than when the work of improvement was commenced."

Thus, after an experience covering nearly 20 years, and under frequent changes of administration, it becomes important to

[1]By November, 1905, the channel had been driven several hundred feet beyond the north jetty, and the space between them was closed by a bar at low water. Temporary works are in progress.

note the plans adopted and the cause of their failure at the only inlet where any efforts have been actually made to improve the bars of the coast of New Jersey.

The cycle of changes at this inlet and the means proposed to prevent them are briefly set forth in the following extract from reports of the Engineers:

"This opening is situated in Monmouth county, and is about 25 miles south from Sandy Hook. The drainage basin embraces about 80 square miles. With a view to its improvement a survey was made in September,

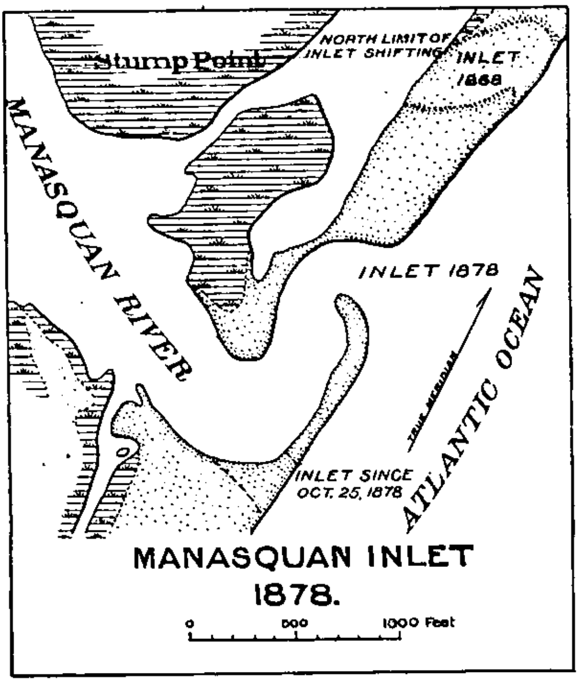

Fig. 5.

Showing the S-form of the Inlet.

1878. It showed a depth on the bar at low water varying from about 1 foot to 18 inches. The tidal range is about 2.4 feet, and the inlet was slowly working to the northward by wearing away the main beach on the north side of the lowest bend, the south beach following."[1]

"Subsequent to the heavy storm of October 25th, 1878, the inlet broke out nearly in the position of the proposed jetties. This action is entirely characteristic of the habit of the inlet. Its normal and effective position is the present one, viz., on the prolongation of the inner neck, which does not vary. At such times the depth on the bar is from 3 to 4 feet or more. The inlet does not, however, remain in this position, but gradually forms the *S* shown on the chart from the northward movement of the sands along the front beach." Fig. 5.

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[1] Reports Chief of Engineers.

"The main stem of the *S* lengthens by degrees and the inlet advances northwardly, eating its way through the beach, but always maintaining its connection with the inner neck and constantly becoming more obstructed until its discharge nearly ceases. On one such journey northward the inlet reached a point near the present life-saving station, and, in consequence, the river was filled with nearly stagnant water, giving rise to disease and causing great mortality among the fish. The inhabitants of the neighborhood combined and dug the inlet through at the proper place, with the result of immediate relief. Such extreme cases are rare, and the inlet, after traveling a few

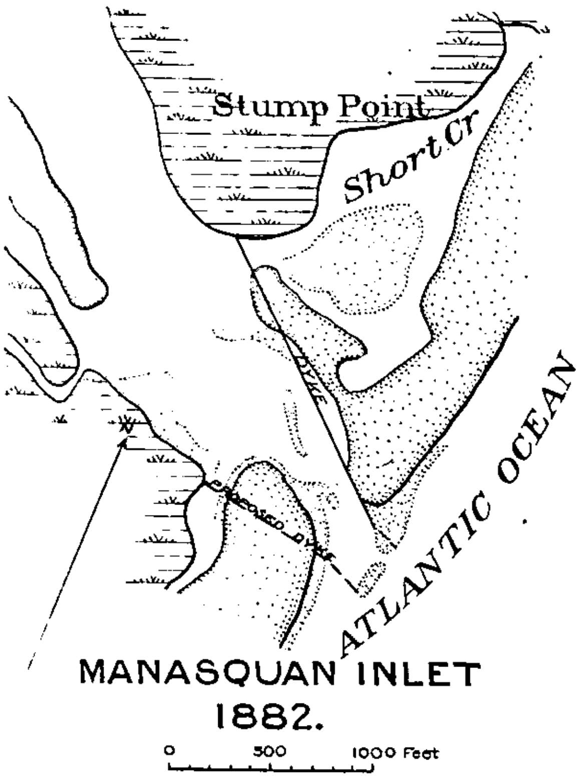

Fig. 6.

Showing location of proposed jetties.

hundred yards, generally under the influence of strong westerly winds, breaks through without artificial aid. The intractibility of the inlet has always been the most serious obstacle to the use and improvement of the river." * * * "The following project for the improvement of the Manasquan is respectfully submitted:"[1]

" 'To construct the piers of the form and dimensions, and in the positions shown upon the chart (see Fig. 6), for the purpose of controlling the inlet and concentrating the scouring action of the ebb."

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[1] Vide Report of Colonel William Ludlow to Chief of Engineers, 1879, p. 463.

"'Assuming that the mean rise and fall in the lower basin will be 1½ feet, it is estimated that the discharge will be sufficient to maintain a low water depth of 10 to 12 feet in the middle of the gorge, and 6 or 7 feet on the bar, which will form exterior to the outer wings.'

"'This bar will be exposed to the action of the littoral currents due to the northwesterly direction of the tidal wave and the effects of winds, and will probably rise to a height above that given.' * * *

"'The axis of the jetty is in near conformity to the general direction of the overflow, and its position is such as to admit of the inner wings making equal angles with it while reaching points on either side where the ends will not be endangered. The outer wings also make equal angles with the axis, and as nearly as possible, without being too much inclined to the shore, face the tidal wave.'"[1]

In a previous paper[2] by the author, the results of this improvement were stated in effect as follows:

The total estimated cost of this improvement was $52,120. This project was referred to the Board of Engineers, who made both a majority and minority report in April, 1880. In the former it is said, *inter alia:* The flood-tide impinges upon the shore from a direction south of east, and the channel wanders in this direction, growing constantly more crooked until it becomes partly, and in some cases entirely, choked. These are familiar features common to sandy beaches, showing a tendency of the inlets to move in the direction of the predominant drift. "In such cases the Board sees no permanent remedy except to transfer outwards and fix the mouth of the inlet by artificial works, terminating at depths where the resultant forces of the waves and currents would prevent the formation of a hurtful bar."

The Board recommended that two dikes should be built out to sea, with a narrow opening between them, and that the north one should be the first built. In the minority report Colonel Macomb states that "the lengthening of the contracted channel will decrease its capacity to admit the tide, and therefore diminish the inner tidal prism, upon which alone the channel must depend."

In September of the same year the data and reports having

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[1] *Ibid.*

[2] See Transactions American Society of Civil Engineers, New York, vol. xx, 1890, by Lewis M. Haupt, M. Am. Soc. C. E.

been referred to Colonel N. Michler, he reported, indorsing the views of the Board, and added:

"The exterior lines of piers beyond the beach will be of an experimental nature; the effects of storms upon them will prove their stability, and the movable drifting sands will in one way or another decide the problem as to the formation of a new bar across the artificial entrance to the inlet. Owing to the absence and untried character of any similar work along the Atlantic coast, * * * a safe estimate cannot be made as to the probable final cost."

While these extracts show the uncertainty attending the methods and anticipated results, they leave no question as to the existence of strong northwardly tidal currents, which are recognized as the principal agencies in shifting and closing this inlet. Yet the method proposed for "opening a direct channel-way across the beach, and protecting the same from the flow of the tidal currents between the river and the ocean," appeared to be designed to utilize the ebb scour rather than to arrest the exterior sand movement and admit the flood tide freely.

Under the approved plans a contract was entered into July 1st, 1881, for the north jetty first, and the construction of the south jetty was left to the discretion of the officer in charge, then Major G. L. Gillespie. The line of this work is shown in Fig. 6. Its position is such as to catch the flood currents charged with littoral drift and deflect them into the inner basin where, in consequence of the increased section and reduced velocity, new shoals immediately formed, while the reaction along the dike itself produced so much scour as to make protecting spurs necessary. These inner shoals operated to deflect the ebb currents over a different path from that by which they had entered, so that they failed to remove these deposits, and the basin rapidly deteriorated. During this part of the construction the depth on the bar was 4 feet, but the work was said to be of so experimental a nature as not to warrant any prediction of final results. "To extend the north jetty 255 feet seaward to its full projected extent and to build 905 feet of jetty on the south side will require, it is estimated, the sum of $40,000." [1] The length of the north jetty, at the close of the fiscal year 1882, was 1,515 feet. On September 26th, 1882, a contract was made with S. A. Kelly

Fig. 1. Deposit of sand at the Belmar bulkhead June 6, 1905.

Fig. 2. Mouth of Shark river June 6, 1905.

for a portion of the south jetty, and operations were commenced in November. It is located 200 feet from the north jetty, and begins at a point 100 feet inside of the end of the north jetty, extending inland 475 feet, and diverging so as to concentrate the effluent river currents and to "prevent the cutting of the beach behind the jetty. The inshore part is still too short, and should be extended 300 feet inshore towards the meadow to remove all

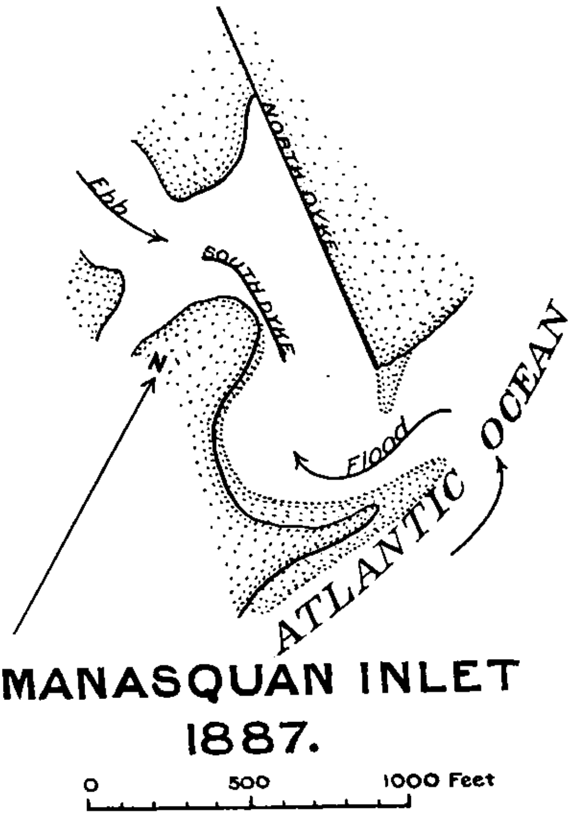


Fig. 7.

Showing the cutting behind the south jetty.

apprehension of the currents making a breach through the South Beach." [2]

The condition in which the work was left is shown in the plan for 1887 (Fig. 7), at which time the river had cut a channel

[1] Report Chief of Engineers, 1882, p. 702.
[2] Report Chief of Engineers, 1883, page 584.

behind the south jetty, leaving it entirely detached from its supporting bank, while the former bed between the jetties was being rapidly filled by sand carried in by the flood tides. In August, 1889, the entire space between the jetties was found to be filled with sand, as shown in Fig. 8. The river had abandoned its former bed, and had been deflected to the southward several hundred feet, leaving the jetties, to a great extent, buried under the drift. The outer end of the south jetty was being destroyed by the cross-currents, and the inlet was almost closed.

The history of this case is given in some detail, since it is one of the most instructive examples to be found of the injurious effects of twin jetties.

The amount expended upon these jetties was $39,000. The north jetty was built first, and catching the flood tide, charged with sand, deflected it, precipitating its load in the middle ground,[1] seen in Fig. 8, which the ebb was unable to remove. Thus these works were found to be unable to concentrate the ebb currents which were relied upon for scour, and they formed a pocket for the littoral drift carried in by the flood.

In the above plans, as elsewhere, the object has been to concentrate the ebb scour, while a much better result would have been obtained had the works been designed to oppose the sand movements and defend the channel from the encroachments of the flood and littoral currents, while freely admitting the tide.

As these outer bars are built by drift and wave action, if the agencies which maintain them can be diverted or partially neutralized and the ebb assisted in its escape, there should result a better crossing on the bar. The general principles which have

[1] The term "middle ground" is applied to those deposits caused by the expanding flood or ebb tides after passing through a contracted space or "gorge." Such expansion of area results in a reduction of velocity, and hence the suspended sediment is dropped in the path of the current, causing a bar, which divides the flow to the right and left. This is the cause of the numerous bifurcations of channels at the delta mouths of sediment-bearing streams as the Mississippi.

At tidal inlets the inward movement of sand predominates, and hence the inner middle grounds are more extensive than the outer. Both are characterized by several channels depending upon the tidal currents for their slopes, depths, form and position.

been formulated to accomplish this result are so fully stated in a paper on "The Physical Phenomena of Harbor Entrances,"[1] that they need not be repeated here; but may be summarized as follows: 1. Keep out the littoral drift; 2. Let in the flood tide; 3. Conserve the ebb energy over a limited sector of the bar, and 4. Maintain a continuous reaction upon the ebb currents.

Fig. 8.

Showing the filled channel between the jetties and the new channel behind the south jetty.

It will be seen that in many cases, particularly where there is a resultant direction to the movement of the drift, all of these conditions can be fulfilled better by a single jetty or breakwater of proper form and position than by two, and at less cost. Thus

[1] See Proceedings of American Philosophical Society, 1888. L. M. Haupt.

it will appear that this single reaction jetty plan, is designed to apply the "ounce of prevention," rather than the "pound of cure."

Old Cranberry Inlet.—In the description of the coast by Woolman and Rose, printed in 1879, it is stated that prior to the War of 1812, Old Cranberry Inlet was one of the best on the coast. It afforded a safe harbor for our privateers on the lookout for British vessels during the Revolution. It was deep enough for square-rigged ships. It opened one night by the sea breaking across the beach, and during the last year of its existence it drifted a mile to the northward. Its closure about 1812 caused so much inconvenience that about 1821 Michael Ortley attempted to cut a new inlet near the head of Barnegat Bay. With the assistance of others it was finally finished, but the following morning the tide, contrary to expectations, had closed it up. Later, another effort was made lower down the bay, near Old Cranberry Inlet, as being a better location. The cut was completed July 4, 1847, by the aid of several hundred men under Anthony Ivens, Jr. The water was let in at high tide inside and low tide of the ocean, but it filled up about as soon as did the Ortley cut. No breaches have since occurred along this section of the coast, so that the former "Island Beach," north of Barnegat Inlet, has become a part of what is now "Long Beach."

Changes at Little Egg Harbor Inlet.—From the British map of Lieutenant Ratzer, of 1769 (see Fig. 3), it will be seen that the only inlets between "Absecum" and "Barnigate" (formerly called "Burninghole") inlets, were the two known as Brigantine (Latitude 39° 27′) and Little Egg Harbor (Latitude 39° 32′), and that the island lying between them, known as "Mihannow Shoal," stretched directly across the mouth of "Mullicus River," near where is now "New Inlet." "Flat Bay" was the name given to the waters now known as Little Egg Harbor and Great Bay to those which discharged through the opening at the southerly point of Old Barnigate Beach, whence started the "Keith Line" separating East and West New Jersey, so that this point was reasonably well established at that date as the site of the inlet. The subsequent changes, so far as they can be made out, can best be understood by reference to Plate IV, on which data from various sources have been compiled.

The next authentic chart available (after Ratzer's) is that of the Coast Survey of 1840, the topographic features of which show a southerly progression of the Barnegat, now "Long Beach," spit of 72 feet per year, or of one mile in the 71 intervening years.

The Mihannow shoal was severed by a channel which broke through about 1800, called "New Inlet," and the northermost island was known as Tucker's or Short Beach, while the southern was variously designated as Flat, Little, Island, or Brigantine, according to circumstances. Old Inlet, north of Tucker's Island, which was 2 miles wide in 1848, was once the best on the coast.

The birth of "New Inlet" is ascribed to the closing of Brigantine Inlet, prior to 1800, and to the gradual reduction in the size of Old Inlet, by the growth of the spit to the southward, so that for a time the enlargement of New Inlet compensated for the loss of capacity in the former openings. Between 1800 when New Inlet opened and 1874 when the "Old Inlet" (Little Egg) had so far closed that "people walked across it," there were the two openings as shown on the chart of 1840, each a mile wide with Tucker's Island, two miles long, lying between them. As the northern opening closed the southern half of the Island was cut away so that this southern opening became two miles wide in 1870. Soon after this date the outer or Long Beach, which had been growing parallel to Tucker's Island, effected a junction with its remaining half, formed a typical hook, and closed completely the "Old Inlet" converting the island into a peninsula.

The inner middle ground, known as Anchorage Island, nearly 1½ miles long and ½ a mile wide in 1840, has been worn away until it is a mere speck on the chart of 1904. In 1878 New Inlet was at its best, but it is now shoaling. In 1803 vessels drawing from 15 to 18 feet entered this harbor at high water. These changes were affected also by changes at Brigantine Inlet, which was reported to have closed before 1800, again opened (in latitude 39° 27′) before 1840 and afterward to have drifted southward ½ mile in 30 years, or at the rate of 88 feet per annum. During this same period (1840–1870) great changes took place in the length and position of "Short" or "Brigantine" Beach, the coast of which, between New and

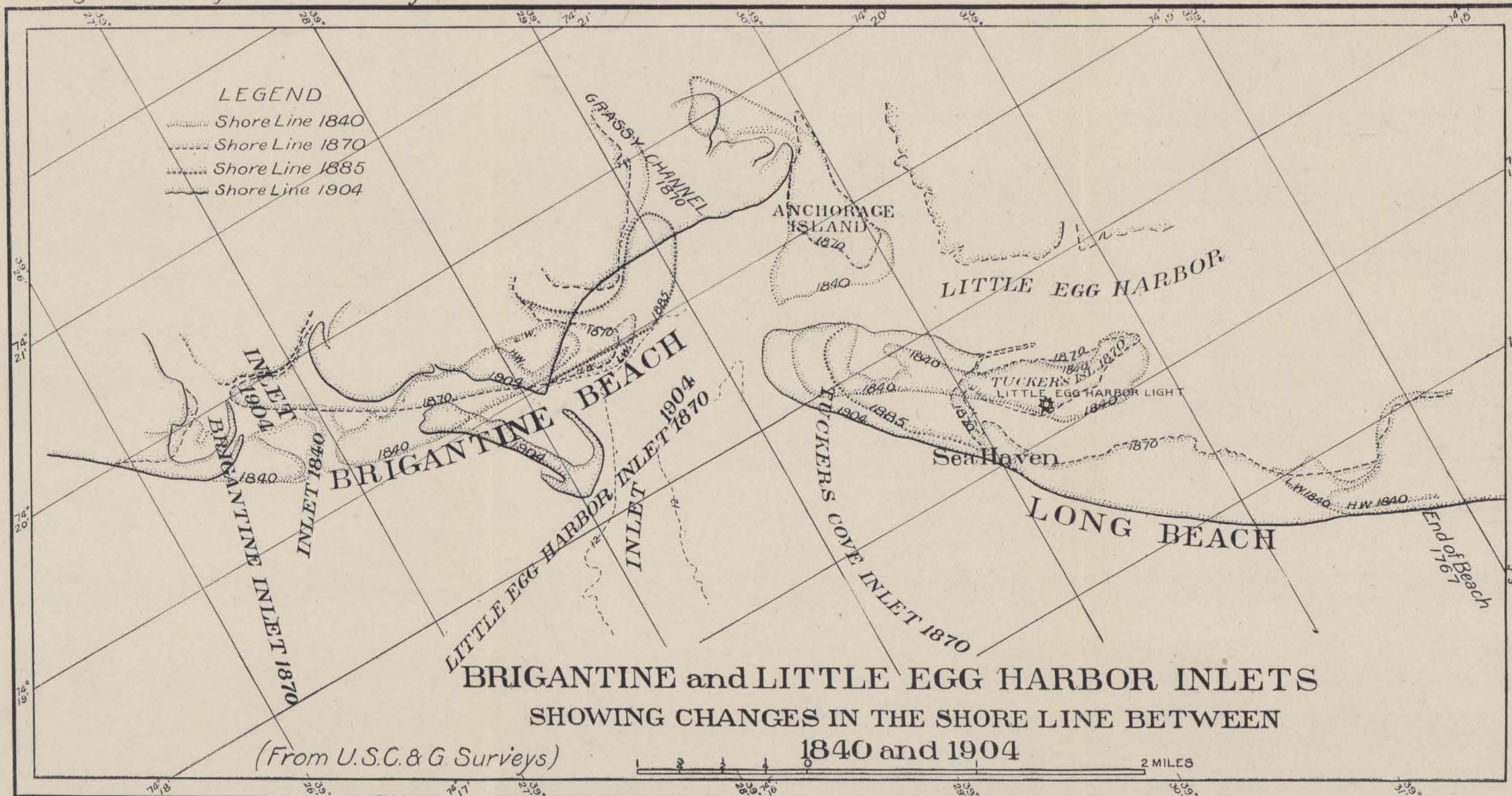
Brigantine inlets was swung to the southwest-by-south and elongated at both ends, but, since 1870, it has lost these accretions and the existing coast line of 1904 is again so modified as to be hardly recognizable. The anchor-shaped island which has formed to the east of Brigantine Beach is suggestive as to the direction of the prevailing forces, having the flukes thrown back parallel to the shank, and all lying in a southwest course. The survey of 1904 also shows a material reduction in the width and direction of New Inlet, due to the extensive shoal covering the site of Grassy Channel and reaching as far as to the former Anchorage Island, thus changing the direction of the main currents through the inlet and causing the bar channels to shift.

The growth of the southerly point of "Long Beach" up to 1904 has caused it to overlap the entire length of Tucker's Island and reach to within three-fourths of a mile of Brigantine Beach, thus congesting the tidal movements. It has filled in at points where the depth was 50 feet, so that the solid earth is above the surface and the resort known as "Sea Haven" is now laid out across a former navigable channel.

This 4-mile extension of the outer breach, the shifting of New Inlet and the large accretions upon the middle grounds are suggestive of rapid deterioration, and point to the importance of early remedial measures to maintain the channel in its present position and prevent a recurrence of the breach in the vicinity of the old location, which may be caused by a severe northwester.

Calling the length of the deposit 4 miles, the breadth ½ mile and the depth 11 yards, this spit would contain about 68,000,000 cubic yards, making the average rate of accretion some 500,000 yards per annum, or almost as great as at Greytown, Nicaragua, and substantially the same as that at Sandy Hook, N. J.

Thus at this point, as at Five Mile Beach, the sea has contributed about two square miles to the fast land of the State. Unfortunately, however, the inaccessibility of this part of the coast has greatly retarded its development and restricted its value, while the frequent changes in the unprotected shore line of the State render titles of little value when based on natural landmarks.



BRIGANTINE and LITTLE EGG HARBOR INLETS
SHOWING CHANGES IN THE SHORE LINE BETWEEN 1840 and 1904

As evidence of the truth of this assertion a portion of the testimony of the "oldest inhabitants" is adduced from the record of the court in the Atlantic-Burlington County-Line dispute, in 1885, showing the frequent changes in the beaches and inlets at its eastern extremity, leading to great confusion as to its true position.

It was contended that the line ran from the mouth of Little Egg Harbor River (now Mullica's River) in a direct course to Brigantine Inlet, on the south side of a beach formerly known as "Flat," "Short," or "Tucker's Beach," the northern part of which beach, since the New Inlet broke though it, has become attached to and is known as a part of Long Beach where Sea Haven is now platted, while the southern part is called Island Beach or "the Beautiful Isle of the Sea." It was testified that "Brigantine Inlet" was small, was not navigable and had no name until the survey of John Alvord, in 1737, while "Little Egg Harbor Inlet" was well known, was navigable, and was laid down on all the old charts from 1670. The old Brigantine Inlet was about where the south side of New Inlet was located in 1885. It was formerly known as the "John Gandy Inlet," when it was discovered way down the beach, where it broke through only about 1854.

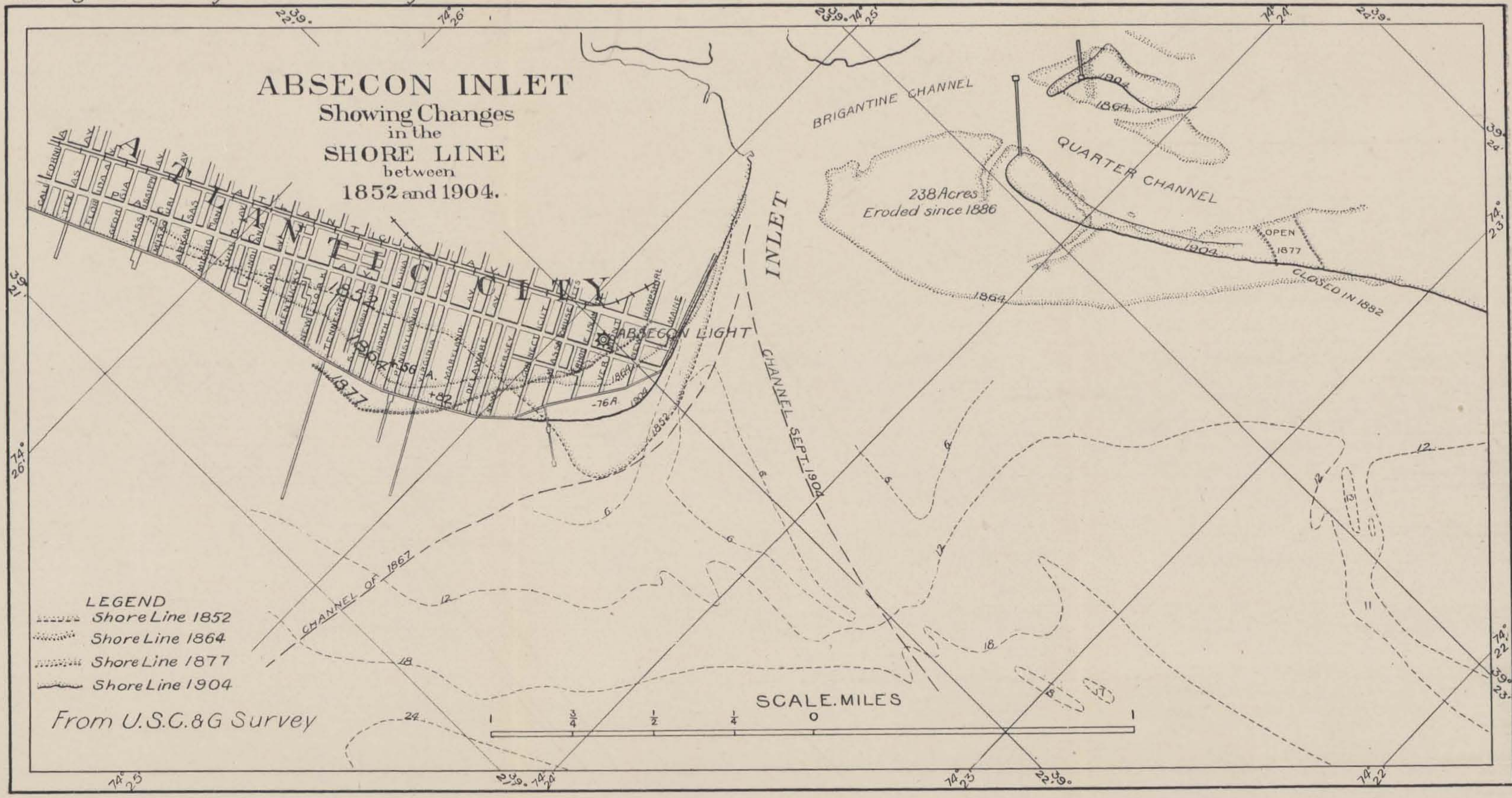
Another witness stated that there were two inlets to Egg Harbor, one known as Brigantine and the other as Little Beach Inlets, the latter was sometimes called "Shell Gut." When the former broke through the latter closed. In 1845 all the inlets on this beach were closed, and where Absecon now is there was a grove of oak trees. Again it was testified in substance that about 1825 there were five inlets on Short Beach. One called "Quarter's," by Smith's Hotel, soon filled up. It was below Brigantine. North of this there was "Shell Gut" on Little Beach, next below was Mark's, then a little one called Ben Hill, next below came Brigantine and then Harvey's Quarter. About the year 1800 Brigantine closed as New Inlet opened, and as the Old Inlet on Long Beach gradually closed the old Brigantine again reopened, thus showing the interdependence of these two openings as feeders to Great Bay. At the present date (1905) all the inlets along Brigantine Beach north of Atlantic City are closed, but to compensate for this closure there has been an unusual increase in the width of Absecon Inlet, as will appear from the following description.

Changes at Absecon Inlet and Island.—Until Absecon Island was made accessible by the construction of the Camden and Atlantic Railroad it was of little worth, but in the year 1853, April 15, an agreement was made between William Coffin, President, C. and A. Land Company, and Robert B. Leeds et al., citizens, dedicating to public uses the streets and alleys as located upon a certain plan which was surveyed by J. L. Rowand for the purpose of establishing a popular resort by the sea. On this chart the city extended from the inlet, then east of Maine Avenue, to below California, a distance of about two miles, and from Adriatic Avenue to the beach. This chart is important as showing the position of the shore line at that date and the inlets which then existed or had closed.

The south side of Absecon Inlet was then 370 feet from the center line of Maine Avenue, at Atlantic, and 740 feet at Adriatic; while the strand on the ocean front was 1,600 feet from Pacific Avenue at New Hampshire, and but 400 at New York Avenue, as shown on the accompanying charts. The chart of 1853 also indicated the location of a "dry inlet" a mile below (southwest of) the city as laid out, and the end of the island was placed at 2.6 miles farther down making its length to "Old Inlet" about 5.6 miles. At its southern extremity it is noted, "the old thoroughfare between the beaches is now filled up.

A map, apparently from an early prospectus of the Camden and Atlantic Railroad, shows an inlet about in the position of "Dry Inlet" as being then open through Absecon Beach.

The United States Coast Survey of 1863–64 indicates some rapid changes at the easterly end of the city where the shore was washed away as far as the intersection of Maine and Atlantic avenues. This represented a loss of nearly one-half a mile on the former avenue, and removed about 76 acres from the site of the city. (See Plate V.) This material was deposited in the lee of the point extending from New Jersey to Ohio avenues, causing an advance of the beach lines at Pennsylvania Avenue of about 1,000 feet, and adding to this part of the plat some 56 acres in the brief space of a decade. This transfer of property


ABSECON INLET
Showing Changes
in the
SHORE LINE
between
1852 and 1904.
ATLANTIC CITY
ABSECON LIGHT
INLET
CHANNEL SEPT. 1904
BRIGANTINE CHANNEL
QUARTER CHANNEL
238 Acres
Eroded since 1886
OPEN
1877
CLOSED IN 1882
CHANNEL OF 1867
LEGEND
Shore Line 1852
Shore Line 1864
Shore Line 1877
Shore Line 1904
From U.S.C.&G Survey
SCALE. MILES

from one riparian owner to another without consideration is not provided for in the statutes, and might properly be regarded as inequitable. Provision should be made to maintain the stability of the beaches by local authorities. The erosion at the point continued so rapidly that by 1878 it had reached the light-house property and was in danger of destroying that structure, thus requiring the Government to protect itself, which it did by the construction of a jetty at the head of Atlantic Avenue. Thus was inaugurated a series of defensive works which has been continued by individuals to such an extent that some 82 additional acres have been reclaimed from the sea, to the great benefit of the city as well as of the riparian owners. In the meantime, however, the channel, which crossed the bar abreast of Pennsylvania Avenue in 1864, having completed its cycle, shifted some 2 miles to the east, with a ruling depth of 8 feet at low water.

The off-shore shoal, 2 miles out, having but 11 feet depth over it and constituting a serious menace to vessels, has drifted nearly ½ mile to the westward and its depth has increased to 15 feet, while the "gorge" at the inlet has widened from 600 to about 4,200 feet by the rapid erosion of the end of Brigantine Beach, where the loss amounts to about 238 acres in a comparatively few years. This may be traceable to the closure of the inlets on Brigantine Beach and the congestion of the exit channels due to the continued encroachment of the great bank of sand drifting in from the east and deposited in front of the inlet.

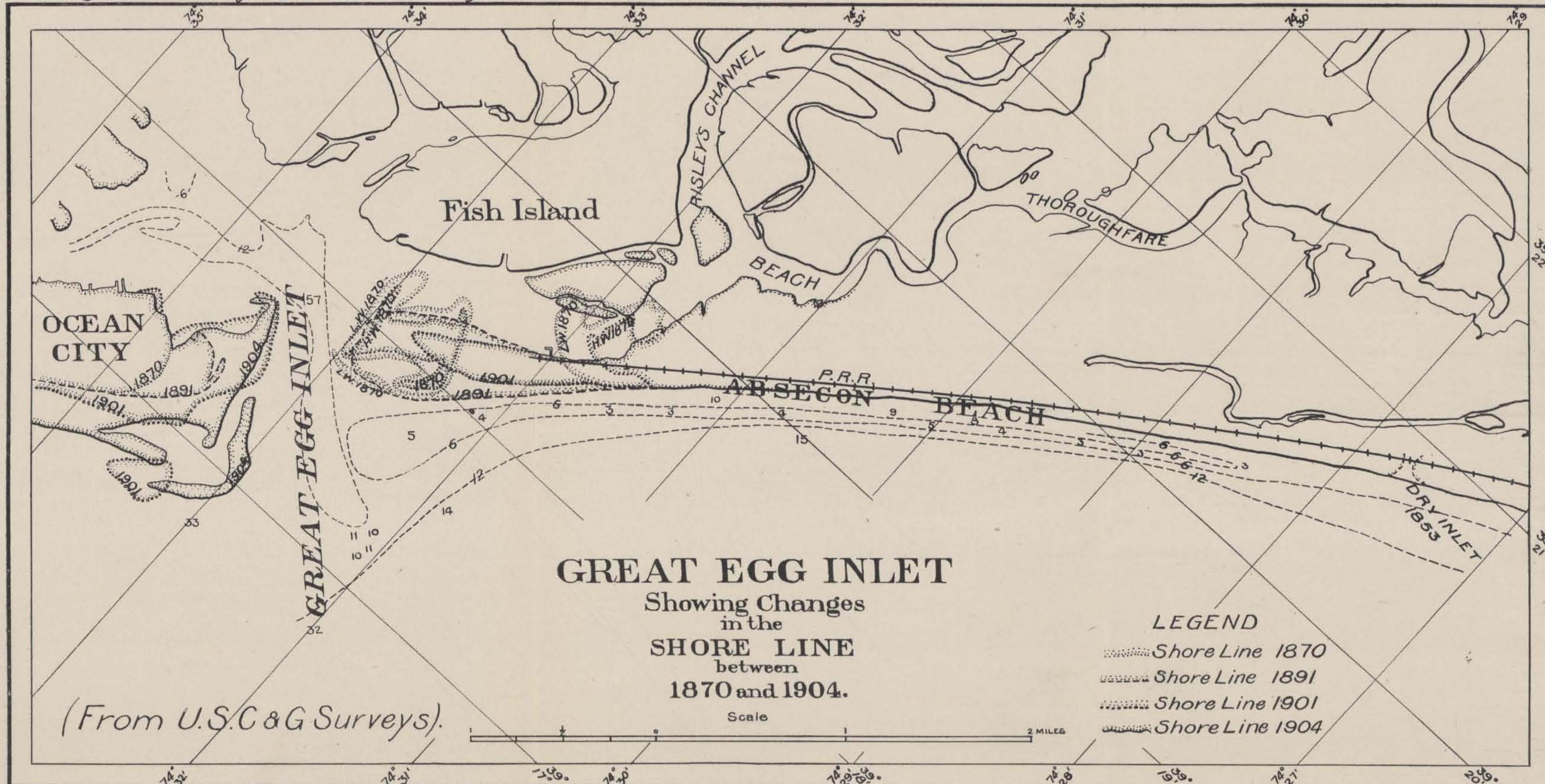
One and a half miles easterly from Absecon Inlet there was, in 1828, an old opening known as Quarters Inlet, which closed, reopened about 1877, and again closed in 1882-3. For a length of 2½ miles in the vicinity of Life-Saving Station No. 26, Brigantine Beach has grown out, about 10 yards per year for 25 years, due it is said to some old wrecks. A breach across the lower end of Brigantine Beach was closed in 1835, and the beach is now continuous from Absecon to Brigantine inlets, a distance of about 6 miles. The effect of these changes on the commerce is set forth by the port pilot Captain Jesse Yates, who testified in 1898 that within 10 years the shipping had fallen off over one-half on account of the shoalness of the bar. In 1886 it was good for 11 feet at high water, while in 1898 the depth was but 7 feet at the same stage and the channel very narrow. He added, "There have been about 25 to 40 vessels this year (1898) that I have had to send away, because their draft would not allow them to come over the bar. * * * There were about 300,000 tons came here last year, and only about 150,000 tonnage this year. There have been about 12,000,000 bricks shipped here this year which have caused lots of trouble, they are shipped in vessels of an average draft of 6 or 7 feet." "The channel changes constantly, while the buoys do not, so that they are of comparatively little use. I think the jetty would protect the beach."

Similarly, the various inlets to the southward along the Absecon Beach, have all closed up and the island is nearly 9 miles in length. A survey of 1715 showed a "Little Inlet" with a small island athwart its mouth on the inside, to the east of "Risley's Channel," and just north of the present position of Life-Saving Station No. 29. (Plate VI.) So that the extremity of the Absecon Beach of that date was about where South Atlantic is now platted. Since then it has been prolonged 2½ miles, but it is now receding.

Great Egg Harbor Inlet.—South of Absecon Island is located the outlet of the drainage basin of Great Egg River and Bay, which has long been one of the most important on the coast. The attractions of this inlet and its adjacent waters are such as to have given rise to the establishment of the popular resorts of Longport on the northern spit and Ocean City on Peck's Beach to the south. These points are connected by a line of ferry boats operated under the management of the West Jersey and Seashore Railroad, during the season.

The maintenance of these communications and the welfare of the resorts is affected by the extensive changes which have been taking place at this inlet.

It has been seen that at Little Egg, as well as at Absecon inlets there was a certain interdependence between the old and new inlets, one closing as the other opened. So it is at Great Egg. The limit of this oscillation is determined by the extent


GREAT EGG INLET
Showing Changes
in the
SHORE LINE
between
1870 and 1904.
(From U.S.C&G Surveys).
LEGEND
Shore Line 1870
Shore Line 1891
Shore Line 1901
Shore Line 1904
Fish Island
OCEAN CITY
GREAT EGG INLET
ABSECON BEACH
RISLEY'S CHANNEL
THOROUGHFARE
BEACH
P.R.R.
DRY INLET 1853
Scale
2 MILES

and form of the interior tidal basins and the constant shifting of the shoals constituting the inner middle grounds. The operation of these forces may be illustrated best by reference to the transition stage at Great Egg Inlet between 1869 and 1886, the condition of which in 1869–70 is shown on Fig. 9.

In describing this inlet the Atlantic Local Coast Pilot, for 1882, states, page 46:

"Great Egg Harbor Inlet, contained between the southern end of Absecon Beach and the northern end of Peck's Beach, is 2 miles wide; but almost exactly in the middle lies Sand Island, about half a mile long in a NE. SW. direction, and of very irregular shape, changing frequently.

"This island divides the inlet into two channels, that to the northward, however, being of little importance. Besides this island there are numerous sand bars between it and Absecon Beach, which further contract the northernmost channel and renders navigation difficult and dangerous. The northern extremity of Peck's Beach is sandy and covered with a mixed growth of pine and deciduous trees. The north point of the inlet, on the contrary, shows only a succession of bare sand hillocks."

This is the condition represented in the survey of 1869–70 (Fig. 9) to a moderate extent. The two openings known as "New" Inlet to the eastward and "Old" Inlet to the westward of Sand Island are complementary. The sand drifting to the southwest along the beach of Absecon Island, where all former breaches have closed, finds its first lee under the northern spit of New Inlet and is there deposited in the usual hooks and crescent shoals, growing in area and traveling inward towards the older middle grounds of Fish Island, thus obstructing the outflow from Lake's Bay by a natural dam extending nearly across the thoroughfare. The enfeebled and diverted ebb discharge is therefore unable to remove this sand, *in situ,* and as a consequence the spit continues to grow southwardly until it reaches Sand island which it seizes and converts into a peninsula.

The four little spits at the corners of the island are also very significant pointers as to the direction of the drift and the origin of the forces forming them, as coming from the northeast and driving the easterly horns back while the others tend to revolve in the rear in the direction of the hands of a clock. "New Inlet" being thus closed, all the tidal flow must enter through the contracted "Old Inlet" and a portion force its way across the newly made shoals of the thoroughfares into the tidal reservoirs, thus deepening the channels and shifting the inner bars. This scour is augmented at the ebb tide by the lateral discharge from Lake's Bay, which impinges upon the westerly bank of the spit as shown by the arrow at "A," and rapidly erodes the bank, thus in time again tending to detach the point and re-create an island. The positions of Risley's Channel and the insular middle ground to the eastward of it indicate that formerly there was an opening in the beach in that locality, and the old deeds of 1715 confirm this opinion by showing an inlet on the site indicated on the chart. It appears, therefore, that the general direction of the drift here is southward, and that the openings move in cycles as elsewhere. The outer deposits on the lee side of the inlets are due mainly to the ebb forces and may readily be mistaken for the result of a northward drift.

From the above brief analysis it will be understood that the banks of sand deposited by the flood tidal currents and driven by waves are the prime factors in moulding the ever-shifting channels, and that the success of any work for the creation of a channel or the recovering of a lost beach must be based primarily upon a control of the sand movements, and secondarily, upon protection from currents and waves as far as practicable.

The record of the changes at this inlet is not complete, but, nevertheless, by a comparison of maps and other data it is possible to fix the dates at which certain phases of the above cycle prevailed. According to evidence gathered by Dr. Cook,[1] "New Inlet" had been working southward for some years previous to 1859, and in that year united with the main inlet (or was closed by sand) so there was but one entrance to Great Egg Harbor. Some time within the next 10 years New Inlet broke out again in approximately its former position (where Longport is now situated) as is shown by the Coast Survey Map of 1869-70 (Fig. 9). In 1882,[2] there were also two inlets with Sand Island between, but the records at hand do not indicate whether this con-

[1] Annual Report of the State Geologist, 1885, p. 89.

[2] Atlantic Local Coast Pilot, see ante.

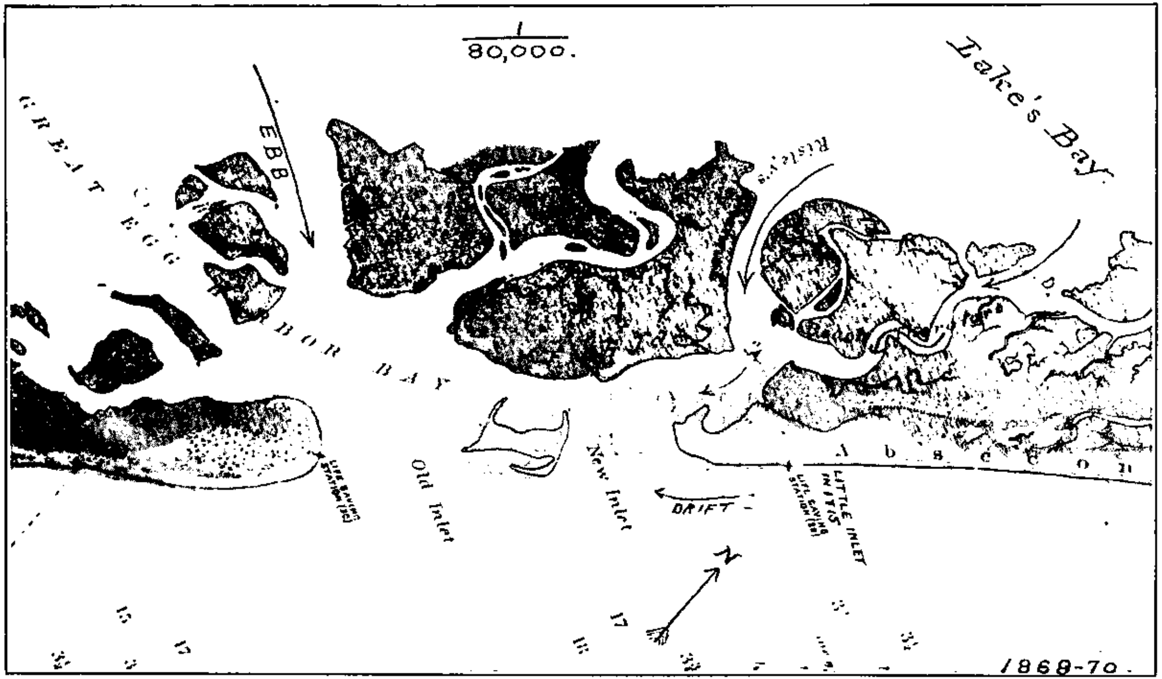


Fig. 9.
Coast survey map of Great Egg Inlet 1869–70.

dition had prevailed continuously since 1870. That the northern inlet was filling up is, however, indicated by the description quoted above (page 67) and it is not surprising, therefore, to find that in 1884 [1] it was closed again, there being as in 1859 only one entrance to Great Egg Harbor. This condition has prevailed to the present time, although with constant changes in the outline of the shore at Ocean City and at the end of Absecon Beach, as is shown on Plate VI, where the shore lines of 1870, 1891, 1901 and 1904 are shown.

Since 1900 several manifestations of an effort to reopen the inlet, which formerly existed on the site of Longport, have occurred in the sudden sinking of large areas of land which have required immediate action on the part of the authorities. This inner frontage is now well protected by a heavy revetment of rip-rap to prevent the recurrence of this disaster. Plate VII, Fig. 1, shows one of these holes where the bottom dropped out suddenly, so that in less than a half hour, on a fine day, the wash-out was 15 feet deep and about 300 feet long. The restored street and track with its revetments is shown in Fig. 2.

The movements at the northerly end of Peck's Beach (Ocean City) have been extensive. In 1885 the wear of the point was said to have been 100 yards in 8 years, but soon after that time it began to accumulate sand, and up to date (1905) the island has been extended more than half a mile, at the expense of the southerly end of Absecon Beach, which is now being held by reclamation jetties.

While the eddy depth in the gorge of the inlet exceeds 50 feet, the ruling depths on the bar are limited to 11 at low water and the channel is constantly shifting. Amid these changes it is evident that there are certain phases which are the best for navigation when the channel could be made permanent at least cost and with the greatest benefit to commerce.

Hereford Inlet and Five Mile Beach.—A brief general idea of the material changes which have been taking place at this locality may be had from inspection of Fig. 10. Between 1771 and 1886, Five Mile Beach advanced at the southern end nearly a

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[1] Sheet 16, Atlas of New Jersey, surveyed in 1884 and published in 1885.

mile and Turtle Gut was almost closed. From 1886 to 1901, recession took place. This is most apparent along the front of Two Mile Beach. The inlets are also drifting towards Delaware Bay, due to the movement of the sand in that direction under the influence of the flood tide. The rapid growth of the "resorts" along this attractive frontage makes protection work at the inlets an early necessity.

In a recent inspection of this region it was learned that a substantial bulkhead, built about 1890 at Five Mile Beach to protect Wildwood and Holly Beach, was carried away and that the island had wasted some 600 feet, when, without apparent cause, the sea began to deposit and the beach to gain its former position. (See Fig. 10.) Upon investigation as to the cause, it was found that Hereford Inlet, at the head of the island, had drifted to the south 1,000 feet in the past 10 years and the shore in front of Anglesea had advanced some 1,500 feet in consequence. This deposit projected the ebb tide farther out and caused an eddy current which cut away the beach to the southwest of the shoal, as was the case at Absecon Beach prior to 1850, when the shore was close to Pacific Avenue.

The Hotel Royal, at Hereford Inlet, a few years ago stood on what is now an extensive outer middle ground, bare only at low water, covering nearly a square mile. (See Plate VIII, Fig. 1.) It has been moved back three times to escape destruction from the rapid shifting of the inlet. Other buildings have had a similar experience, and to-day the high-water line passes through the corner of the Life-Saving Station, and is only 30 feet from the lot of the light-house. (See Plate VIII, Fig. 2.) The jetties and groynes which were built to protect these properties are now destroyed.

Similar movements are taking place at Cold Spring Inlet (Fig. 10), but in less degree, for that inlet is narrow and the basin relatively small. There are no buildings at this point excepting the trolley terminal, but large improvements are contemplated and in process, in the way of bulkheads and backfilling of the salt marshes for a new resort, near Cape May.

These losses of beach front by the action of the sea are a potent factor in retarding the development of the coast, as the riparian

Fig. 1. Sink hole at Longport, N. J.

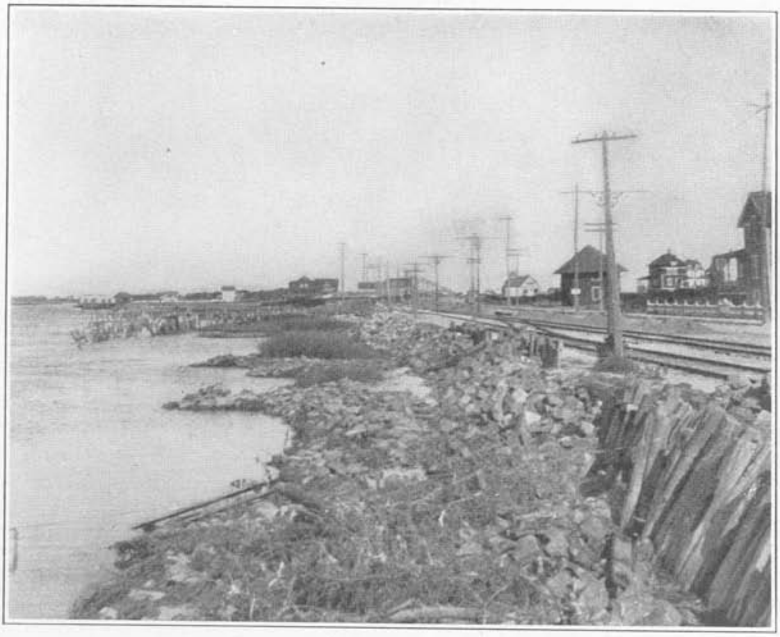

Fig. 2. The same after refilling and building stone revetment.

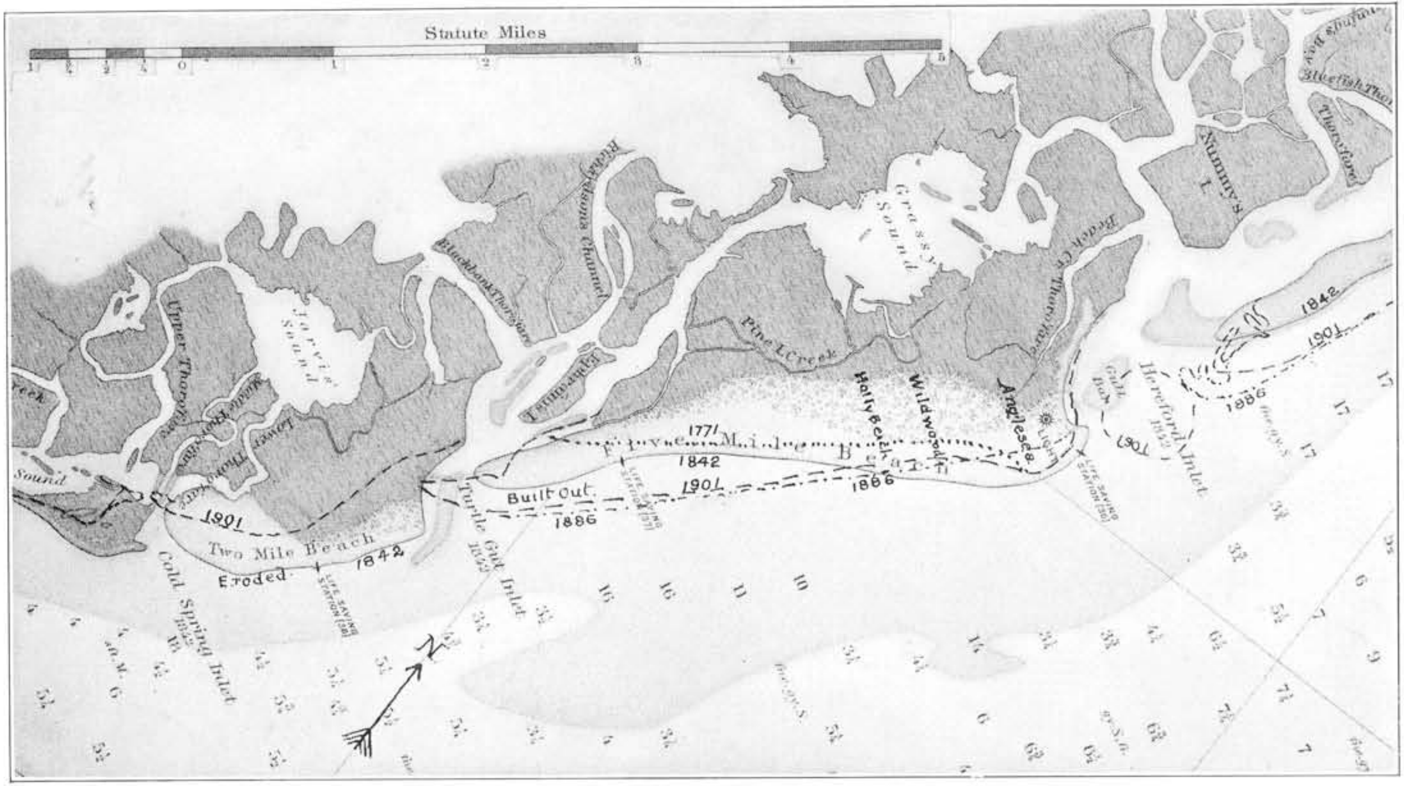

Fig. 10.

Changes at Hereford Inlet and Five-Mile Beach, 1771 to 1901.

Fig. 1. Hereford Inlet from L. S. S. showing the outer middle ground, the former site of Hotel Royal.

Fig. 2. Lighthouse lot with Hereford Inlet on the right.

Jetties and bulkhead at Long Branch.

owner is never sure of his ground nor of the expense he may incur in efforts to protect it from erosion. Moreover, the Land Title Companies hesitate to guarantee titles to properties near the inlets for the same reasons, so that there is early need for some general control and action by the sovereign powers of the State to remove these obstacles to the development of her most attractive and valuable territory.

The forgoing statements will serve to illustrate the frequent changes which are constantly taking place in the coast line of the State, the great risks incurred by shipping, the losses to life and property, the restrictions placed upon the growth of the most attractive and popular seaside resorts and the uncertainties as to titles resulting from the operation of the complex forces which characterize these coasts.

REMEDIAL WORKS, FOREIGN AND DOMESTIC, AND THEIR RESULTS.

Examples along the New Jersey coast.—Many individual efforts have been made to protect personal property, by the construction of jetties, dikes, retaining walls, revetments, and deflectors, but all without reference to their general effect on the destructive forces, or on the adjacent properties, and it frequently happens that a device which may temporarily relieve one section of beach will produce erosion and waste on an adjacent section. This is well illustrated by the condition of the bluffs at Long Branch, where each owner has adopted more or less independent devices. Plate IX shows a continuous bulkhead with back-ties and a roofing in process of construction. Spur jetties at frequent intervals protect the bulkhead by catching the drifting sand, but the beaches beyond, their supply being cut off, have frequently been denuded and their bulkheads destroyed. Locally, another form of defense is employed, consisting of an inclined apron, or "ramp," with beveled sides placed on a concrete foundation and rising on a slant from the beach nearly to the level of the boulevard. The effect of this slope is to aid the waves to surmount the parapet in its rear and break over on the boulevard, whilst the receding water, shooting down with high velocity, cuts a trough around the base and tends to undermine the structure.

The character of the works formerly adopted for protection at Belmar are shown in Plate X, where Fig. 1 represents the high spur jetties projected across the strand at the end of each street, about 350 feet apart. These were soon battered down and rebuilt at a lower elevation, as seen in Plate II, Fig. 2, and Plate XIII, Fig. 2. The bulkhead built along the south bank of Shark River to reclaim the land has not been a marked success, its condition being shown in Plate XI.

The most effective work, in view of its cost, has been done at Longport, where sand fences have been placed across the strand between high and low water. These (Plate XII) consist of light piles driven about five feet apart by water-jet and having horizontal strips spiked on with spaces of 2 inches between to permit the waves to carry sand to leeward and deposit behind them. As the beach fills, more strips are added and the line extended, as shown in the illustration.

The stockade method was tried at Holly Beach (Plate X, Fig. 2) where a large number of piles were promiscuously driven in juxtaposition to impound the wind-driven sand, without regard to any systematic plan of defense.

These works are all of a temporary nature, constructed by private or local parties with limited resources, because permanent works of stone, properly placed to produce general results, are not within the means of the individual, who may own but a few feet of frontage.

Opinions of British engineers.—In a recent discussion on "Coast Erosion," before the Institution of Civil Engineers of Great Britain,[1] so great a variety of conflicting opinions were recorded, as to the relative efficiency of these various devices, that it may be well to note them briefly with reference to the problems under consideration.

In the case of a sea wall having a curved face, or one with a steep batter, it was found that the latter produced less erosion at the toe and was more stable. With reference to the merits of high or low spur-jetties, it was asserted that the low ones gave better results in general, and that jetties were cheaper and far preferable to continuous sea walls.

[1] See Proceedings, Inst. Civil Engrs., London, on Coast Erosion, 1905.

Fig. 1. High jetties at Belmar.

Fig. 2. Stockade at Holly Beach.

Bulkhead, at Belmar, at the mouth of Shark river.

Fig. 1. Sand fences at Longport.

Fig. 2. Sand fences at Longport.

"Stepped" walls were better than "sloped," and a curve slightly concave upward was a good expedient to protect the backing from being eroded by the falling water. Again, if one portion of the coast was protected by jetties, the immediate result was denudation of the coast to leeward. It would be improper for a seaside resort to let the beach sand on the foreshore go by, merely because by retaining it they might be robbing somebody else. The object of a sea wall should not be to arrest the impact of the waves, but to form a barrier against which the "shingle," sand, or other drift along the coast, might be arrested by natural action. It was this bank of material which became the real protection, and not the sea wall. "A high wall, on high-water line, becomes one of the most effective excavators of a foreshore that could be imagined." It was impossible to lay down any hard and fast rule, as the conditions were seldom alike. In some places the shingle traveled in the direction of the prevailing wind, in others in nearly the opposite direction.

The amount of money which was being frittered away in useless devices for checking the littoral drift on some foreshores was appalling. The opinion that spur-jetties were an essential element in any effective scheme for defense was altogether a mistake, and they were unsightly and inconvenient obstructions to the beach; as a means of coast protection they were, speaking generally, a complete failure and the money spent upon them was all wasted. The system must be based upon the geological and topographical conditions, with consideration for the winds and waves.

With regard to the direction of travel of the detritus, it would be better to say that it was with that of the flood tide, which was generally the case. Any object in the sea, intended to coerce, was a source of danger, foredoomed sooner or later to complete failure. Persuasive rather than coercive methods must be adopted. Again, it was stated the high-water mark could not be driven seaward by the construction of high timber jetties or by great stone or concrete structures built into the sea, but excellent results have been secured on the New Jersey coast by short, curved jetties properly placed, with large accretions and reclamation of lost beach frontage. A sea wall was not a true remedy, but only a palliative by substituting a harder for a softer material. Relief must come from a thorough study of the nature of the forces at work.

There was great diversity of views also on the subject of erosion and its remedies, as shown by the papers submitted. The low sea wall, with or without groynes, appeared not only to be a useless expenditure of money, but also to provide direct inducement to the sea to attack adjoining property. Such structures formed a just cause of complaint by a propriêtor of adjoining, unprotected land who might be victimized through his neighbor adopting this means for saving his own land. A case was cited where a sea wall without any apron or groynes had eroded the foreshore to a depth of several feet below the footings, requiring underpinning and auxiliary works to prevent its complete destruction. If some means could be found to prevent the waves from breaking on the shore but slight erosion would be caused by simple undulations. Oil bags were suggested but believed to be too expensive. The growth of kelp was found to be a great protection in certain latitudes. Another speaker thought a good method would be the cultivation of beaches by the study of the causes producing them.

These few disjointed extracts from a prolix discussion will suffice to convey some impression of the state of the art of beach protection in a country where the subject has engaged attention for many years. Nevertheless, it appears from these statements that no well-established and relatively economical methods are in general use. It is apparent, however, that a purely local treatment may do more harm than good, and that the general conditions should be carefully considered before any remedy can be applied. To this end, a complete diagnosis should precede the formulation of any project for the improvement of channels or the reclamation of beaches. The relation of cause to effect should be observed, and the resultant of all the variables, as recorded on the face of Nature, should be carefully interpreted and applied before the improvements are commenced.

Attempted improvements at Atlantic City.—Before making such an application it is necessary to note what has been proposed, and why no progress has been made as yet in the relief of the bars or the defense of the beaches. Taking the specific case of Atlantic City, it is found that the prevailing sentiment of the permanent residents as well as transients is strongly in favor of a harbor of refuge, and it has been urged, estimated and reported on time and again, yet no definite relief is obtained, possibly because the resources available at the time were not sufficient to meet the great expense of the plans proposed for relief, as well as because of the reported uncertainty as to their beneficial results. This question is therefore one which will merit a brief statement as to its history, with a view of suggesting some early measure of relief.

Twenty-five years have passed since an appropriation was first made for a survey of Absecon Inlet, upon which an extensive report was submitted in connection with other points on September 20, 1881. In this report it was said in substance:

The inlets are variable both in depth and position, from the mobility of the sand that constitutes their beds and banks. * * * The principal are five in number, with low-water entrances ranging from 7 to 10 feet, increasing at high water to 11 to 15. Of these Absecon ranks second in depth. In none of these is an entrance safe in stormy weather. * * * The great increase in the number of coasters and the frequent disasters suggest the desirability of some harbors of refuge, so fixed in both depth and position as to admit of their being suitably lighted and entered with safety by at least the smaller classes of vessels. It is not a local matter, since the benefit would accrue to all coasters seeking shelter therein. * * * It is no doubt feasible to improve the entrance by means of suitable jetties, but the preparation of plans and estimates for these does not appear to be called for in this preliminary report. Further observation of the changes in progress, and a resurvey of the locality during the ensuing season, are desirable if further study of this harbor should be called for. An appropriation of $2,500 is recommended.

The Act of June 14, 1880, authorizing this survey stated:

"The Secretary of War is hereby directed, at his discretion, to cause examinations or surveys, or both, and estimates of cost of improvements proper, to be made at the following points, namely, * * * Absecom Inlet, Atlantic County, New Jersey."

Thus was inaugurated a policy which has up to this date failed to provide any definite method for the amelioration of the inlet. This becomes, therefore, one of the fundamental difficulties which beset the question from a business point of view; the remedy for which is enabling legislation, either from the general Government or from the State, without which it is manifest that no improvements can be effected. Legislation is therefore a *sine qua non*. No appropriation was made, however, for a resurvey until July 5, 1884, and the report[1] following stated that,

"The residents of Atlantic City desire to have the entrance of their harbor improved. It is now obstructed by a bar distant about 1½ miles outside of Absecon Inlet * * * having a depth of only 8 feet of water at mean low tide." * * * "The commerce of Atlantic City is now considerable and is increasing. * * * There is no question but that the commerce would greatly increase if the entrance were improved, &c."

Then follows a plan for two jetties convergent seaward and a little less than one-quarter for a mile apart at the outer end, concerning which the officer in charge says:

"If the jetties could be made to stand they would * * * scour away the material (sand) forming the bar and scatter it into deeper water. Whether or not the current would be sufficiently strong to produce the required result is a matter of uncertainty; * * * The two conditions, to concentrate the outflow and not obstruct the inflow of the tide, are not easily overcome. * * * Two jetties, if constructed and extending nearly 2 miles seaward would soon cause the shore lines of both beaches to build out towards the ends of the jetties, and it would not be a very long time before another bar would again form beyond the outer ends of the jetties. It is also probable that the jetties, if built, would destroy, for a considerable time at least, the surf in front of Atlantic City, one of the most attractive features of the place." * * * In great storms "It would be impracticable for them (vessels) to enter the comparatively narrow and long channel between the jetties." * * * "It would be useless to dredge the bar without protecting works." * * * For these reasons, "and from the fact that a detailed survey has been made, it is thought that no further survey is necessary here."

The report of 1884 is concluded with this paragraph:

"I am not prepared to say that the harbor is not worthy of improvement, but as the cost of making the improvement is far greater than the benefits to be derived therefrom, and as the works, if constructed, would not necessarily effect a permanent improvement, and as there is no ***public necessity*** for the works, the deduction from the facts must be that the harbor is not worthy of improvement."

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[1] Vide Report Chief of Engineers, 1885, i: 862.

Nothing daunted by the recommendation that no further survey was required the local interests secured an appropriation of $5,000 in the Act of August 5, 1886, for a survey by a Board of three United States Engineers, with a view to making a harbor of refuge at Atlantic City. The resurvey was made in November and December, 1886, and the report on May 31, 1887.

In reporting on this survey the Board stated that the inlet had increased in width about 1,000 feet by the cutting away of the southern end of Brigantine Beach, and that the ruling depth on the bar was less than 8 feet. It recommended two stone jetties having a total length of 3½ miles, converging seaward to a width at the outer end of only 800 feet and estimated to cost $3,000,000 with an addition of $600,000 should it be found necessary to open the channel by dredging. No recommendation was made, but the report closed by stating that:

"The effect of the construction of the jetties would probably be to cause an accumulation of sand north of the north jetty and to a limited extent immediately south of the south jetty, but it is not improbable that farther southwest the beach will be cut away in front of Atlantic City, as the supply of sand coming from the northeast during the northeast gales will be diminished by the jetties. Another effect of building the jetties will be, by interfering with the flow of the tides, to increase the danger of breaches through Brigantine Beach, which has heretofore been breached several times, but it is now continuous."

The depth proposed was to have been 20 feet, but nothing further has been done on this project.

In 1898 a radical modification of the above 2-jetty plan was submitted, in the hope that at least some measure of relief might be secured for the use of the harbor by steam and naphtha launches. The report says:

"The project for improvement now presented (1898) provides for maintaining 10 feet at mean low water over the bar by the construction of a stone jetty on the east side of the inlet * * * estimated to cost, including contingencies, $500,000."

The report further states that this jetty, which does not reach to deep water, "Has been located solely with a view to economy of construction, and without regard to its influence as a training wall." It is suggested that "it can be best and most economically done under a continuous contract." Nearly seven years have elapsed but no work has been done, and the project is evidently abandoned.

The above abstracts furnish a type of the difficulties which beset the improvement of the minor inlets of our alluvial coasts. A change of local authority, variations in the composition of the Boards of Engineers; modification of plans and estimates; excessive costs; uncertainty as to character and permanency of results, and a lack of personal responsibility are the main defects of a system which militates against local improvements by appropriation from the Federal Government where there is no commerce of importance. But, as will appear below, the physical problem is readily resolvable at a very moderate expense by a judicious application of the local forces operating at these inlets.

OCEAN DYNAMICS.

To ascribe the physical changes on alluvial coasts to the preponderating influences of one or more of the forces, as is frequently done, would manifestly lead to erroneous conclusions and failures in the proposed remedies. Evidently, all the elements must receive their due weight, and since no extended instrumental observations can give so reliable an indication as those recorded upon the plastic material of the sandy beaches themselves, it will afford a better clue to the operation of the forces to note carefully their effects by a thorough study of the positions of the shoals, and channels, with their cross sections and slopes, as indicative of the directions of their movements.

The elements which must be considered are therefore the tides, currents, winds, waves, nature of the material composing the strand, position of the water contours, slopes of the foreshore, angle of wave impingement, frequency and size of breaches in the coast, capacity and form of interior tidal compartments, amount of land drainage, rate and amount of littoral drift, and local accidents interrupting the continuity of the movements, whether natural, as in rocky headlands, or accidental as from wrecks; in short, not only the local and terrestrial, but the cosmic influences must be considered as factors in producing the observed effects.

It is a well-known fact that the flood tide on entering a bay with converging shores will rise higher and higher as the bight of the bay is approached so that a few feet of rise at the salient capes may be augmented to even 60 feet at the bight as in the Bay of Fundy. The same principle applies but in a lesser degree when the shores are indented by large subordinate bays and sounds, such as are found between Capes Cod and Hatteras, in the great Middle Bay, of which New Jersey forms a part of the boundary. The entrances to Long Island Sound, New York, Delaware and Chesapeake bays by interrupting the continuity of the tidal movement and permitting it to enter these interior waters modify the general law as to increasing height of tides on the outer coast, as well as the prevailing directions of the wave approach which is an important factor in the propulsion of material.

It is also well known that during the prevalence of the flood tide the breakers are more heavily charged with silt than during ebb, so that it is scarcely possible at that time to use a water-jet in sinking piles because of the rapid filling of the holes with drift. This, with the direction given to the wave by the form of the beach contour, determines very largely the direction of the sand movement where the shore is continuous. Where a breach occurs other factors enter, especially if the inlet be large as at New York, where the spits of Sandy Hook and Coney Island serve as positive indices to show the direction of the drift towards the bay from both flanks, which are nearly at right angles to one another. So, too, at the Delaware estuary, the drift is inward at both Capes May and Henlopen. There must be a node, therefore, or point of division on the Jersey coast, somewhere between these bays where the direction of movement of the drift changes from north to south. Such a point is found to exist near Bay Head, as shown by the shifting of the various inlets throughout a period of years, as already set forth in the charts of the various breaches along the coast. (See Plates IV, V, VI, and Figs. 2, 5–11.)

Littoral drift.—The wasting of the beaches is due mainly to the action of the breakers, especially at flood tide. These angular waves (Plates II and XIII) moving in a resultant direction, which depends largely on the form of the beach contour and the submerged topography, drive the heavier particles of sand before them in a zigzag path until the continuity of the supporting strand is broken by an inlet, when the drift will be carried inside and be deposited under the lee of the outer beach, or be precipitated in the bay by the inertia of the still waters. In this manner the deposit known as the "inner middle-ground" is built up and the entrance of the tidal waters so impeded that they are divided to the right and left, thus creating the ramifications of islands and channels which check the tides and direct the currents at egress, in such manner as to determine the channels and depths on the outer bar crossing.

It is of fundamental importance that the prevailing direction of the littoral drift be determined, as it is the key to the successful solution of the opening of the inlets across the bar. Instead of laying stress on the concentration of the ebb tides by means of twin jetties on the outer bar, as has been the general practice of maritime engineers, it is far more important to control the movement of the drift, which is in fact the medium which moulds the channels and directs the currents. It is because of the greater specific gravity of sand, that it plays so important a part in the regulation of the currents which are diverted by its constant encroachments from a prevailing direction. By its deposition the less resistant medium (the water) is crowded over against the "lee-shore" until the currents can no longer cut a sufficient channel for their escape, when they will break out anew at some former outlet and so complete the cycles in periods of many years. (See Plates V, VI and Fig. 9.)

By the operation of these natural laws it will be found that the best channel across an outer bar, in a state of nature, will shift to leeward (speaking with reference to the direction of the drift, and not to that of the prevailing winds), and that immediately abreast of the inlet or "gorge," both inside and out, the deposits of sand will be the greatest, while a "flood channel" will be formed in many instances seaward of the "windward

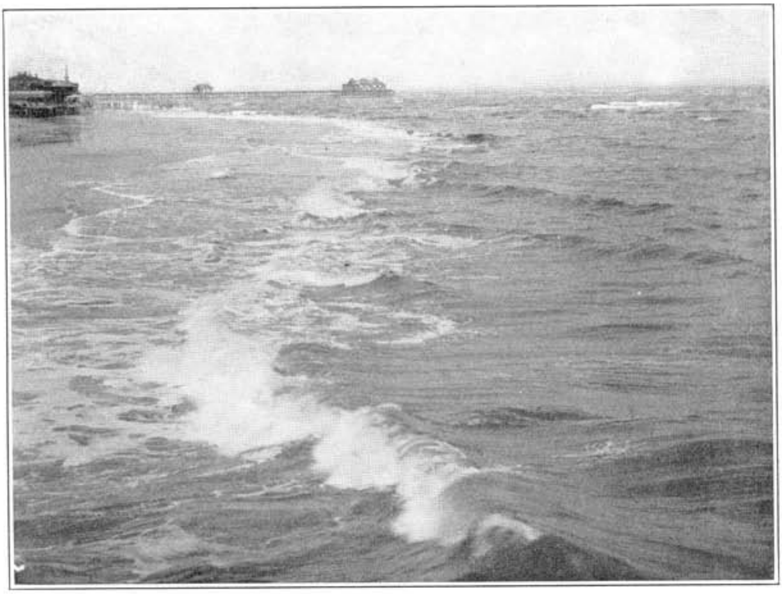

Fig. 1.—Waves causing the southward drift of sand at Atlantic City.

Fig. 2. Waves causing the northward drift of sand at Belmar.

Geological Survey, 1905.

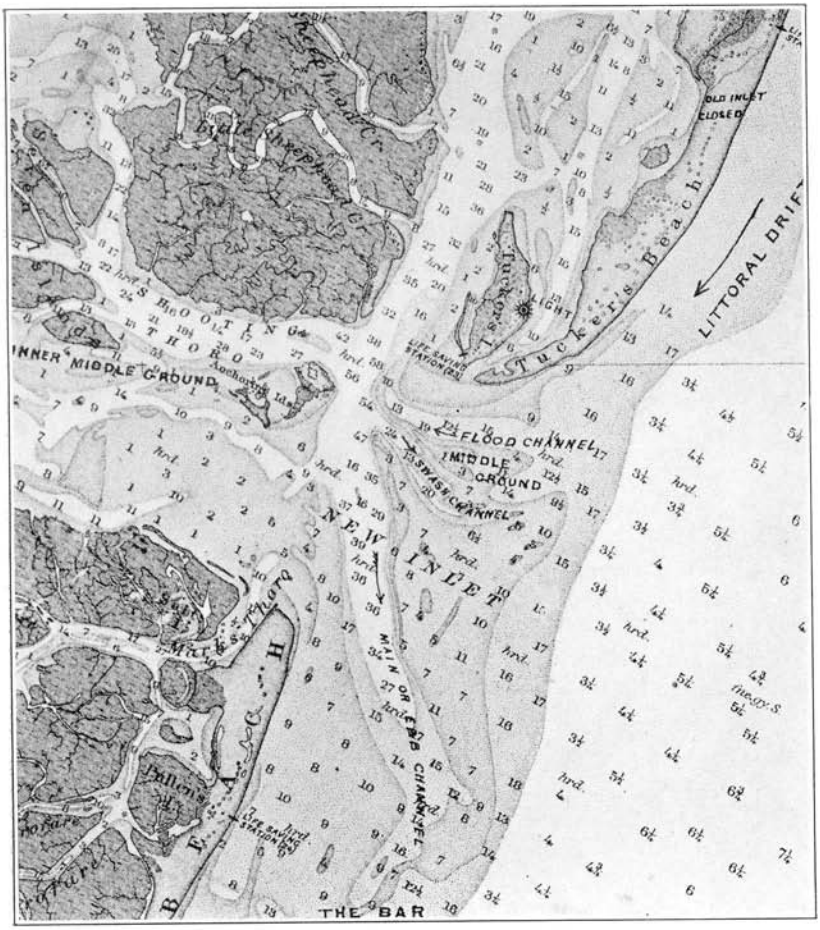

Fig 11.

Entrance to Little Egg Harbor in 1870 (U. S. C. and G. S.), showing typical arrangement of flood and ebb channels with inner and outer middle grounds.

spit," and "swash" channels may be formed between it and the main or ebb channel. These features may be seen in the typical diagram of Fig. 11, where the drift comes from the northeast and the tendency of the inlet is to move to the southwest as at New Inlet.

In tidal inlets it is of the utmost importance that the full prism of the flood tide be admitted to the inner bays, that the ebb may have sufficient volume to maintain the normal size and best position for the orifice. This results, in nature, in a trumpet-shaped mouth, opening outwardly; hence, to reverse this, as was suggested in the plans for Atlantic City, by building convergent jetties across the outer bar, does violence to a fundamental law. The conclusions reached by the officer in charge were unquestionably sound as to the injury which would follow the construction of two jetties, not only in reducing the tidal inflow, but also in impounding the drift in the angle to the eastward of the works, thus robbing the beach below of the requisite quantity to supply its loss from wave and eddy action.

The problem to be solved, therefore, is to determine some form of "tool" or structure which will protect the channel across the bar from the encroachments of the drifting sand, and at the same time admit the full tidal prism and confine the ebb discharge, after passing out through the gorge, to a more limited section of the bar, where the work of erosion will be intensified and the amount of material to be displaced be a minimum. These are some of the conditions to be fulfilled to insure a satisfactory result at a minimum of cost. The evolution of the proper form and position of a structure which will best meet these conflicting conditions, is the result of an extended analysis of the physical forces which are found to be operating upon all alluvial formations. A few only will be cited.

Channel formations.—Such an analysis reveals the fact that the deeper portions of the bed of a stream are generally located in the concave bends and under the points where the incident stream meets with some resistance; that in consequence of the change of direction due to its deflection and momentum, a downward cross-current is generated which scours out the bottom material and carries it to the opposite or convex bank, which is thus built up and becomes a region of deposit. This is well illustrated at the mouth of the Columbia River (see Plate XIV), where a single rocky headland (Point Ellice) has caused a scour to a depth of 100 feet and created a counterscarp some half mile distant, near the middle of the estuary, having depths of from 6 to 12 feet only, while it maintains a curved channel

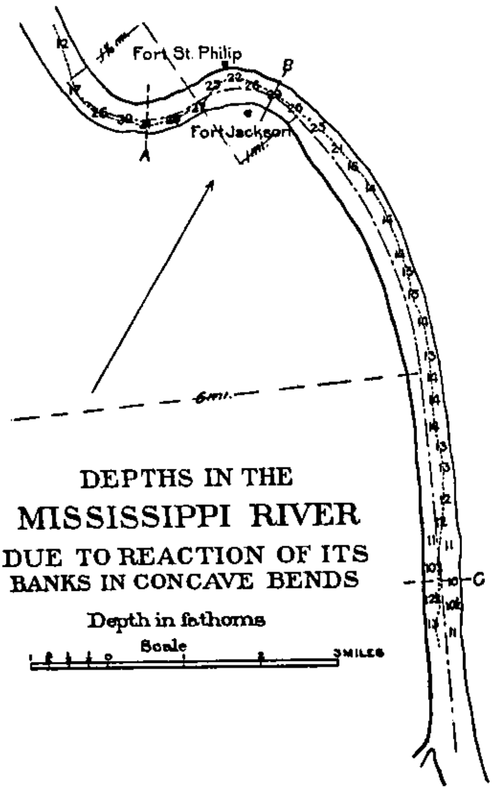

Fig. 12.

over 40 feet deep, having a radius of 5 miles for a distance of about 8 miles below the point. Here the tidal oscillation of 8 feet, is augmented by the floods of the river. Again in a nontidal stream, as in the Mississippi, the effect of curvature is strikingly shown in the reaches below Forts Jackson and St. Philip (Fig, 12) where the depths at the bends at points

PLATE XIV.

Channels and bars at the mouth of the Columbia river—Proposed reaction jetty shown in black on the outer bar.

Model of Lower Bay, New York harbor, showing assumed effect on Ambrose channel of a proposed reaction jetty.—Six-foot contours.

A and B reach to 186 and 174 feet, while, with the same volume of water passing through a cross section at C only about one-half as large, and hence having double the mean velocity, the resulting depths are but 60 feet or one-third as great. These facts refute the generally accepted dogma that the depths are directly due to velocity and volume. whereas they are chiefly dependent upon the reaction generated by contact with some resisting medium, which renders the potential energy of the stream, kinetic. Illustrations of this kind are numerous and may be found wherever a current meets with any obstacle which may have formed, or been placed, in its path, as for example at Sandy Hook, where there is no opposing bank of earth to confine the currents and create a gorge such as is found at the Narrows of New York Bay, yet the reaction depth off the Hook reaches to 60 feet and over. Plate XV. will convey a good idea of the great irregularity which is to be found in the channels and shoals of an ocean bar. The deep hole at the head of Sandy Hook is caused by the resistance which this spit opposes to the passage of both flood and ebb tide. The ebb discharge from the Narrows has cut the trough known as the main ship channel, with the slough or swash channels to the eastward excepting the one under Coney Island.

This ebb current, meeting the effluent setting eastward from Raritan Bay and the northward component on the inner face of the Hook, has combined with them to cut through the bulkhead of sand which would otherwise connect the end of the Hook with South West Spit and Flynn's Knoll (a part of the inner middle grounds) and bored out the deep pocket by reaction. A similar depth also exists at the extremity of the advancing spit at Rockaway Beach. The great depth of 114 feet at the "Narrows" is not due to the velocity of the ebb tide, as has been asserted, but to the "welling" of the flood in the effort to enter the upper bay, causing the currents at the bottom to run flood. for 10 hours out of 12 because of the vertical eddy thus created and to carry material into the upper bay. This model also shows a method of deepening Ambrose Channel to a 40-foot passage across the bar by a permanent training wall placed so as to control the ebb current from the

Narrows, without closing any of the present channels or obstructing the flood tide, and at a relatively moderate cost.

The angle between an impinging current and the obstacle designed to cause the reaction effect controls materially the result. For instance, if the obstacle be placed at an abrupt angle to the general direction of the flow it will generate a local resistance and scour a deep hole, but the deflected current will have its energy so dissipated as to be unable to maintain the depth, and no channel will be secured but merely a basin, such as is found at the end of all spur-jetties projecting from banks of streams abruptly into the current. Such constructions soon deteriorate from the undermining caused by the eddies they create, whereas a continuous, curved directrix, whose radius is proportional to the volume of the discharge and the depth of the desired channel will be found to give a far more permanent result since it will be one created by the natural conditions and adjusted to the particular volume of the stream.

Reaction jetties.—From the above general statements it follows that even a single straight jetty is not well adapted to the training of a current, and that one placed so as to present its convex face, if curved, to the direction of flow, thus permitting the energy to be dissipated, is of little use, save as a device to arrest or impound sand drift and create bars. (See Plate XIV, where a single convex jetty at the mouth of the Columbia River has caused an enormous deposit and advance of the spit some four miles at Point Adams.) Again, if connected rigidly with the shore, it must interrupt the travel of the silt and cause advance of the strand, while it also cuts off the supply from the beaches to leeward so that these are more rapidly eroded. This defect suggests the importance of detaching the jetty from the shore for this reason, as well as to avoid the interference with the free ingress of the tide at inlets, where it is vital to the maintenance of the full volume for ebb scour.

Bar advance.—Another important requirement to be fulfilled in the effort to open channels across ocean bars arises from the fact that when the two jetties are applied the currents must move to and fro through the same channel, between them, so that, if there is any preponderance in the ebb due to fluvial or upland

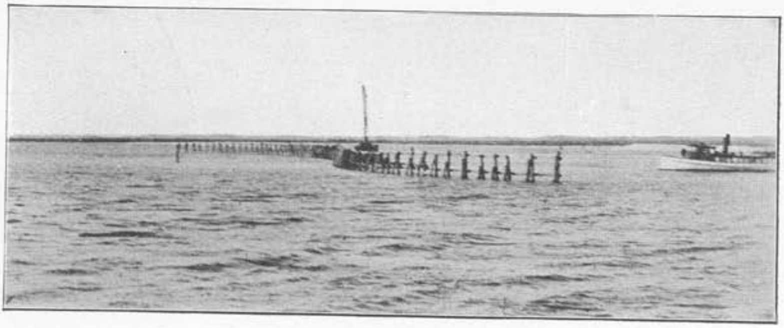

Fig. 1. Longport reaction jetty during construction.

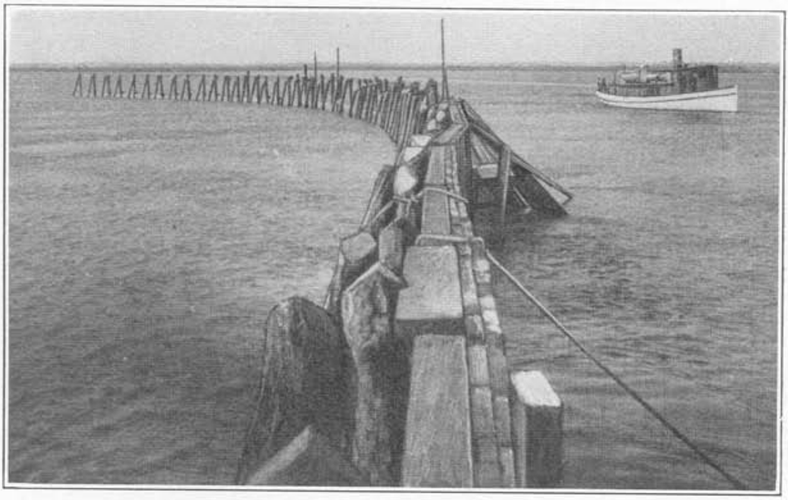

Fig. 2. Western half of the same jetty, showing planking undermined by the deep scour, 1901.

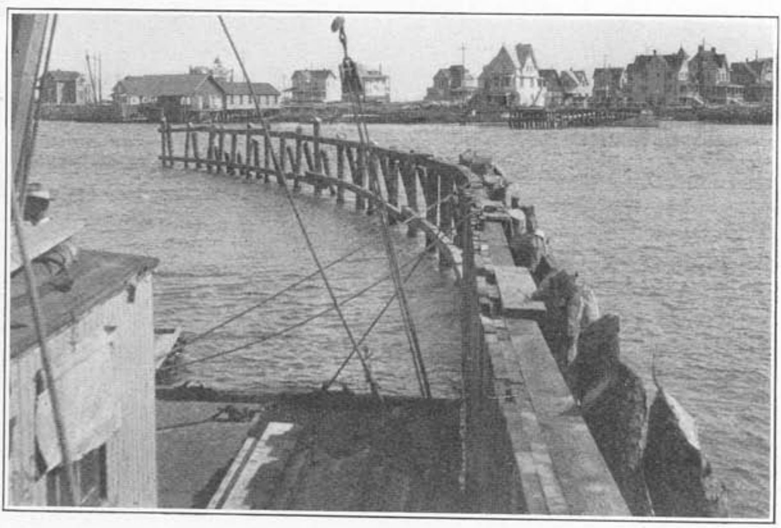

Fig. 3. East end of the Longport reaction jetty, 1901.

waters, the material scoured out is rolled seaward in front of the new mouth and is there deposited. This merely transfers the bar seaward where it is still in the path of vessels. This necessitates the ultimate extension of the jetties and congestion of the tides. Moreover, in building such works outward from the shore as is the general practice, by the use of fixed plants or trestles, the material scoured from the channel is rolled forward upgrade on the inner face of the submerged bar. This necessitates a longer jetty than would result from beginning the works on the outside of the bars and proceeding shoreward, thus working on the outer or downgrade slope of the bar and utilizing the force of gravity to aid in cutting out the channel, and the curvature or reaction, in casting it to one side. By the latter process, it is actually found that Nature may be compelled automatically to carve out her own channel of greater or less dimensions, depending on the radius of the curve and the volume of the flow. Moreover, under these conditions, dredging will not be required to maintain it.

RESULTS FROM USE OF REACTION JETTIES.

Longport.—In the few instances where this system of reaction jetties has been applied it has fully demonstrated the soundness of the above principles. For example, the thoroughfare at Longport was so rapidly filling up with bars that communications by water were threatened and the inner shore line of the beach was being rapidly cut out at the site of the railroad-landing pavilion. Numerous spur-jetties had been built to protect it, but they were soon carried out by the strong ebb tide. In 1901 a portion only of a reaction jetty was located on a reverse curve in the middle of the thoroughfare which was then a sand bar, bare at low water. (Plate XVI.) Within a few months, the current had cut to a depth of over 20 feet where the work was completed. The sheet planking at first used offered too great resistance and caused too deep a scour, so that the planking was undermined and floated up. It was therefore omitted and the piling spaced farther apart. The easterly section was curved upstream to catch and divert a portion of the ebb tide. These views were all taken at low water. It was predicted that the work, in its exposed position, subject to heavy ice flows and strong winds, would not stand over one winter, but it is still in place, after four years, doing good service. The cost was only about five dollars per lineal foot. The channel created by this light and cheap work has been self-maintaining.

Aransas Pass, Texas.—Again, at Aransas Pass, on the west Gulf Coast, efforts had been made since 1870 to improve the entrance to Corpus Christi, and it was estimated that by building two jetties at a cost of over $2,000,000, a 20-foot channel might be secured. After expending about $500,000 on this work with "insignificant" results, it was relinquished to local control in 1892, and after further expenditures, resulting in failure, the reaction jetty was finally adopted in 1895 and partially built, with decided improvement. The funds, however, being exhausted, the franchise was released to the Government, and Congress appropriated about $550,000 in all to complete the work. Of this sum, $50,000 was applied to the removal of the obstructing Government jetty, which was blasted out in 1904, and $200,000 is not yet expended. So that for $300,000 of the public funds there is now over 20 feet of water, where the work is finished, secured without dredging and by the scour from a diurnal tide of only 14 inches. This is a result wholly unprecedented in the annals of bar removal, and it will have saved to the Government over $1,000,000 in construction and the entire cost of maintenance, with a far better result than was predicted for the two jetties. Plate XVII gives a general plan of the detached reaction breakwater in its incomplete condition and also shows the United States jetty, which lay across the channel and obstructed the flow up to 1904. The littoral drift here is to the southwest, and the channel has formed in the lee or concave side of the work. The flood tide enters the inlet freely. There is no advance of the bar seaward nor interference with drift. The action is local and effective.

Reduction in the cost of bar improvements.—One of the important results of the above analysis is the ability greatly to reduce the extent and cost of the works required to create a navigable channel at the various inlets along an alluvial coast. For example, the length of the reaction breakwater at Aransas Pass

Aransas Pass, Texas, showing improvements up to 1901, and the consequent deepening of the channel.

is but 5,700 feet, instead of the 5 miles required in the two-jetty plan. Moreover, the latter would doubtless have been greatly increased in length by the advance of the bar, as has happened at Galveston, where it became necessary to build 6 miles of extensions to cover the 3 miles of advance due to the building of the leeward or south jetty, before arresting the drift by the construction of the windward jetty.

If temporary works only be considered expedient, the cost may be reduced to about one-tenth of that of the permanent work for the same system, or, in some cases, to less than one-sixtieth of the two-jetty system, and the channel will be self-maintaining, thus further saving large annual expenditures for maintenance. The question of opening harbors of refuge, therefore, becomes practicable by being brought within the reach of very moderate expenditures, with results which are assured, by merely utilizing the natural agencies available at the localities. Thus, at Atlantic City, instead of $3,000,000 for two jetties, a permanent reaction breakwater would cut a deep channel without dredging at a cost of about $500,000, or a temporary jetty could be built for $50,000.

THE PROTECTION AND RECLAMATION OF BEACHES.

As has been shown, many promiscuous expedients have been erected to defend valuable improvements from the sea, but they are generally placed between high and low water and immediately on the face of the property to be covered, regardless of the direction of the attacking waves and drift. It may often happen that by a combination of interests much more effective work might be erected off shore, which would also be more durable and generally beneficial in causing accretions, and so, far more than compensate for the cost by the additional land reclaimed.

From what has already been said, it will be seen that no general rule can be given as to form, position, or dimension of remedial structures. A jetty on the wrong side of a current or turned the wrong way would be more injurious than useful. The change of a few hundred feet will make a vast difference in its action. Curved jetties have been built with spurs on the concave face to prevent undermining, thus neutralizing the benefit of the curvature. Each case is a special problem, to be treated according to its local physiography, and this must be determined from comparative surveys and studies of the district, covering at times a considerable area. Certain local features, where they exist, may be used to advantage, as follows:

The counterscarp.—A characteristic natural form which may be used to advantage in the protection of the beaches, where it exists, is the offshore, submerged ridge which is the result of wave action. It is frequently found that in a flat foreshore the wave of oscillation is converted into one of translation which moves up the slope with increasing velocity until the frictional resistance of the bottom causes it to break and churn up the strand, charging itself with sand or "shingle" which is excavated from the trough thus created, and projected shoreward to or above high water. Thus is formed the low ridge or terrace and the intervening trough so typical of some alluvial beaches. A good in-

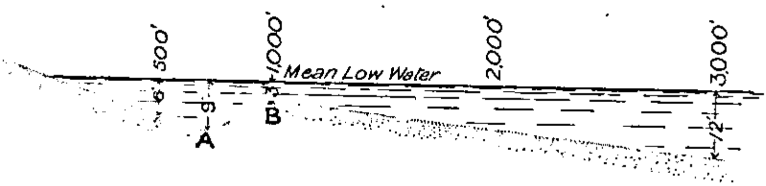

Fig. 13.

The counterscarp B, and its relation to the beach.

stance of this is to be seen along the front of Absecon Beach, where such a counterscarp lies with its crest from 3 to 5 feet under low water and about 1,000 feet distant. The depth in the hollow varies from 9 to 11 feet. (See Fig. 13.)

The crest of the counterscarp is manifestly the best location for a series of wave breakers so placed as to cause the overfall to cushion on the water behind them, which will be comparatively still. Such structures should rise somewhat above the high-water level and be curved in plan to decompose the waves. Openings should also be left to admit detritus and pass fishing boats and other small craft. These devices do not interrupt the use of the beaches for driving, bathing or other purposes, as is the case with spur-jetties.

"Excellent examples of detached or insular wave-breakers and hidden banks are to be found off the Dublin Coast. * * * Farther south, the Burford and Kish Banks afford excellent examples of these occult banks to which Mr. Haupt alludes, * * * and there appears to be every reason to believe that, but for the existence of this long line of shoals, or string of submerged islands running parallel to the shore, the erosion of the Dublin and Wicklow Coasts would be far more rapid than at present."[1]

The insular breakwater.—Still another typical feature, which is found in many places, is the connecting ribbon of sand which joins an isolated point of rock with a neighboring coast and which might very appropriately be styled the *pendent terrace.* It is the product of wave action and currents charged with silt, being split by an isolated point of resistance, and again meeting in its lee where deposition is produced by conflicting forces brought to relative rest. There are numerous types of this action in Massachusetts Bay; as at Marblehead, Nantasket, Nahant and Winthrop-Head. Similar effects have followed the construction of solid pier-heads having an open viaduct to connect them with the shore, as at Ceara, Brazil. Such structures may be made of great use in protection works, if advantage is taken of local conditions to place them so as to invite deposit. Other examples of this tendency to deposit in lee of islands are numerous, but one instance should be given to show their efficiency as a defensive measure. In his discussion (ante), Mr. Winn calls attention to "the Islands of Lambay and Ireland's Eye," concerning which he states:

"It would seem likely that the varying currents brought about by these rocky obstructions would cause frequent alterations in the coast line. Yet the 'Velvet Strand,' as the eastern shore of the peninsula which terminates at Portmarnock Point is called, is always the same. If any slight temporary erosion takes place, the loss is always made good, and no changes of wind or tide seem capable of interfering with this beautiful stretch of sand."

Thus, by following Nature's well-established precedents, it is practicable so to place offshore insular barriers as to cause reclamation and maintenance of the highly prized beaches along our ocean fronts, or in the creation of channels and opening of har-

[1] Discussion on Protection of Foreshores, by Allauson Winn, Transactions Am. Soc. of C. E., l: 66, 1903, N. Y.

bors, but, as another writer very appropriately says,[1] "Considerable sums have been wasted by the unscientific treatment heretofore prevailing."

A careful study of the causes of erosion and deposit will enable the engineer to plan his improvements with great economy by laying the greatest stress upon the control of the drift. It is illogical to attempt to secure results by opposing the forces where their energy is the greatest, as at the foot of the bluff, and especially to place an inclined-plane in the path of the breakers, to aid them to surmount the bank and attack the works in the rear, while the advancing waves undermine the toe or footings of the bulkhead or sea-wall and thus hasten its destruction.

This destructive action of the breakers is well illustrated by some work recently done on the Pacific Coast, where a temporary timber sand-fence was erected, a few feet in front of a vertical bluff, which rose some six feet above the top of the fence. The fence, which was built in February, 1905, was almost buried under the accretions of sand in a few weeks. (Plate XVIII, Fig. 1, taken March 3d.) On March 10th, a severe storm occurred, during which the breakers surmounted the fence and recoiled with such force from the bluff that in a few hours all the sand accretions of weeks were cut out (Fig. 2) and the bluff itself greatly eroded. By the following day only isolated sections of the fence remained (Fig. 3), and the bluff had receded in one place over 100 feet. The fatal error in this work was the presence of the bluff so close in its rear. A substantial rock wave-breaker offshore would have effectually protected the frontage.

Similar effects have been observed on the New Jersey coast in consequence of the inclined revetments built by individual owners, which not only aided the waves to surmount the scarp and fall on the boulevards, but also formed re-entrant angles on their windward faces, causing the wasting of the adjacent properties by retaining the shore drift. It is manifest that the remedy should be applied offshore and in such manner as to cause the energy of the waves to be dissipated before reaching the foot of the bluff.

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[1] F. Collingwood, C. E., of Avon, N. J.

Fig. 1. Beach defended by bulkhead, partly buried by sand.

Fig. 2. The same after storm of March 13, 1905.

Fig. 3. The same March 14, 1905, at 11 A. M.

CONFLICTING JURISDICTION.

Prior to the civil war it was the policy of the General Government to relegate the improvement of the rivers and harbors to the several states. Since 1870, however, its powers have been greatly extended, in consequence of the Supreme Court decision to the effect that the clause of the Constitution authorizing Congress to regulate commerce covers such waters or channels as "Form in their ordinary condition by themselves, or by uniting with other waters, a continued highway over which commerce is or may be carried on with other states or foreign countries in the customary modes in which such commerce is conducted by water."

Under this ruling and consequent assumption of paramount jurisdiction, the demand for appropriations from all sections of the country has far exceeded the limits of the National Treasury. A reaction appears to be taking place in the adoption of a more systematic policy of confining the Government appropriations to the most imperative public works, and relegating the undeveloped waterways to private or local control. To this end, the Act of June 13th, 1904,[1] provided:

> "Any person or persons, corporations, municipal or private, who desire to improve any navigable river, or any part thereof, at their or its own expense and risk, may do so upon the approval of the plan and specifications of said proposed improvement by the Secretary of War and Chief of Engineers of the Army. The plan of said improvement must conform with the general plan of the Government improvements, must not impede navigation, and no tolls shall be imposed on account thereof, and said improvement shall at all times be under the control and supervision of the Secretary of War and Chief of Engineers."

The latter provisions, prohibiting tolls and placing the works under the control of the War Department, were not conditions precedent, and neutralized the practicability of the proposed law by destroying its commercial features. Accordingly, the Act of 1905 has, in a few cases, set aside these limitations in part and

[1] Amended in compliance with a Resolution adopted by the Trades League of Philadelphia, on the thirteenth of the March preceding.

authorized the collection of tolls, retaining the right of the Government to purchase the works after a term of years.[1]

As the enormous development of the highways, bridges, railroads, and canals of this country has been and is due mainly to private and corporate interests, it would seem that ample precedents exist for the return to the use of local capital for the further improvement of the waterways, which are so fundamental to the commerce of the Nation. Especially is this so in cases where the Government, after due examination, has reported the project unworthy of improvement by National funds, as has happened at all of the important inlets on the New Jersey coast.

Under the present law[2] no improvements may be made in any part of the country, even by local municipalities or by states, unless the plans therefor are first approved by the War Department, although the locality may have been reported as not being of sufficient importance to justify improvement by the National Government. In case approval is withheld, legislation

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[1] "A franchise is granted to the Cumberland River Improvement Company, of Kentucky, to improve that river and its tributaries above Burnside, Ky., by the construction of necessary locks and dams. The right is given to charge tolls. It is, however, provided that the franchise shall terminate forty years after the completion of Lock and Dam No. 21, &c. * * *. The committee thought it advisable to grant this franchise for the reason that it is in a portion of the river in which improvement at the expense of the United States would not be probable for many years to come, if at any time," &c. Hon. T. E. Burton, Chairman River and Harbor Committee, Report of February 6th, 1905.

[2] "The creation of any obstruction not affirmatively authorized by Congress, to the navigable capacity of any of the waters of the United States is hereby prohibited; and it shall not be lawful to build or commence the building of any wharf, pier, dolphin, boom, weir, bulkhead, breakwater, jetty, or other structure in any port, roadstead, haven, harbor, canal, navigable river, or other water of the United States, outside established harbor lines, or where no harbor lines have been established, except on plans recommended by the Chief of Engineers and authorized by the Secretary of War, and it shall not be lawful to excavate or fill, or in any manner to alter or modify the course, location, condition, or capacity of any port, roadstead, haven, harbor, canal, lake, harbor of refuge, or inclosure within the limits of any breakwater, or of the channel of any navigable water of the United States, unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War prior to the beginning of the same." Act of Congress, March 3, 1899, Section 10.

becomes necessary, but without the endorsement of the Department this is almost impracticable. But the fact that an improvement by the National Government which must needs consider the demands of the whole country, is not warranted, does not prove that work under local auspices might not be wisely done. It would seem, therefore, that the localities which have been rejected by the Government as being unworthy of improvement by National aid should be released from the necessity of securing approval of plans which may meet local requirements and be instrumental in stimulating local interests. This would appear to be justified by the Report of Judge Burton, of January 4, 1901, wherein he said:

"The total amount required for the completion of projects for river and harbor works, the cost of which has been estimated by the War Department, now approximates $300,000,000. It will thus appear that it has been necessary either to omit entirely or only partially provide for a large number of improvements, many of which are no doubt deserving of early attention." * * * "It is considered that the results obtained by the annual expenditure of amounts, which are only a small share of the total amount required, are neither economical nor desirable." * * * "It is evident that the prosecution of many of these improvements must be postponed for a long time or they must be rejected altogether."

From this general review of the status of the legislation it seems that there is little or no prospect of any relief being afforded by the National Government for the inlets of the New Jersey coast. Under the present laws, approval of plans by the Chief of Engineers and authorization by the Secretary of War must first be obtained before local or State authority can be made effective. Owing to adverse reports upon the inlets, the partial or complete failure of efforts heretofore made, and the vast number of projects demanding the attention of the Chief of Engineers, this recommendation is extremely difficult to obtain. Congressional legislation authorizing the State and localities to undertake the creation of such ports and harbors as may seem desirable to preserve these interests must be obtained, if any effective action is to be taken in the future.

CONCLUSIONS.

The observations and reports of residents and coast guardsmen are of value in a general way as to the location and amount of changes which are taking place, but are not of sufficient accuracy nor continuity to afford the proper basis for remedial improvements. It is also apparent that in the matter of repairs great diversity of method exists both as to the constructive works, as well as to the proper authority, and that serious losses and delays are incurred by the conflicting jurisdiction between the general, State and local authorities, so that in emergencies, riparian owners are compelled to protect themselves at their own risk even at the expense of their neighbors.[1]

Under the existing conditions it would seem expedient for the State to exercise some general supervision and control over the character of the improvements to be erected by the riparian or other local owners, not however with a view of placing additional obstacles in the way of reclamation works but to facilitate them in every possible way, as a means of adding to the wealth and revenues of the State through the additional safety thus provided for the lives and properties of her citizens, or of transients seeking health or pleasure on her coasts. It is also very desirable that a scientific method be adopted of collating data as to the frequent and serious changes which are taking place. This should be done independently of the local surveys made by the General Government and the State at long intervals and without giving the dates of their parts so that the quantitative movements cannot be determined. This could be done by the establishment of fixed elevations and gauges at the impor-

[1] The State claims original jurisdiction and title to all of the water frontage, but any riparian owner can secure the rights held by the State by filing an application of his intention. The Riparian Commission then fixes upon a price at which it may be bought, and in case the right is desired by a non-resident, the owner is given six months in which to secure the title to his frontage. If he does not, another may acquire it.

tant points along the coast and the accurate location, by surveys referred to these "Benches" of the high and low-water contours. Such data would enable reliable estimates to be made of the amount of the drift, and would also permit definite titles to be prepared of the properties which are becoming more and more valuable. It would also avoid the expense of actions to determine the location of county or other boundaries.

From this general review of the conditions along the coast it would appear that there is urgent need for remedial legislation looking to the opening of the harbors, the reclamation of the beaches and extension of the seaside resorts, the increase in the accessibility of all parts of the shore and its adjacent waters, the establishment of permanent land marks along the coast, the encouraging and restoration of the fishing, shipbuilding and manufacturing interests along the seaboard, and the utilization of the tidal power and reclamation of the tide flats, as a source of wealth.

Philadelphia, Pa., September, 1905.

PART II.

A Brief Sketch of Fossil Plants.

The Flora of the Cliffwood Clays.

By EDWARD W. BERRY.

A Brief Sketch of Fossil Plants.

BY EDWARD W. BERRY.

CONTENTS.

Paleobotany is that branch of the elder science of paleontology which treats of the ancient plants and plant assemblages or floras of the globe. It derives its main facts from those relics of ancient vegetable life which have been preserved as fossils, but takes into account as well all the collateral evidence

[1]I am indebted to William K. Gregory, of the American Museum of Natural History, for much valuable criticism.

of contemporaneous animal life and physical conditions in working out what Huxley has most happily termed "retrospective prophecy."

By the term "fossil" we understand any body or the traces of the existence of any body, whether animal or vegetable, which has been buried in the earth by natural causes. This was Sir Charles Lyell's definition, and it is probably as good a one as has ever been formulated. It will be seen that not only are the preserved remains of bygone vegetation fossils, but any traces of them that we may find in the rocks, such as internal casts of stems where the soft pith decayed and the cavity became filled with sediment after which the outer part of the stem also disappeared leaving only this internal cast. Again a stem may have persisted long enough for the containing sediment to solidify after which it was dissolved by permeating waters charged with chemicals, leaving only the external cast for our study.

Paleobotany may be considered under two principal aspects, unfortunately not yet entirely coördinated, the one botanical or biological and the other geological.

BOTANICAL RELATIONS.

It is assumed throughout this brief sketch that all plants are genetically related, and that they came into existence by some natural process of evolution. We can be certain of this much without equal certainty as to what the specific factors of evolution were. Biologists may hold antithetic views regarding the causes of evolution and the manner in which they operated, but opinion is practically unanimous in all branches of science that evolution itself is an indisputable fact.

All plants are what they are because of evolution. This is the great outcome of all modern botanical study, just as the similar generalization holds for the animal kingdom. But this evolution can be known only at first hand and in detail by the examination of the fossil ancestors of the forms involved. We may infer from their present structure and development their relations to each other and to some ancestral types in a certain number of instances, but we cannot determine the reasons for the existence and development of modern floras and their broader interrelations except through the truths of paleobotany.

And just as it is coming to be recognized that we cannot understand the relations of living plants to each other without a knowledge of their fossil ancestors, so, too, it is perfectly obvious that we cannot understand the distribution of the existing flora without knowing something of the distribution of the floras of the past. The plants of the various existing genera and orders have either originated in or migrated into their present habitats so that the records of their appearance in geological time becomes of the utmost importance.

Since the early beginnings of science discussion has been rampant as to what constitutes a species, so that a word of explanation of the way this term is used in paleobotany, and paleontology as well, is necessary. Species in paleobotany depend largely upon the completeness of the remains of any one type which are available for our study. Particularly is this true in dealing with the remains of leaves. If we have two different forms of leaves, especially if they are from different geological horizons, or are more or less widely separated geographically, we are obliged to consider them as distinct species. Now it is quite possible that these two leaves, which are dissimilar in appearance, may represent the two extremes of variation of leaf-form on a single plant, so that in the presence of a representative collection of the intermediate forms we can often unite in a single circumscribed group under one specific name what would otherwise necessarily be considered as distinct species. When it is remembered how incomplete the record necessarily is and always will be, we cannot hope to have the different stages of variation preserved in any large number of cases, much less the "missing links" of the evolutionary tree.

GEOLOGICAL RELATIONS.

It has often happened that objects whose relations are entirely doubtful from the standpoint of the botanist, may be of constant occurrence in certain strata or of particularly characteristic form, or both, so that they become very valuable to the geologist as indices of the contemporaneity of the containing formation in different regions.

Many objects of this nature might be mentioned, *e. g.*, the Cliffwood beds of New Jersey contain detached cone-scales which have been referred to *Dammara* without any very conclusive evidence that they are related to that antipodean genus. They are very characteristic objects and much more valuable for purposes of geological correlation than many fossils from the same beds which are much more interesting from a botanical viewpoint. Another fossil of an entirely unknown botanical affinity is known as *Tricalycites*. It consists of two or three bract-like wings radiating from a central nucleus, and characterizes the Raritan formation. It is an unmistakable object wherever found, and hence has a geological value entirely aside from its botanical interest. Examples might be multiplied indefinitely, but one other must suffice, that of the leaves from the Raritan formation which have been doubtfully referred to *Eucalyptus* (*attenuata* Newb.). This species was described by Professor Newberry from South Amboy, N. J., and it has been positively identified from Maryland, Alabama and Tennessee. At Pocahontas, in the latter State, it furnishes the only satisfactory evidence of the age of the interesting outcrop at that locality, illustrating again the correlative value of remains of doubtful botanical affinity.

While this increased value in the correlation of different strata of fossils whose biological status is questionable has been of great use to the geologist, it has awakened in the minds of many botanists the feeling that paleobotany was, after all, a science of more or less doubtful and undeterminable remains, and that its pursuit was a matter of indifference to the botanical world on whose problems it was incapable of shedding any light. This attitude soon had its effect on the geologist who could hardly be expected to weigh the evidence at first hand, and it came about that paleobotanical evidence became discredited in the minds of the geologists, from which *status dubio* it has only emerged within the last few years. Some allowance should, of course, be made for the respective points of view, which may be best explained by a brief illustration. If the leaf of an Angiosperm should be discovered in the Carboniferous rocks of Eastern Pennsylvania the botanical world would be vastly interested in finding this strictly modern type of plant in strata so old as the coal-measures, while this particular discovery would not appeal to the geologist at all. On the other hand, if in a well-boring in the red sandstone region (Triassic) of New Jersey, beneath the red sandstone strata there was found a layer filled with the leaves of Cordaites, fronds of Carboniferous ferns, etc., this discovery would be of little interest to the botanist, but vastly interesting to the geologist as a possible indication of the presence of workable coal, and such a discovery would be followed in all probability by the sinking of innumerable shafts.

Since the history of the earth is largely a record of its life, it follows that fossil plants are important factors in determining the age of the various strata which contain them. There have been sands and clays, chalks and greensands, shales and sandstones, etc., etc., ever since the earth has been cool enough to permit water to condense and stay on its surface, so that were the geologist to depend upon the lithological character of the various formations, he would often be sadly at a loss to know just what formation he was dealing with. But the fossils are similar for contemporaneous periods, no matter what the material. Plants are more conservative types than animals, they migrate more slowly as a rule, and are more dependent upon climatic conditions. With the changing of rocks from age to age there has been going on a parallel evolution of plant types, so that the ancient plant assemblages become a living chronometer by which the geologist ascertains the age of his formations, and a living thermometer by which he can determine ancient climates as well. A single leaf, almost, may determine for us the climatic phenomena of a whole continent.

Plants also have a further value for the evidence which they furnish regarding the geographical relations of the ancient land masses. For instance, if a large proportion of the Cretaceous species of Greenland are found along the Atlantic coast of North America in Cretaceous times, we can be sure that the climate of Greenland and that of New Jersey at that time were equally warm, and we have the further assurrance that the land-connections which permitted this spread of identical species were much more intimate and extensive than they are at the present time.

Again, if we find an interchange of species between Western America and Eastern Asia at various times in their geological history, such as that which took place during the Jurassic, we can rest assured that Behring Strait was dry land during those particular periods when this interchange of life took place.

Naturally, a branch of botany, paleobotany, has until recent years, as we have already mentioned, been largely ignored by the professional botanists until it has come to be considered the natural child of its foster mother, geology. Since it is almost axiomatic that we can only know fossil plants as they resemble or differ from existing plants, it follows that prehistoric floras can best be understood by those most familiar with modern floras, and paleobotany is about to assume its rightful place as a biological study to be pursued by botanists. It furnishes much aid to its sister science of geology, and in turn is reinforced by geology, which study often sheds much light on the causes of variation in floras, both past and present.

EARLY VIEWS REGARDING FOSSILS.

Nothing can be more interesting or more important than a knowledge of the past life of the world, and we find as far back as there are any human records that fossils, if noticed at all, were objects of considerable wonder, although, strange as it may seem, only animal fossils were known to the ancients, bearing in mind when we make this statement that all their writings have not come down to us. Through modern eyes the various theories of the origin of fossils often seem ludicrous. The healthy common-sense of the Greeks, unrestrained by any supposed divine revelation, saw in them the remains of the life of bygone days, but this keenness of apprehension was not shared equally by their contemporaries or successors, and we find, under the scholastic cloud which overhung the world for centuries, that fossils were attributed to the workings of various mystical forces.[1]

The *vis lapidifica* of Avicenna (sixteenth century), the stone-making spirit of Sperling (seventeenth century), the architectural spirit which controlled the petrifying juice (Kirchner) were all conjured up to explain or mystify. Nothing was farther from the accepted thought for ages than that fossils were the remains of real creatures which had once been alive. Even after the latter notion began to gain adherents it was assumed that they were the relics of the Noachian deluge. This flood theory or diluvial hypothesis found numerous advocates during the seventeenth century, and may be said to have become established as a scientific dictum by Scheuchzer during the first decade of the eighteenth century. From that time forward it was the accepted theory for upwards of a century, during that period of speculation, conjecture and groping through which the study of the natural sciences was passing.

That none of the ancients mention fossil plants is especially to be wondered at for the reason that Greece with her limestone quarries has plentiful remains of petrified wood, and the fossil trees of Egypt are especially noteworthy. While coal mines were not operated, some minerals were mined, and the Romans carried on vast public works, such as aqueducts and roads, so that it seems almost inconceivable that fossil plants were not discovered. Such, however, appears to have been the case, for the first mention of petrified wood that has been found is that by Albertus Magnus, about the middle of the thirteenth century, and we find no record of the discovery of fossil leaves until the time of Major (1664), in Germany, and Lhwyd (1699), in England.[2]

Modern paleobotany may be said to date from Sternberg and Brongniart, who published their first contributions to the science in 1804 and 1822 respectively, although previous to the latter

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[1] For early views of the nature of fossils see Lyell, Principles of Geology, vol. 1, Chapters 1-4. Leonardo da Vinci, Literary Works, compiled and edited from the original mss. by J. P. Richter, London, 1883.

[2] Ward, Ann. Rept. U. S. Geol. Surv., v: 357-452, 1885.
They were noticed in recent volcanic tufa somewhat earlier.

date there was some commendable work by Scheuchzer, Schlotheim, Parkinson and others. All of which shows what a young member of the family of sciences paleobotany really is.

METHODS OF PRESERVATION.

Fossil plants have been preserved by two methods, the first by infiltration, the second by inclusion. In the first method the plant substance is more or less completely permeated or finally replaced by silicic acid or calcium carbonate, the less stable compound being replaced by the more stable. Other petrifying agents, such as carbonate of magnesium, pyrite, marcasite, and a variety of other mineral substances, are sometimes the means of preservation. In accordance with the delicacy and completeness of the replacement, this class of remains presents the internal structure with more or less fidelity, sometimes to an extraordinary degree.

Calcified remains characterize the English coal-measures, and their study has made famous the names of Witham, Binney, Williamson and Scott. Silicified remains occur in the French measures, and these have been largely exploited by Brongniart, Renault and Zeiller. The American Carboniferous plants are largely impressions, without structure, due to the apparent lack of calcareous or other petrifying agents in the waters in which they were submerged. They are consequently less satisfactory objects for study than the European fossils of like age.

The second method by which fossil plants have been preserved is by simple inclusion in clay, shale, amber or other material. This method is known as incrustation. Almost all the fossil plants with which the general public is familiar belong to this type, which often shows the most beautiful impressions or prints of ferns, leaves and even flowers, the finer grained the sediment in which the plants were entombed, the more perfect being the impression. In this class of fossils the plant substance may be present as carbon, or it may have entirely disappeared, leaving simply the cavity or impression, as is often the case with flowers, seeds, etc., found in amber. Again pieces of wood and cones may be incrusted with pyrite or other mineral substance, and these, when we uncover them from their hermetically sealed tombs, become much cracked in drying, oxidizing rapidly and crumbling.

The foregoing are all very beautiful objects, but do not show any internal structure, which is such an important matter in determining plant relations. The beautiful ferns from the shales of the coal-measures in Pennsylvania, and the leaves from the Cretaceous clays of New Jersey are familiar examples of this class of remains. The coal seams of Pennsylvania and lignite beds, such as those occurring in the New Jersey clays near Raritan Bay, are really examples of inclusion (incrustation) on a grand scale.

THE CLASSIFICATION OF PLANTS.

In the classification of recent plants the gross morphology of the reproductive organs is largely relied upon, but these characters are usually absent in fossils, so that we have to rely on other combinations of characters, such as the venation, if we are dealing with leaves.

In the case of the lower plants of the fern, club-moss and horse-tail kinds, plants whose allies were predominate in the vegetation of the earlier periods, few conclusions of a positive character can be reached without a consideration of their microscopical characters, although there has been built up a large body of very interesting facts on the evidence furnished by form, venation, leaf-scars, etc.

I have inserted here the following diagram which shows the classification of the vegetable kingdom. It is not worked out in detail, and is introduced simply to render intelligible the terms used in the discussion which follows.

SUB-KINGDOMS.	CLASSES.	ORDERS.	COMMON NAMES.
	Angiospermæ	Dicotyledones	Willows, oaks, elms, maples, roses, composits, etc.
		Monocotyledones	Grasses, sedges, lilies, palms, orchids, etc.
	Pro-angiospermæ		
Spermatophyta	Gymnospermæ	Gnetales Coniferales Ginkgoales Cycadales	Pines, sequoias, cedars, junipers, hemlocks, cycads.
	Pro-gymnospermæ	Cordiatales	
	Pteridospermæ	Paleozoic fern-like plants with true seeds.	
Pteridophyta		Filicales	Ferns.
		Equisetales	Horse-tails and Calamites.
		Sphenophyllales	
		Lycopodiales*	Club-mosses, quill-worts, Lepidodendrons and Sigillarias.
Bryophyta	Musci		Mosses.
	Hepaticæ		Liverworts.
Thallophyta	Algæ		Seaweeds, etc.
	Fungi		Bacteria, molds and fungi.

LEAF VENATION.

While the arrangement of the veins in leaves seems, at first thought, to be entirely fortuitous and subject to great extremes of variability in the individual species, it is found to be remarkably constant, as a rule, within generic limits. Even in the larger

*This order includes the following families: Lycopodiaceæ, Psilotaceæ, Lepidodendraceæ, Sigillariaceæ, Selaginellaceæ and Isoetaceæ.

plant divisions, the reader will readily recall the parallel-veined leaves of the monocotyledons (lilies, palms, grasses, etc.) clearly to be distinguished from the netted-veined leaves of the dicotyledons (oaks, maples, roses, etc.).

Ettingshausen laid the foundation for a proper understanding of the principles of venation, in 1854, and published many detailed investigations.[1] It would take us too far into the technical details to pursue this subject exhaustively, and we will therefore confine our attention to a few points.

Ordinarily, netted-veined leaves may be palmately or pinnately veined, dependent upon whether the veins radiate from the top of the petiole, as they do in the familiar gum-tree (*Liquidambar*), etc., or whether they branch from the midrib at regular intervals, as they do in the linden (*Tilia*), catalpa, elm, etc. These secondaries, as the branches of the primary veins are called, may run directly to the margins of the leaf, as they usually do in leaves that have a toothed margin like the elm or birch, when they are known as craspedodrome; or they may curve upward to join the secondary next above or its branches, as in the Magnolia, when they are known as camptodrome. When the secondaries soon lose their identity in the general net-work by repeated branching, the venation is said to be dictyodrome. When the leaves are very thick and coriaceous and the venation is concealed in the leaf substance, as in certain Ericaceous and Proteaceous leaves, it is said to be hyphodrome. When a strong vein forms a marginal hem, the venation is paryphodrome, as in numerous Eucalypts.

Other terms occasionally used are brochiodrome, for looped veins; acrodrome, where they all converge toward the apex of the leaf, as in the lily-of-the-valley; parallelodrome, when they are all approximately parallel, as in most monocotyledons; campylodrome, when they curve from the base to the apex, as in numerous

[1] Sitzungsb. Akad. Wiss. Wien., xii: 138-154, pl. 1-17, 1854.
Ibid. 600-663, pl. 1-22.
Monatsbericht Berlin Akad. Wiss., 1852, 42-49.
Weiner Denksch. xv: 181-272, pl. 1-51, 1858, etc., etc.
See also Heer, Fl. Tert. Helv., ii: 2-6, 1856.

monocotyledons, such as the mud-plantain, smilax, golden-club, etc.

A study of special cases reveals numerous constant characters of various kinds, as, for instance, the peculiar arrangement in the lobed leaves of sassafras, where a secondary passes directly to a strong vein which runs along the sinus, as will be readily seen by the examination of one of these leaves.

GEOLOGICAL TIME.

For the benefit of those but slightly familiar with the teachings of geology and paleontology, it may be said that geological time is measured by a scale that uses thousands of years as a unit. Thus, the Cretaceous or chalk period, of which the Cliffwood beds of New Jersey mark the transition from lower to upper, is estimated to have lasted something like five millions of years, and this is a conservative estimate.

A great many widely divergent estimates regarding the age of the earth have been made. The different data used being, among others, the rate of the formation of peat in bogs, or of stalactites in caverns, or the rate of sedimentation in different localities, or the amount of salts held in solution in the oceans, supposed to have been derived from the air and land, or the rate of cooling of lavas, or the effect of the tides in retarding the earth's motion by friction, or the rate of the loss of heat by the sun, etc. These estimates vary from ten to a thousand million years, the geologists and biologists inclining to more liberal estimates as affording time for the wonderful changes which the earth and its inhabitants are known to have undergone, while the physicists, notably Lord Kelvin, cut the time interval down to a minimum. The recent discoveries in radioactivity, while thus far simply suggestive and not at all conclusive, would seem to discredit the too conservative estimates of the physicists, which are based largely upon the rate of the loss of heat by the sun. We can be certain of this much, that geological time was of vast duration—millions and millions of years.

While, of course, all estimates contain large elements of chance, and can never be anything but mere rough estimates, still we can get approximate ideas of the duration of time, which become fairly exact when it comes to the relative duration of the different geological periods. These durations, as expressed in years in the diagram at the end of this article (Fig. 21), are to be understood as mere approximations, so expressed to render more vivid the fact of the immeasurably long intervals of time with which the geologist and paleobotanist is obliged to deal.

While it might be assumed that the Cliffwood flora, because of the well-known plant names used, was like that of a somewhat lower latitude at the present day, Georgia, for instance, in reality the plant grouping, while decidedly modern as compared with the Triassic or Carboniferous, still possessed an entirely different arrangement of units, and while there appears in its description the familiar names, such as oak or palm, they were all different oaks and palms from those which lived in Tertiary times, and these again were different from those which are living at the present time. In an account in which popular names are used it is impossible to realize the full force of the fact that these ancient floras consisted of a certain particular assemblage of forms which gives them a certain facies, and makes it possible to recognize their relative age in any part of the world where they may be found.

GENERALIZED ANCESTRAL FORMS.

There are several broad truths brought out in studying paleobotany, and one of these is the occurrence in times past of plant types of an intermediate character. The most noteworthy examples of prophetic or synthetic types (polymorphism), or forms that combine characters which afterward become separated to mark distinct orders, is furnished by those Paleozoic plants (*Lyginodendron, Heterangium, Medullosa,* etc.) which have, until recently, been referred to the order Cycadofilicales, the name indicating their combination of characters. These characters came to be segregated as time passed, and in later times serve to mark ferns on the one hand and cycads on the other.

We find in *Lyginodendron*, for instance, which is mentioned because it has been more largely studied than any other type, that the leaves were large and decompound, and were entirely fern-like in form and structure. In fact, they have always been considered ferns until a year or two ago, and were referred to the fern genus *Sphenopteris*. The stem, on the other hand, is like that of a cycad in its microscopical structure. The young roots are like those of a fern, but with maturity they undergo changes, and we have roots like those of a gymnosperm. In addition to this combination of characters, which might be greatly amplified were it worth our while in this connection, discovery has recently shown us that these curious plants bore true seeds, a condition of affairs unheard of among ferns, while the pollen-producing organs were decidedly fern-like. So much so, that it is doubtful whether the product should be regarded as "pollen" or "spores." Thus, in all their attributes, these plants show conclusively that they represent forms which were very near to their fern ancestors, while, at the same time, they were true seed-plants, foreshadowing the great development during the Mesozoic age of the Cycads and later Gymnosperms. In other words, they constitute a true "missing link" in the chain of evolution. So comprehensive are the structural variations of these ancient synthetic types that it is quite probable that the ancestry of the Angiosperms, which has always been a problem that has baffled the botanist, will be solved by further study of the morphology of some of the members of this remarkable plexus of early forms.

Referring briefly to those synthetic types of which we know only the leaves, the mid-Cretaceous furnishes us with a number of genera, *e. g.*, *Menispermites, Araliopsis, Protophyllum, Aspidiophyllum, Credneria*, etc. While the evidence is much scantier than in the case of the Cycadofilicales, where we know the whole structure, even better than we do that of numerous modern plants, and while the leaves alone are available to throw light on the subject, we are at a loss to interpret correctly the facts we have in any other way than that we are again dealing with primitive genera of synthetic character.

For instance, a variety of leaves have been referred to the genus *Sassafras*. Saporta argues that they are Aralias. Ward thinks that they are ancestral Platanus leaves. Lesquereux refers them first to one genius and then to another. A critical examination of the American species by the writer, some years age,[1] showed that some of these leaves are to be considered true *Sassafras* leaves, others should be referred to *Platanus* or *Protoplatanus,* while others are referable to *Cissites,* and still others remain doubtful. While it is hardly safe to draw too definite conclusions from the evidence of one set of organs, such as leaves, and there is always the possibility that the forms in question might be instances of homoplastic variation or convergence of characters in different genera, still, from the numerous similar cases which could be mentioned in strata of the exact age where we would expect to find synthetic genera, it seems safe to infer that if we could only know the whole structure of these plants we would find that we were dealing with considerably generalized ancestral forms.

THE RECAPITULATION THEORY.

A principle derived from a study of fossil forms, and from the development of recent forms, shows us that the individual, during its development, passes through a series of stages, roughly approximating the stages through which its ancestors have passed, in the course of their evolution. In other words, the history of the individual is a condensed epitome of the history of the race.

Suggested by von Baer and others, nearly one hundred years ago, it was established beyond cavil by Agassiz[2] in his studies of fossil fishes, so that the principle is often mentioned as Agassiz's law of palingenesis (Hyatt). It is also known as the law of biogenesis or von Baer's law, and is aptly defined by Haeckel in the phrase, "Ontogony repeats Phylogeny." This principle is of wide application, but is subject to many limiting forces not well understood, as can be readily imagined when we remember the complex totality of factors concerned in individual development. Among plants there are numerous cases, however, where we cannot have a shadow of doubt but thát the juvenile stages are truly atavistic.

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[1] Berry, Botanical Gazette, xxxiv: 426-450, 1902.

[2] Agassiz, Louis, Poissons Fossiles, 1: 208-270, 1883; Nat. Hist. of U. S., i: 112, 1857.

See also various papers by Hyatt, Cope, Jackson, Beecher, Clarke and Schuchert.

We will consider briefly two such cases of recapitulation. The first is that of the tulip-tree (*Liriodendron*). In the modern seedling the first leaf, the one above the cotyledons or seed-leaves, is a small, simple, rounded leaf with a retuse apex like that shown in 1 or 2 of figure 14. Each succeeding leaf becomes more like the adult form shown in 3 of the same figure, which, as will be observed, is quite different from the first leaves. A similar series of forms occurs in a regular order upon growing shoots from the older branches.

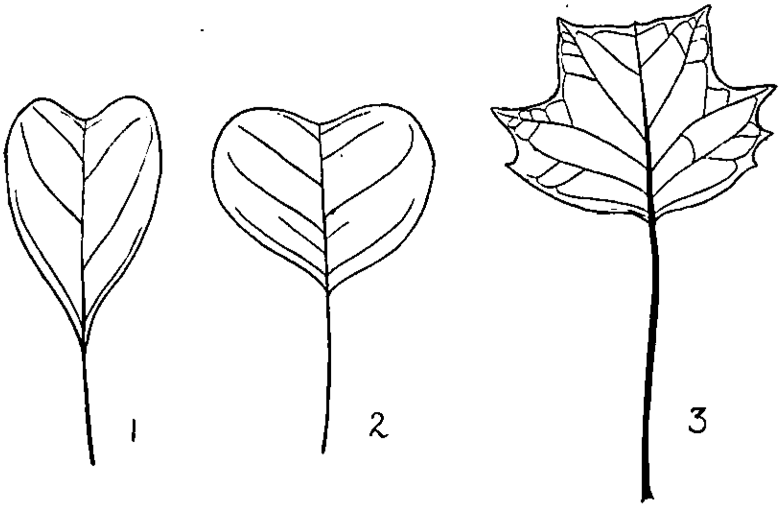

Fig. 14.
Liriodendron leaves.

In looking up the history of *Liriodendron* we find that the earliest known leaves, which occur in the Raritan formation here in New Jersey, are just such small, simple, rounded leaves as 1 and 2, figure 14, of the modern tree. And we find that these varieties were succeeded by a series of intergraded forms which duplicate in a general way the modern series of leaves, thus confirming in a remarkable way the evidence derived from a study of modern seedling Liriodendrons.[1]

[1] Those who desire to pursue this most interesting subject of the history and leaf variation in *Liriodendron* in more detail may consult the following papers by the writer: Bulletin Torrey Botanical Club, xxviii: 493, 1901; Botanical Gazette, xxxiv: 44, 1902; Torreya, i: 105, 1901; ii: 33, 1902; iii: 129, 1903.

Another plant, which has a most interesting history, is the *Comptonia,* or sweet-fern as it is called. It is not a fern at all, but a close relative of the Myrica or bayberry, and very common here in New Jersey. The first leaf of the seedling is a small, lanceolate leaf with only one or two pointed teeth on each side. The succeeding two or three leaves are similar to those shown in figure 15 A of a seedling plant, and these are almost exactly

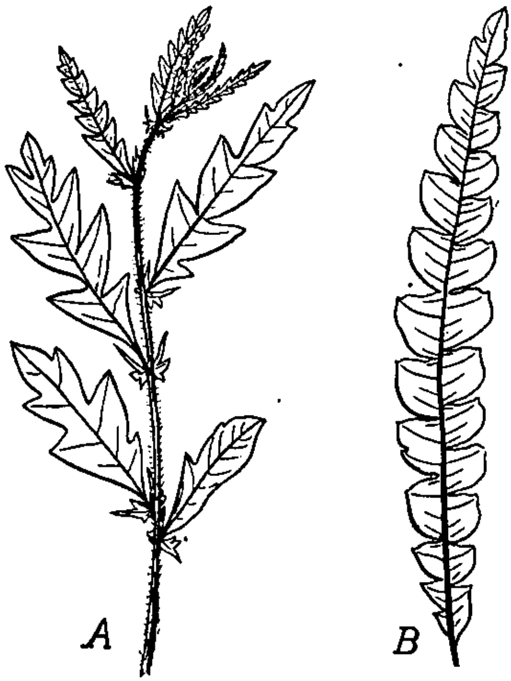

Fig. 15.

Comptonia leaves.

like the earliest known fossil Comptonias which are also found in the Raritan formation of New Jersey and elsewhere. Figure 15 B shows a leaf from a mature plant which emphasizes the striking difference in form habitually exhibited by the extremes of the series.

RACE PERIODS.

Each race of plants seems to have had a life period somewhat analogous to that of an individual, or that of nations. A period of early development, a period of culmination when they were a "world-power," and a final period of decadence, perhaps followed by total extinction.

In plants, and animals as well, there arrives a time in the history of the race when variation reaches its acme and the group consists of numerous and widespread species. The third period, that of decadence, seems to be marked by the loss of this power of adaptation, variation or evolution, whichever we may be pleased to call it. Numerous specialized forms could be mentioned in illustration which became extinct because of their inability to adapt themselves to changed conditions in their environment. We can sometimes point to physical changes, such as those of climate, as the cause of wholesale extinctions. The Glacial period is the greatest known example of such a cause. Again we can sometimes predicate possible causes of extinction, such as the effect of greatly increased numbers of herbivorous animals upon the vegetation, or the competition of plant types of a higher and more efficient organization with their more lowly kin. In numerous other instances, however, the extinction of forms seems to happen in accordance with some limiting law which we do not at present understand. It may well be that this cause resides in the nature of the protoplasm of the integral cells and that senility is the sure result after a certain period of evolutionary activity which may be sometimes continued for ages, while in other instances for only a comparatively brief period.

THE SUCCESSION OF FLORAS.

The imperfection of the geological record of plant life need not be enlarged upon in this place. The rocks furnish us with an unfinished chapter here or an incomplete page there, which we do our best to piece together to get the real history. As can be readily imagined, fossil plants are not evenly distributed through the various formations. So many circumstances enter into their successful preservation that the wonder is that the record is as perfect as we find it.

Laurentian.—The earliest known sedimentary formations, which are metamorphic and much disturbed, contain practically no evidence of plant life. We have every reason to believe, however, that the lower types of plants, probably aquatic and with a cellular structure, but little fitted for preservation, were common and widespread. Indirect evidence that such was the case is furnished by the abundant deposits of graphite, which like the coal of later ages, is believed to have been of organic origin, at least in a large measure. Again the iron ores which occur as marsh ores and are due to the action of acids released by the decaying vegetation upon the iron oxides, are believed to indicate the presence of a considerable vegetation. Indications of animal life are furnished by the immense beds of limestone, which is usually of organic origin. Beside these indirect facts we may note the occurrence of possible animal remains (*Eozoon*), and Dawson reports the macerated remains of plant fibres in beds of this early age.

Algonkian.—The Algonkian of New Jersey furnishes a supposed seaweed, *Archæphyton,* from the white crystalline limestone of Sussex County,[1] and fucoidal impressions, of a somewhat doubtful nature it must be confessed, have been reported from the same formation in other regions.

Cambrian and Silurian.—During the Cambrian and Silurian ages we find all classes of invertebrated animals swarming in the ancient seas, and the first curiously organized fishes as the only representatives of vertebrated animals. Along with seaweeds we find the first remote and poorly preserved representatives of ferns (Filicales) and horsetail rushes (Equisetales), both orders destined to become large in stature and widespread and dominant in the later Paleozoic ages.

Previous to the upper Silurian the earth was characterized by

[1] Britton, Ann. N. Y. Acad. Sci., iv: 123, pl. vii, 1888.

vast continental seas and relatively little dry land,[1] the modern continental masses having not as yet been elevated above the waters. With the increasing land areas of the upper Silurian the progress of vegetable life was marvellously great, for in the next age, the Devonian, we find a considerable variety of plants from the principal grand divisions of the flowerless kingdom, foreshadowing the lavish display of the coal period. The various mechanical problems which were solved by these early plants that aspired to the stature of trees, and the way in which these problems were worked out during the evolution from lowly herbaceous forms to complex arboreal forms, is an exceedingly interesting study, too lengthy and technical, however, to be more than mentioned in this connection. Recent studies along this line, to which botanists are devoting considerable attention, show that in all orders that have developed arborescent forms, the formation of wood increases with the requirements as they arise, the tissues being so placed that they afford the most effective resistance to stress and strain. In polystelic stems, such as those of ferns, this strengthening is accomplished by the transformation of the primary tissue into hard sclerenchyma, which also forms sheaths around the bundles of vessels. In monostelic stems this strengthening takes the form of a cylinder of secondary growth which enlarges radially by the addition of regular external layers. These layers become fibrous in character and have their walls thickened, or by a specialization of certain cells, some become especially adapted for circulation purposes, while others become specialized for purely mechanical purposes.

Devonian.—The Devonian age is remarkable in many ways, containing as it does the first extensive display of land plants, including a considerable variety of ferns, as well as the early ancestors of the Calamites or giant horsetail rushes, the Lepidodendrons and other early forms of arboreal club-mosses, be-

[1] This is a comparative statement. Walcott's Cambrian studies lead him to think that the broad interior region of North America, for instance, was above the sea during the lower Cambrian, while the Appalachian and Rocky Mountain areas were submerged and accumulated enormous sediments. See map, pl. iii, Bull., U. S. Geol. Surv., 81, 1891.

sides the earliest known plants with seeds. Other plants were also present for the Devonian shales are full of spores denoting a vast growth of plants which Dawson refers to the Rhizocarps (*Salvinia, Marsilea,* etc.). This origin of seed-bearing plants is a most fascinating subject, one signalized by physiological and morphological changes of the utmost importance. The step from spores to seeds as a means of reproduction is perhaps the most profound advance which the vegetation of the world has ever taken, signalizing such an epoch as did the acquisition of a backbone in animals, and relatively of equal importance, in both cases eventually marking the culmination of the transfer of activity from aquatic to terrestrial conditions.

Before considering the floras of the Carboniferous and succeeding ages it will be profitable to emphasize the modern dominance of seed-plants, a dominance of importance and size, rather than in number of species. To this end we must first consider briefly the modes of reproduction of the higher non-seed-bearing plants.

In some, such as ordinary ferns, the spores, which are all alike, upon germination give rise to a small plantlet, the prothallus, on which the sexual organs are borne. Others, such as the so-called water-ferns (*Salvinia, Azolla, Marsilia,* etc.), the Selaginellas, and the Quillworts (*Isoetes*) produce two kinds of spores (Heterospory)—numerous small male spores (microspores) and a single or but few large female spores (megaspores [1]). There are a number of advantages in producing two kinds of spores. The male element can be kept small and be produced in correspondingly large numbers, consequently being of easy dispersal and much more likely to effect the proper fertilization of the female spore. The latter can be correspondingly larger and will serve as a storehouse of food-material.

Along with these advantages there are certain disadvantages. The germination of both kinds of spores at the same time, near enough together, and in the presence of an adequate water-supply is left entirely to chance. When the plants are the size of trees, as they were in the old days, and the two kinds of spores

[1] Sometimes termed macrospores.

differed widely in size and weight, the chances of both even coming to rest near together were more or less uncertain.

While the production of the two kinds of spores was an advance, the next problem to be faced was how to bring the two kinds together on the parent plant, and this was the problem which was worked out among the early members of the fern family, in all probability during the Devonian age, and later among the ancient clubmosses. It seems to be in the process of accomplishment at the present time among the Selaginellas. Beside bringing the male element to the near vicinity of the female element on the parent plant (pollination), further obvious advantages would be the actual bringing of the two elements together, or fertilization, on the parent plant, the secure protection of the young prothallus, a certain water-supply, and similar nutritive and protective advantages for the young plant while it was being formed within the seed.

We have become familiar within the last few years with some of these ancient plants which had commenced to bear true seeds, plants with large and elegant decompound fern fronds for leaves, the seeds borne on the fronds in a manner somewhat similar, for example, to the way the modern climbing-fern (*Lygodium*) bears its spores.

These plants were the ancestors of that class of seed-plants called Gymnosperms. This class includes our modern Conifers such as the pine, spruce, hemlock, etc. It includes also the Cycads represented by our commonly cultivated "sago-palm." Figure 16 is from a photograph of a modern Cycad (Cycas revoluta) and shows the wide-spreading whorl of older foliage leaves, with an erect cluster of young foliage leaves, just unfolding in the center. Between the two whorls is seen a set of the scale-like leaves, the whole inserted on the apex of a pineapple-like trunk, which becomes much more elongated in some of the tropical species. The class of Gymnosperms also includes the Ginkgos, solely represented in the modern flora by the maidenhair tree of Eastern Asia. This tree has been widely introduced in modern times as an ornamental tree for lawns and parks. A magnificent double row of these trees border the path leading

Fig. 16.

A modern Cycad—*Cycas revoluta.*

(From Coulter's Morphology of Spermatophytes, courtesy of D. Appleton & Co.)

to the building of the Agriculture Department in Washington, and all who visit that city should make it a point to see them.

Carboniferous and Permian.—With the ushering in of the Carboniferous and continuing through the Permian age, the

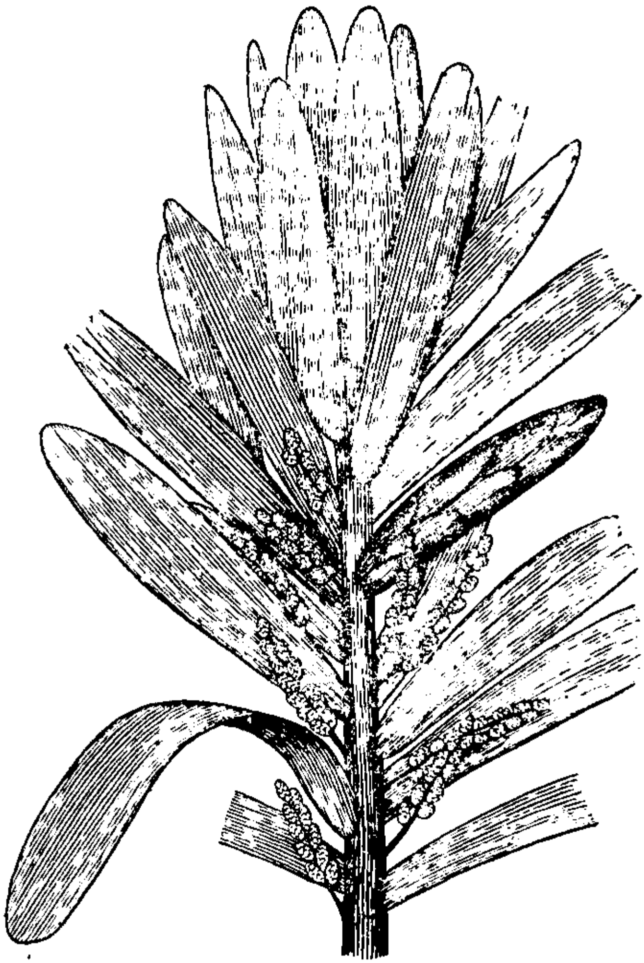

Fig. 17.

A restored branch of *Cordaites lævis.*

(From Coulter's Morphology of Spermatophytes, courtesy of D. Appleton & Co.)

class of fern-like plants with true seeds was an abundant element in the flora, which included as well, a diversified display of true ferns, both herbaceous and arboreal. These ferns are largely referable to a group which answers in a general way to the modern Marattiaceæ, although we find among the remaining ferns of those ages indications which stamp them as the synthetic ancestors of the modern families Osmundaceæ, Gleicheniaceæ, Hymenophyllaceæ and Schizæaceæ. A prominent feature in the flora of the coal period was the gigantic horsetail rushes (Calamites, etc.) which were the size of trees and looked much like modern giant-bamboos. They were much more complex in structure than are their degenerate descendents, the Equisetums. Along with the foregoing plants were Conifers with long strap-shaped leaves. Figure 17 shows a restored branch of one of these Cordaitales, as they are called (*Cordaites lævis*). This gives a very fair idea of the ribbon-like leaves. A large bud is shown at the right and several catkin-like clusters of the cones (strobili) are also shown. These are all reduced in the illustration, as can be judged from the fact that some of these Cordaitales had leaves over a yard long and six or eight inches in breadth. In habit and appearance these trees must have been very different from any of the Conifers of the modern flora, for they had slender trunks, sometimes one hundred feet tall and branched only near the top. These branches, which were numerous, bore the large parallel-veined leaves.

The Carboniferous flora also included ancient club-mosses with woody trunks as large as modern forest trees, their trunks artistically sculptured by the large and varied scars where the leaves were attached (*Lepidodendron*, *Sigillaria*, etc.). These sculptured fragments of trunks are familiar and beautiful objects. Examples will be found figured in all geological text-books.

All of these orders of flowerless plants culminated during this age, becoming cosmopolitan and abundant, and evolving a great number of species. In the luxuriance of the hot, humid Carboniferous marshes we even find the remains of fungi, and in these haunts a large number of insects flourished and the amphibians were the dominant animals. It has been supposed that all of the carbon which is present in the earth's crust in the limestones and other carbonates, in the coal, graphite, lignite, gases and oils, was originally in the air and water. On this account the early atmosphere is supposed to have been dense and heavy, almost effectually screening the sun's rays. The vast amount of carbon dioxide which was washed out of the air during the early Paleozoic, involving, as it did, a more abundant supply of oxygen for plant life, and consequently greater growth activity, and a proportionately rapid transformation of the remaining carbon dioxide into assimilable products, was probably one of the most important factors in the great diversification of the vegetation during the Carboniferous age.[1]

By the end of the Paleozoic period the Appalachian mountains had finally been lifted to their greatest height. The Calamites, Lepidodendrons and most of their kin had become extinct, and a newer race of plants had appeared to carry on the great history of evolution.

With the close of the Paleozoic the amount of carbon dioxide in the atmosphere had been further reduced by its abstraction during the vegetative activity of the Carboniferous and Permian. This reduction has been estimated to amount to seventy-five per cent. Thus during post-Paleozoic times the air was much less dense and more readily penetrable by the sun's rays. The climate was correspondingly variable locally, stimulating renewed vegetable activity. This is supposed to have in part accounted for the rise of the Angiosperms during the Mesozoic, with their foliage of broader leaves and increased functional capacity. All these changed factors tending to an increased diversity of forms,

[1] During the last ten years Professor Chamberlin has formulated his brilliant theory of glacial action based upon the relative depletion of the carbon dioxide of the atmosphere. In numerous contributions the history of the atmosphere has been taken up, and he has endeavored to show that the atmosphere has not varied its gaseous content to the extent formerly assumed, but only within certain not very wide limits. That the periods of depletion are those of land extension such as (1) at the close of the Silurian, (2) the Permian and early Triassic, (3) the Pliocene and Pleistocene. The periods of enrichment were those of sea extension and prolific lime-secreting life. Professor Chamberlin has marshalled a long array of facts in support of this theory, and if his interpretation be accepted, it replaces, in a large measure, the older ideas of Paleozoic climates, which I have implied in the text.

just as in modern plants especial luxuriance of growth always goes hand in hand with greater variability.

Triassic.—With the dawn of the Triassic age we find a time of shallow seas and lagoons, brackish and fresh-water deposits, vast mud-flats and swamps at near sea level. New Jersey, which contains no Carboniferous plants, was one of the theaters of life that swarmed over these flats and lagoons during the time that the red sandstones and shales of the Newark system were being laid down.[1]

The conditions of deposition here in New Jersey were not suitable for the proper preservation of fossils as can be imagined from the fact that some hundreds of dinosaurian reptiles that haunted these estuaries are known from their footprints alone, which is all that has been preserved. This fact hints at a teeming life which the imagination almost fails to picture. Less than a dozen species of plants have been identified from the New Jersey Triassic, a few additional have been found in Connecticut and in Pennsylvania, so that we have only a few actual representatives of the vegetation which clothed the shores and hills of the New Jersey of the red sandstone days.[2]

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[1] Dr. Eastman, in last year's report, has given a picture of the life of the times, and has described the fossil fishes which have been found at Boonton and elsewhere.

[2] A small collection of Triassic plants in the possession of the New Jersey Survey contains the following:

1. Unidentifiable stems from Newark, Little Falls and Milford.
2. Several fine specimens of *Cheirolepsis Muensteri* Schimp. from Milford.
3. Cone of *Pachyphyllum sp.* from Milford.
4. Several specimens of *Equisetum Rogersii* (Bunb.) Schimp. from Milford.
5. Compressed internal cast of a trunk from Newark, identical, except in size, with what Newberry calls *Palissya sp.* It is somewhat similar to *Cycadeomyelon yorkense* Font., but all that can be safely said is that it is the decorticated trunk of a Gymnosperm.
6. *Baiera multifida* Font. ? Milford.
7. *Podozamites longifolius* Emm.? Milford.
8. *Sphenozamites Rogersianus* Font. ? Milford.

   The last three determinations tentative because of the poorness of the material.
9. Fragments from Milford which might be identified as *Yorkia gramineoides* Ward. They are stems of some sort, and not the remains of a grass.

But in other parts of the world the Triassic has not been so chary of its plants, and we are enabled to get a reasonably good picture of the characteristic vegetation, which we have every reason to believe flourished in New Jersey also, but failed to be preserved.

The Triassic coal-basins of Virginia and Carolina, unlike those farther north, have yielded an abundant flora, which is conceded to stamp them as practically the same age as the New Jersey deposits.

The consensus of opinion makes the American Triassic correspond to the Keuper or late Trias of Europe, where abundant plant remains of this age have been elaborated, chiefly from Neue Welt, near Basle, in Switzerland, Stuttgart in Würtemberg, Lunz in Austria, Raibl in Carinthia, etc. The lower Triassic is not present in America, at least if it is, it is entirely unfossiliferous, so that there is an immense chapter in plant evolution missing here, during the long period of time following the close of the Permian age, when the buntersandstein (grès bigarré) and muschelkalk were being deposited in Europe.

In the marshes grew great ferns with undivided evergreen fronds (Marattiaceæ) and numerous other representatives of the fern family (*Acrostichites, Adiantites, Cladophlebis, Clathropteris,* etc.). There were also horse-tail rushes of modern structure but of large size, one of these being rather common in the old flagstone quarries near Milford, N. J. In the dryer spots flourished the numerous ancestors of the Ginkgo, the maiden-hair tree, and it is interesting to note that the seedlings of the modern tree, the sole representative of this once abundant order, has leaves divided into several small ribbon-like lobes almost exactly like those of the ancestral Triassic Baieras.

There was a plentiful display of Conifers, the Voltzias, thought by many to be the ancestors of the Sequoias, flourishing, besides species of *Palissya, Pagiophyllum* and *Cheirolepis.* A species of the latter genus (*Muensteri*) is a most widespread fossil in the American Triassic, occurring in Massachusetts, Connecticut, New Jersey, Pennsylvania, Virginia, North Carolina and New Mexico, as well as in Europe. This species is very common at Milford, N. J., and the State Survey is in possession of several fine specimens. A figure of a small one of these is introduced (Fig. 18) to show the peculiar direction of the twigs which are all distad, except toward the tips of the lateral branches. It will be noticed also that they branch at a very wide angle. These two features are not well shown in any published figures of this species, although they are constant characters of the New Jersey material, and are even more emphasized in some of the larger specimens than in the small one figured.

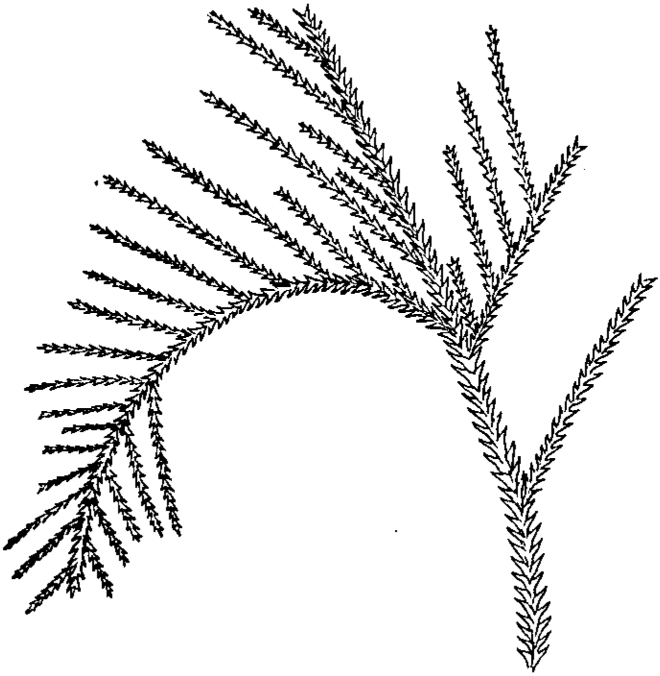

Fig. 18.

A twig of *Cheirolepis.*

Ward (1892) enumerates the following major plant groups as having known representatives in the American Triassic: Fucoids, Ferns, Equiseta, Lycopods, Rhizocarps, Cycads, Conifers and Monocotyledons.

Numerous synthetic types of Cycads of a variety of genera thrived in the more humid regions.

Jurassic.—The next period, the Jurassic, is unrepresented in New Jersey. Through its long ages sedimentation was going on elsewhere, and the plants of the Triassic largely reached a culminating point in their evolution and then became extinct. During the Jurassic there was an amazing variety of Cycads (Bennettitales), numerous Conifers, including the first Sequoias, tree ferns (Cyatheaceæ) and representatives of the modern royal and cinnamon ferns (Osmundaceæ). The Marattiaceæ had dwindled to a few species, almost as sparingly represented as they are in the modern flora. The following fern families, beside those just mentioned, were present: Matonineæ, Schizaeaceæ, Hymenophyllaceæ, Gleicheniaceæ and Protopolypodiaceæ.

Notable localities for Jurassic plants are found on the Pacific coast in Oregon and California.

The Jurassic is remarkable for the first recorded appearance of plants which were the prototypes of the dominant modern plants, the Angiosperms. We only know them from their leaves, and therefore cannot estimate properly the light which they might throw upon the evolution of plant types. Angiosperms have their seeds enclosed in ovaries, and a perfected fertilizing apparatus, and the fact of their present dominance is evidence enough of how greatly they became advanced, as compared with their ancestors of the Jurassic, with a less precise mechanism for the fertilization and nutrition of the young plantlet. It seems probable that the Angiospermous genealogy goes back to the Paleozoic, to that plexus of forms from which the Gymnosperms took their origin, but this is only conjectural as yet.

Cretaceous.—The New Jersey record opens again toward the close of the lower Cretaceous with the formation of the fresh or brackish-water clays and sands constituting the Raritan formation (Amboy clays), which outcrop across the State in a belt a few miles in width, extending from Raritan Bay southwardly to Camden, in this State, and beyond in Delaware and Maryland. The interval since the Jurassic is also unrepresented in New Jersey, so that we have another long break in the record representing a time interval which has been estimated at somewhere between two and three million years, and which includes the period of evolution of many modern types. This interval is partially represented by the Potomac formation in Maryland and Virginia, the Kootanie formation of the West and the Kome beds of Greenland,

and opens with a flora containing a few representatives of the modern types of plants, such as figs, poplars, aralias, and trees with oak-like and willow-like leaves, together with numerous cycads and a host of ferns and conifers, the latter two classes of plants vastly predominating.

We find from the remains of the leaves and cones preserved in the Raritan clays that the more archaic types had largely disappeared, though here and there they lingered, and that they were replaced by more modern kinds. We find along with these ancient types of ferns, but sparingly represented, conifers and juniper-like evergreens (Moriconia), numerous willows, figs, magnolias, sequoias, tulip-trees, sassafras and laurel. The more we know of this flora the more modern representatives do we find that it contained, so that it seems probable that the real ancestors of numberless modern genera, such as those mentioned above, are to be found in the older Cretaceous or even earlier formations of other regions. These ancestors are as yet practically unknown, but were derived, in all probability, from the north, which seems to have been the center of radiation of the Mesozoic waves of plant migration.

At the close of the Raritan period the sea had commenced to encroach upon the land which was slowly sinking, and marine conditions were inaugurated toward the northeast, at Cliffwood, N. J., causing some greensand to be formed and introducing marine forms of molluscs and crabs which we find in nodules (the "clay-dogs" of the clay miners) in the Cliffwood clays.

The flora is well preserved and has been collected at Cliffwood bluff on the shore of Raritan Bay, from Morgan, on Cheesequake Creek, from the pits of the Cliffwood Brick Company, near the head of Whale Creek and sparingly from Kinkora, across the State, on the Delaware River. Traces of plants occur at numerous other points, generally much comminuted by wave action before their entombment. There is much sand in this formation, alternating indiscriminately with the thick lenses of dark-colored clay. All through the formation are seams of lignite ("niggerheads" of the clay miners), ranging from a mere film to beds several feet in thickness, bearing striking evidence to the abundance of vegetation at the time they were being laid down. Sometimes these lignite beds are full of little globules and "tears" of amber, which is the fossil resin of the sequoia or other contemporaneous conifers. They also contain a considerable number of well-preserved remains which can be washed out of the lignite. Some of these forms are shown in figure 19.

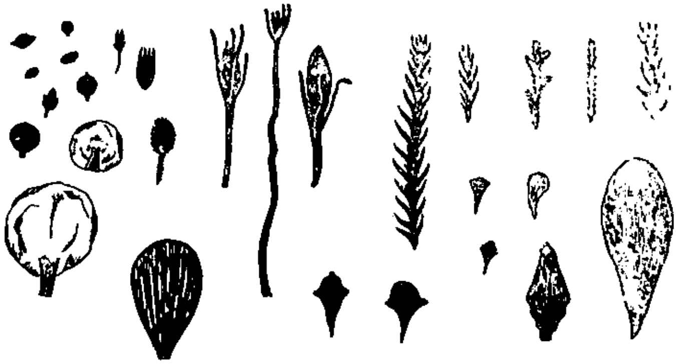

Fig. 19.

Plant remains from lignite beds of Cliffwood and elsewhere.

In the vicinity of Cliffwood bluff grew many Sequoias, distant ancestors of the "big trees" of California. The clays are full of their twigs, and hundreds of their cones have been washed out by the waves during winter storms. (Fig. 20.) The first palms occur in the clays of this age, in Delaware, Maryland and New Jersey. There were also many hardwood trees in the forests.

The flora differs from the Raritan flora in its abundant oaks, in its two kinds of sheep-berry, a distinctly later type, and in numberless other species which have not been found in the Raritan, but do occur at higher geological horizons elsewhere. At the Cliffwood Brick Company pits the most abundant fossils are the broken leaves of a large-leaved sycamore or plane-tree (*Platanus*, see Plate XXIV), with leaves often seven or eight inches across, and with these leaves we find dozens of the flattened remains of the "button-balls" of long ago (Plate XXIII, Fig. 2), both the leaves and the fruit being very similar to those of the modern tree. Beautiful leaves of a tulip-tree (*Liriodendron*, see Plate XXI, Figs. 2–4, and Plate XXV) are plentiful in the plant beds at Morgan, N. J. They are undoubtedly the direct ancestor of one of our handsomest and most useful modern forest trees.

The climate at this time was much warmer and more equable than now, for we find the leaves of several varieties of figs, magnolias, camphor trees, laurels, aralias, sterculias and other trees which grow only in warm climates at the present time.

Fig. 20.

A Sequoia cone from Cliffwood.

As time passed and the country continued to sink slowly, so slow in fact that it would not have been perceptable had man existed, marine conditions became general over this region and the Cliffwood beds pass into the typically marine beds of the overlying Matawan formation.

Henceforward we find deposited beds of sand and marl and marly clay. Some of them are full of marine shells and shark's teeth, but we find no determinable remains of plants, so that the New Jersey record is again a blank during the time that the bulk of the Tertiary formations were being deposited in the Western United States and elsewhere, with their floras of hardwood trees, their magnificent palms and other modern types.

Tertiary.—The late Tertiary or Miocene is noted for its rich plant beds in all parts of the world, those of Switzerland, for instance, furnishing Heer with over nine hundred species, including representatives of nearly all of the higher families of plants.[1] No plants of importance occur in the New Jersey Miocene or later formations except those leaves and pods which are found in the coarse sandstone near Bridgeton. Among these remains occur a variety of species identical or very close to the existing species inhabiting the latitude of Virginia at the present time, and including magnolias, holly, gum, elm, hickory, chestnut, tupelo, paw-paw, oak, mulberry, spice-bush, etc. These dwelt here until the advance of the ice sheet of the Glacial period, when they retreated southward, being replaced by the northern poplars, spruce, hemlock and larch.

With the final retreat of the ice many of the former plant inhabitants again reached New Jersey, forming the nucleus of our modern flora, which has been further recruited in a variety of ways—by the northward spread of pine-barren plants from the south, the southward extension of northern types, occasional western immigrants, and probably also by the evolution of numerous, especially herbaceous, species in this general region.

Figure 21, while serving as a reference for the clearer understanding of the geological formations and the order of their appearance, including the three great eras of fossil-bearing sedimentary rocks, the Paleozoic, Mesozoic and Cenozoic,[2] and the manner in which they are subdivided into the various ages from the Cambrian upward, is also designed to show in a rough way the probable time of origin (in the light of our present knowledge) of the principal types of vegetation and the relative abundance of each from age to age. In addition it is aimed to express the filiation of the different groups with as near an approach to accuracy as is possible in a diagram of this sort. For instance, we see that in the Devonian age the Ferns gave rise to a group of fern-like seed-bearing plants which we call the Pteridosperms among some of which are probably to be found the ancestors of the Cordaitales. These orders, as will be no-

[1] He includes the Oligocene with the Miocene.

[2] The durations as expressed in years can only be taken as the roughest sort of an estimate, showing, however, that Mesozoic time was about three times as long as Cenozoic, and Paleozoic time was more than twice as long as Mesozoic time.

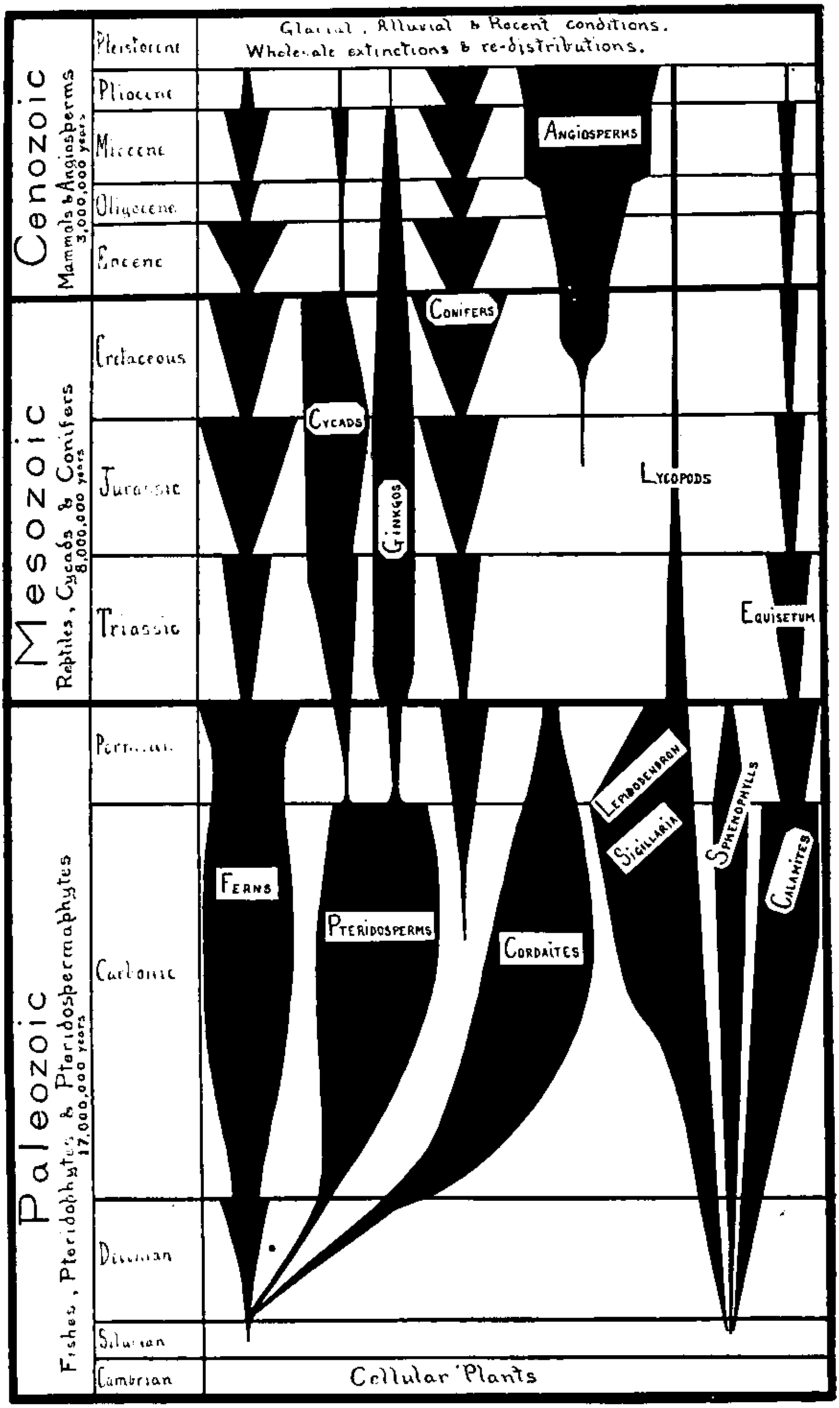

Fig. 21.

Diagram showing geological distribution of plants.

ticed, were largely developed during the Carboniferous, both being reduced in numbers during the Permian and becoming extinct with the close of the Paleozoic era.

Referring to the diagram again, we see the Pteridosperms giving rise to the Cycads toward the close of the Paleozoic, and this group in turn quite largely diversified during the Mesozoic, becoming much reduced during the Cenozoic, slightly increased in the Miocene, but an unimportant element in our existing flora. As another illustration of the purpose of the diagram take the Angiosperms. Appearing first in the Jurassic they suddenly increase greatly in numbers during the middle Cretaceous, continuing to increase from that time onward, particularly in the Miocene, until they are the most important type in the modern flora.[1] Take again the slender lines representing the modern club-mosses (Lycopods) and Equisetums, and follow them back through the ages and note how diversified and abundant were their forbears during the Paleozoic, each group probably taking its rise during the Silurian from the extinct group of Sphenophyllales.

[1]To make room for the lettering the lines of plant types are not continued up through the Pleistocene as they should be.

October, 1905.

The Flora of the Cliffwood Clays.

BY EDWARD W. BERRY.

The lignitic sands and dark-colored clays outcropping at Cliffwood bluff on Raritan Bay are well characterized in the Report on the Clays and Clay Industry of New Jersey, pp. 166–168.[1] They are there included in the Raritan formation although previously they had been referred to the overlying Matawan formation.

Perhaps too much reliance has been placed on the presence or absence of glauconite in these beds. As a matter of fact, glauconite is present, although sparingly and in small pockets about the size of a hen's egg, in which the greensand is rather "crumby" and of a light color.

Recent work of the Maryland Geological Survey in that State renders it necessary to recognize a distinct formation transitional in character and intercalated between the Raritan and Matawan formations.[2] Darton,[3] some years ago, proposed the name Magothy for this formation, from the fact that typical exposures occur along the Magothy River in Maryland.

This formation, much more arenaceous to the south, becomes more argillaceous toward the northeast, in Monmouth County, N. J., and is a continuous and readily mapable formation from the Potomac River northeasterly to Raritan Bay in New Jersey, and very probably beyond, as the writer has observed suggestions of the Magothy on Staten Island and Long Island. It is

[1] Vol. vi, Final Rept. State Geologist, 1904.

[2] Clark, Am. Journ. Sci. (4) xviii: 435-440, 1904.

[3] Darton, *Ibid.* (3) xlv: 407-419, 1893.

considerably developed in New Jersey, where it is characterized by the rapid alternation of its beds and the abrupt transitions both vertically and laterally from sand to clay or *vice versa*. Much lignite is present, sometimes in the form of large logs, two or three feet in diameter, particularly at the pits of the Cliffwood Brick Company. Iron carbonate nodules with leaf and invertebrate remains are also present, as well as large concretions of ironstone, the latter especially prominent on the beach near Cliffwood, toward the base of the exposure.

While my work has been more in the nature of a reconnaissance, and not sufficiently detailed for more than tentative conclusions, it would indicate that the Amboy stoneware clay proper marks the upper limit of the Raritan. This reduces the Raritan to a more orderly sequence by simply taking out the variable members that overlie the very much eroded surface of this Amboy stoneware clay. These lower Magothy members, which would then include the laminated sands,[1] are in one place a dark clay which, within a short distance, may thin out and be replaced by a sugary, somewhat iron-stained sand. These sands are mined at Florence, on the Delaware River, and White Hill, on the Amboy division of the Pennsylvania Railroad, south of Bordentown, gets its name from these light-colored Magothy sands. Within 100 yards of White Hill, coming north, we find the Matawan overlying a black clay similar to that at Cliffwood bluff.

As aforesaid, the Raritan contact is much eroded, and this feature seems to hold good wherever the contact is exposed, and is particularly well shown along the Delaware River at Florence, in the Hylton pits along the Pensauken Creek and along the south shore of the Bohemia River, in Maryland. This lower contact of the Magothy was observed at a number of points southwest of Morgan, N. J., along the western bank of Cheesequake Creek, south of the town of Ernston, and at several points along the Delaware River, in the vicinity of and south of Kinkora.

The upper contact with the Matawan is a very distinct one. The lower Matawan, in New Jersey, is a glauconitic micaceous clay with the glauconite more disseminated and abundant than in

[1] Final Rept. State Geologist, vi: 168, 1904.

the Magothy, but also occurring in pockets. This clay, while dark in color, weathers to a rusty brown, and the contact with the Magothy is very often marked by iron crusts, notably so at Cliffwood bluff. The lower Matawan is much more uniform lithologically than the Magothy, and the contact can be readily traced across the State, being beautifully shown at various localities in the vicinity of Bordentown, Kinkora, Fieldsborough, etc. Contrary to Darton, it would seem that while this line is so distinct it does not mark an erosion plane during a period of elevation, but simply the slowly continued sinking, which was inaugurated at the commencement of the Magothy and culminated in the lower Matawan in typical marine conditions, by the encroachment of the sea which already, at the time of the deposition of the Cliffwood clays, had more or less access to this region. There seems to be, however, some evidences of a break in sedimentation to the southwest, since in Prince George's County, Maryland, the Matawan transgresses the Magothy and rests on the Raritan.

A secondary feature of the Magothy formation is the occurrence of amber, which is found in the form of globular and tear-shaped drops, disseminated in the lignite beds from Cliffwood bluff, in New Jersey, southwesterly to the type amber locality of the coastal plain, at Cape Sable, Md. I have not found this amber in pieces larger than a lima bean, although occasionally one hears from the foremen of the clay pits of much larger masses having been found.[1]

While I have collected indications of plants in a much broken condition at various other localities, the following, presented in tabular form, represent the only New Jersey localities where recognizable plants have been collected:

Upper Magothy, ...	Kinkora. Cliffwood bluff.
Middle Magothy, ...	Cliffwood bluff. Cliffwood Brick Company.
Lower Magothy, ...	near Morgan.

[1] Hollick, Am. Nat., xxxix: 137-145, 1905, summarizes our knowledge of coastal plain amber.

From the Morgan localities I have collected the following species:

Carex Clarkii Berry.
Cunninghamites squamosus Heer.
Hymenæa dakotana Lesq.
Laurus Hollickii Berry.
Laurus plutonia Heer.
Laurus proteæfolia Lesq.
Liriodendron morganensis Berry.
Magnolia Capellinii Heer.
Nelumbo Kempii Hollick.
Salix flexuosa Newb.
Sapindus Morrisoni Lesq.
Widdringtonites Reichii (Ett.) Heer.
Heterofilicites anceps Berry.

From Cliffwood bluff the following species have been identified:

Acer paucidentatum Hollick.
Andromeda Parlatorii Heer.
Aralia Brittoniana Berry.
Aralia grœnlandica Heer.
Aralia mattewanensis Berry.
Aralia palmata Newb.
Aralia Ravniana Heer.
Aralia Towneri Lesq.
Araucarites ovatus Hollick.
Arisæma cretaceum Lesq.
Arisæma ? mattewanense Hollick.
Banksia pusilla Velen. ?
Betulites populifolius Lesq. ?
Brachyphyllum macrocarpum Newb.
Carpites minutulus Lesq.
Carpolithus cliffwoodensis Berry.
Carpolithus drupæformis Berry.
Carpolithus juglandiformis Berry.
Carpolithus ostryæformis Berry.
Carpolithus mattewanensis Berry.
Carex Clarkii Berry.
Celastrophyllum elegans Berry.
Celastrophyllum Newberryanum Hollick.
Chondrites flexuosus Newb. ?
Confervites dubius Berry.
Cunninghamites elegans (Corda) Endl.
Cunninghamites squamosus Heer.
Dammara cliffwoodensis Hollick.
Dewalquea groenlandica Heer.
Eucalyptus ? attenuata Newb.
Eucalyptus Geinitzi Heer.
Eucalyptus Wardiana Berry.
Ficus atavina Heer.
Ficus daphnogenoides (Heer) Berry.
Ficus reticulata (Lesq.) Kn.
Ficus Woolsoni Newb.
Frenelopsis hoheneggeri (Ett.) Schenk. ?
Geinitzia formosa Heer.
Gleichenia Saundersii Berry.
Gleichenia Zippei (Corda) Heer.
Gymnospermous cones and stems.
Laurus Hollae Heer.
Laurus Hollickii Berry.
Laurus plutonia Heer.
Laurus proteæfolia Lesq.
Laurophyllum angustifolium Newb.
Liriodendropsis angustifolia Newb.
Magnolia Capellinii Heer.
Magnolia obtusata Heer.
Magnolia speciosa Heer.
Magnolia tenuifolia Lesq.
Magnolia woodbridgensis Newb.
Microzamia ? dubia Berry.
Moriconia cyclotoxon Deb. and Ett.
Myrica cliffwoodensis Berry.
Myrica Brittoniana Berry.
Myrsine crassa Lesq.
Nelumbo primæva Berry.
Paliurus integrifolius Hollick.
Phyllites cliffwoodensis Berry.
Phragmites ? cliffwoodensis Berry.
Pinus Andræi Coey. ?
Pinus delicatulus Berry.
Pinus mattewanensis Berry.
Picea cliffwoodensis Berry.

Pityoxylon hollicki Kn.
Podozamites marginatus Heer.
Populites tenuifolius Berry.
Protophyllocladus subintegrifolius (Lesq.) Berry.
Quercus eoprinoides Berry.
Quercus Hollickii Berry.
Quercus Holmesii Lesq.
Quercus Morrisoniana Lesq.
Quercus ? novæ-cæsareæ Hollick.
Quercus sp., Berry.
Rhamnus inæquilateris Lesq.
Rhamnus novæ-cæsareæ Berry.
Salix flexuosa Newb.
Salix mattewanensis Berry.
Salix Meekii Newb.
Salix proteæfolia Lesq.
Sassafras acutilobum Lesq.
Sassafras progenitor Newb.
Sapindus apiculatus Velen. ?
Sapindus Morrisoni Lesq.
Sequoia gracillima (*Lesq.*) Newb. "cones."
Sequoia Reichenbachi (Gein.) Heer.
Sterculia cliffwoodensis Berry.
Sterculia minima Berry.
Sterculia Snowii bilobatum Berry.
Sterculia sp., Hollick.
Strobilites inquirendus Hollick.
Tricalycites papyraceus Newb. ?
Viburnum Hollickii Berry.
Viburnum mattewanense Berry.

From the pits of the Cliffwood Brick Company the following forms have been obtained:

Brachyphyllum macrocarpum Newb.
Cinnamomum Heeri Lesq.
Cinnamomum intermedium Newb.
Cunninghamites squamosus Heer.
Diospyros rotundifolia Lesq.
Eucalyptus Wardiana Berry.
Ficus aligera Lesq.
Ficus Woolsoni Newb.
Flabellaria magothiensis Berry.
Hymenaea dakotana Lesq.
Juglans arctica Heer.
Juniperus hypnoides Heer.
Laurus Hollickii Berry.
Laurus plutonia Heer.
Malapœnna falcifolia (Lesq., Kn.).
Myrica cliffwoodensis Berry.
Picea cliffwoodensis Berry.
Platanus Kummelii Berry.
Protophyllocladus subintegrifolius (Lesq.) Berry.
Salix flexuosa Newb.
Salix proteæfolia Lesq.
Sassafras acutilobum Lesq.
Sapindus Morrisoni Lesq.
Sequoia Reichenbachi (Gein.) Heer.
Sequoia heterophylla Velen.
Sterculia minima Berry.
Ilex strangulata Lesq.
Paliurus populiferus Berry.

From the brownish clays, just below the Matawan contact at Kinkora, I have obtained

Carex Clarkii Berry.
Gleichenia Saundersii Berry.
Sequoia gracillima (Lesq.) Newb. "cones."
Heterofilicites anceps Berry.

together with fragments of dicotyledonous leaves. The clays at this point are literally packed with the remains of a fern with tiny spatulate fertile pinnæ. So common are these remains, which also occur, but in less abundance, at the Morgan locality, that they almost exclude all other remains.

While the Kinkora outcrop has been put above that at Cliffwood bluff in the table, it contains but a sparing representation of the flora of this stage of the Magothy. Immediately beneath the Matawan contact, at one point along Cliffwood bluff in a lense of massive dark clay, the following species were collected:

Laurus plutonia Heer.
Ficus daphnogenoides (Heer) Berry.
Sequoia Reichenbachi (Gein.) Heer.
Cunninghamites squamosus Heer.
Cunninghamites elegans (*Corda*) Endl.
Dammara cliffwoodensis Hollick.
Carex Clarkii Berry.

showing that these well-known forms persist to the top of the formation. The flora, as a whole, sustains the conclusions arrived at from a study of the previous less extensive collections, and while this flora is still comparatively little known, particularly in its development south of New Jersey, such evidence as we have shows that while it has many points of similarity with the Raritan flora, it is somewhat more recent and shows a greater similarity to other and upper Cretaceous floras, just as the fauna as studied by Weller,[1] while it has a facies of its own, is still very close to that of the overlying and typically marine Matawan formation.

Forms which characterize the Magothy formation in New Jersey are the following:

Dammara cliffwoodensis Hollick.
Flabellaria magothiensis Berry.
Laurus Hollickii Berry.
Sterculia minima Berry.
Sequoia gracillima (Lesq.) Newb. "cones."
Carex Clarkii Berry.
Cunninghamites squamosus Heer.
Salix flexuosa Newb.

Of these the first occurs only at Cliffwood bluff, and the last two are found elsewhere in this country or abroad, but the balance are confined to the Magothy, and are especially prominent elements in its flora, as developed at a number of localities, both in New Jersey as well as in Delaware and Maryland.

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[1] Ann. Rep. State Geol. (N. J.), 1904, pp. 131-145, 1905.

A list of the species which are confined to the Magothy formation, although one or two are also found in Europe, embraces the following:

Acer paucidentatum Hollick.
Aralia Brittoniana Berry.
Aralia mattewanensis Berry.
Araucarites ovatus Hollick.
Arisæma ? mattenwanense Hollick.
Carpolithus cliffwoodensis Berry.
Carpolithus drupæformis Berry.
Carpolithus juglandiformis Berry.
Carpolithus ostryæformis Berry.
Carpolithus mattewanensis Berry.
Carex Clarkii Berry.
Celastrophyllum elegans Berry.
Confervites dubius Berry.
Cunninghamites squamosus Heer.
Dammara cliffwoodensis Hollick.
Eucalyptus Wardiana Berry.
Flabellaria magothiensis Berry.
Gleichenia Saundersii Berry.
Laurus Hollickii Berry.
Liriodendron morganensis Berry.
Microzamia ? dubia Berry.
Myrica cliffwoodensis Berry.
Myrica Brittoniana Berry.
Nelumbo primæva Berry.
Phyllites cliffwoodensis Berry.
Phragmites ? cliffwoodensis Berry.
Pinus Aureæi Coey.
Pinus delicatulus Berry.
Paliurus populiferus Berry.
Pinus mattewanensis Berry.
Picea cliffwoodensis Berry.
Pityoxylon hollicki Kn.
Platanus Kuemmelii Berry.
Populites tenuifolius Berry.
Quercus eoprinoides Berry.
Quercus Hollickii Berry.
Quercus novæ-cæsareæ Hollick.
Quercus sp. Berry.
Rhamnus novæ-cæsareæ Berry.
Salix mattewanensis Berry.
Sequoia gracillima (Lesq.) Newb. "cones."
Sterculia cliffwoodensis Berry.
Sterculia minima Berry.
Sterculia Snowii bilobatum Berry.
Sterculia sp., Hollick.
Strobilites inquirendus Hollick.
Viburnum Hollickii Berry.
Viburnum mattewanense Berry.
Heterofilicites anceps Berry.

This gives us a total of forty-nine forms and eliminating doubtful species such as those of *Strobilites, Carpolithus, Phyllites,* etc., it leaves good species widely distributed through twenty-seven orders, and these species are largely advanced types as, for instance, the two species of Viburnum, four species of Oak, one species of Spruce, three species of Sterculia, one species of Platanus, etc. In adition to this it should be remembered that there are several species which are recorded from the New Jersey Raritan at South Amboy, *e. g., Cunninghamites elegans, Eucalyptus ? attenuata* and *Moriconia cyclotoxon,* in which there is a possibility, I might say probability, that they are from the Morgan locality or its equivalent, and are not true Raritan forms at all, as they are not found in the comparatively abundant collections from elsewhere in the New Jersey Raritan.

Of the Magothy species, with an outside distribution, there are thirty-six which are also found in the New Jersey Raritan. If we eliminate from these those species with a wide geographical and geological range such as *Widdringtonites Reichii, Sequoia Reichenbachi, Cunninghamites elegans, Andromeda Parlatorii, Eucalyptus Geinitzi, Gleichenia Zippei, Sapindus Morrisoni*, etc., and the species which are represented in the Magothy by very unsatisfactory remains, such as *Frenelopsis hoheneggeri* and *Tricalycites papyraceus,* we get something like 25 per cent. of the flora common to the Raritan. With the flora of the supposed Raritan on Staten Island, Long Island and eastward there are thirty-one common species, including several not found in the New Jersey Raritan, and it is quite possible that some of these Island forms may have come from the Magothy. The latter flora, as found at Morgan, includes six species found on the Islands, the striking *Nelumbo Kempii* being confined to Morgan and Long Island.

There are twelve species confined to the Magothy and Dakota floras and these embrace such characteristic forms as *Ficus aligera, Aralia Towneri, Myrsine crassa, Quercus Morrisoniana, Rhamnus inæquilateris, Salix Meekii,* etc. On the other hand, there are only five species peculiar to the Magothy and Raritan floras, including the Island species as well under the heading of Raritan, and of these five species there are *Chondrites flexuosus* and *Frenelopsis hoheneggeri,* whose occurrence in the Cliffwood clays is founded upon very doubtful remains, and neither are especially good species anyway, so that it will become apparent that while there are numerous Raritan species in the Magothy flora, and while it is not a much more modern flora, still it contains a number of modern types not found in the Raritan, and has a general facies allying it with those floras elsewhere which are usually classed as Cenomanian, such as that from the Dakota sandstone of the West or that from the Atane beds of Western Greenland. Comparing this flora with that of the world we note that it contains forty-two species of the Albian or Gault and forty-nine species of the Cenomanian or Senonian, and that while it marks the upper limit of thirteen *manni* Engelm., both of the western United States. Perhaps, the most similar modern spruce is the European *Picea excelsa* (Lam.) Link., a cone of which I have reproduced on the same plate with the fossil specimen to show their great similarity.[1] It is interesting to note that *Picea excelsa* occurs in the Interglacial deposits of Denmark. Among the fossil species the closest is the gigantic cone from the Cenomanian sandstone of Vyserovic, Bohemia, which Velenovsky has described as *Pinus protopicea*[2]. It is 16 cm. long and 5.5 cm. wide and very similar to our specimen in general appearance. The scales, however, are rounded and somewhat more like those of *Pinus* than ours. Velenovsky, however, compares his species to the European *Picea excelsa* so that the resemblance to the Cliffwood species may be closer than his description or figures indicate. A variety of indefinitely-determined fossil cones have some resemblance to ours. For instance, Ettingshausen has figured a cone of this size from the homotaxial horizon of Niedershöna, in Saxony, which he calls *Cunninghamites oxycedrus* Sternb[3]. Fontaine figures a cone of this size from the Potomac formation of Virginia under the name of *Abietites macrocarpus*[4], but so poorly preserved that any accurate determination of its relations is impossible. Newberry figures cones of this size from the Raritan, at South Amboy, N. J., referring them to *Brachyphyllum macrocarpum*[5]. A comparison with Newberry's types shows that their structure is entirely different from that of the Cliffwood Picea. Finally, because it is from a homotaxial horizon, I might mention *Ptenostrobus nebrascensis* Lesq[6], from the Dakota group, which has never been positively identified, but which is obviously different from the Cliffwood specimen.

Picea has upward of a score of species in the modern flora—

[1] In this connection I wish to express my gratitude to Professor Charles S. Sargent, of the Arnold Arboretum, who kindly furnished me with cones of some of the living Piceas for comparison.

[2] Velen. Gym. böhm. Kreidef, 31, *pl. 7, f. 1, 4, 6; pl. 3, f. 4*, 1885.

[3] Ettings. Stiz. Akad. Wiss. band *55;* 12. *pl. 1, f. 9*, 1867.

[4] Font. Potomac Flora, 262, *pl. 132, f. 7*, 1889.

[5] Newb. Fl. Amboy Clays. 51, *pl. 7, f. 3*, 1896.

[6] Lesq. Cret. Flora, 114, *pl. 24, f. 1*, 1874.

Albian or Gault species, it marks the lower limit of seventeen Cenomanian or Senonian species.

There follows a description of those species new to science or of especial interest which have been discovered during this investigation.

Picea Cliffwoodensis (sp. nov.).

(Plate XIX.)

A single remarkably well preserved cone of *Picea* was found on the beach at Cliffwood bluff. It is pyritized and slightly flattened, and is complete, except for the apical fourth. It measures 8 cm. in length, 2.6 cm. in its greatest and 1.6 cm. in its shortest diameter. In its original state this must have been a most magnificent cone, as the thinner tip and edges of each scale has been worn away in the trituration which the specimen underwent before its final preservation. The softer parts, such as the seeds, and the seed cavities and interstices between the scales are filled with pyrite. The scales are rather thin, and broadest across the middle, as in the modern spruces, and their external contour shows that each contained two rather large seeds.

At the top of the specimen where the tip is broken off, and at one or two places where the substance of the scales is worn away, are glistening pyrite geodes, showing conclusively the position of the seeds.

A single scale of a *Picea* cone was washed out of the lignite at the pits of the Cliffwood Brick Company. Among recent species, this scale is nearest to those of *Picea Engelmanni* Engelm., and if it is from the same species as that furnishing the cone found at Cliffwood bluff, which is assumed to be the case, the latter specimen lost considerable in size before preservation.

I consider the reference of this cone to the genus *Picea* as beyond question. The only other reference considered was *Abies,* in which genus, however, the cones are relatively stouter, the scales broader and deciduous, thick in texture to their tips, not becoming alate as in *Picea.* Among existing American spruces the nearest are *Picea Parryana* (André) Parry and *Picea Engel-*

five or six in North America, three in the elevated region of central Asia, five or six in eastern Asia and Japan, one in northwestern Europe, one in the highlands of southeastern Europe and another in a similar habitat in Asia Minor. The genus is decidedly a north temperate and arctic type, reaching moderately low latitudes only in the mountainous regions, in which localities relics of the last glacial retreat have evolved into distinct species. The geological history of the genus is obscure. Two probable species have been recorded from the Gault of Belgium. The Cenomanian has yielded one, or possibly two, species in Bohemia and the one under discussion from New Jersey. Two species are recorded from the Baltic amber, and the European and Arctic Miocene furnishes six or seven additional forms. Finally, the Pleistocene, notably of North America, has furnished four species, all forms which still survive in the present flora.

Salix flexuosa Newb.

Salix flexuosa, Newb. Later Ext. Fl. Ann., N. Y. Lyc. 9:21, 1868.
Ill. Cret. & Tert. Plants, *pl. 1, f. 4, 1878.*
U. S. Geol. Surv. Mon., 35:56, *pl. 2, f. 4; pl. 13, f. 3, 4; pl. 14, f. 1, 1898.*
Salix proteæfolia flexuosa (Newb.) Lesq.
Lesq. Fl. Dakota Group, 50, *pl. 64, f. 4, 5, 1892.*
Hollick, Bull. Torrey Club, 21:50, *pl. 174, f. 5, 1894.*
Ann. N. Y. Acad. Sci., 11:59, *pl. 4, f. 5a, 1898.*
Berry, Bull. N. Y. Bot. Gard., 3:67, *pl. 48, f. 12; pl. 52, f. 2, 1903.*
Salix proteæfolia linearifolia Lesq.
Lesq. Fl. Dakota Group, 49, *pl. 64, f. 1-3, 1892.*

This species enjoyed a wide distribution in Mid-Cretaceous times, occurring in Kansas, Nebraska and New Mexico during the deposition of the Dakota sandstone and in the eastern part of North America, on Marthas Vineyard, Block Island and Long Island. In the Cliffwood-Magothy beds I have collected it at Cliffwood bluff, at the pits of the Cliffwood Brick Company, at Morgan on Cheesequake Creek, New Jersey; Deep Cut, Delaware, and at Grove Point, Maryland.

The Morgan leaf is exactly similar to the smaller leaf from Cliffwood bluff, and agrees perfectly in size and outline with Newberry's figures, the only point of difference being that the latter show somewhat more ascending secondaries. Among the leaves which Lesquereux refers to this species, ours is rather closer to his variety *linearifolia* than to his variety *flexuosa*, which latter is somewhat shorter and a trifle stouter, but there can be no doubt that both forms should be referred to one species, which should be separated from *Salix proteæfolia* Lesq.

It may be remarked in passing that these small narrow leaves are very similar to what Lesquereux calls *Eucalyptus dakotensis* from the Dakota Group.

A very similar willow to the species under discussion is *Salix assimilis* Saporta, indicative of the similarity between the conditions and the flora on the opposite side of the Atlantic during the transition from the lower to the upper Cretaceous.

Platanus Kümmelii sp. nov.

(Plate XXIII, Figs. 2 and 3; Plate XXIV.)

Leaves large, palmately trilobate when mature, triple-veined from the base, which is cuneate and entire; margin sharply and widely serrate; main sinuses deep and narrow for this genus, rounded; petiole, midrib and lateral primaries stout; secondaries nearly straight, one running to the tip of each marginal point, intermediate secondaries in the lateral lobes occasionally camptodrome; tertiary venation characteristically platanoid.

The most perfect specimen found indicates a leaf 19 cm. long and about 21 cm. broad, and fragments of somewhat larger leaves are often met with. The young leaves (Fig. 3), so far as known, are rhomboidal in outline, the basal half entire and rounded with a slightly decurrent base, the upper half, with three or four points separated by shallow-rounded sinuses on each side, greatly resembling in appearance the more entire-leaved species of Platanus and quite different from the juvenile leaves of the existing species.

The remains of the fruit ("button-balls") are very common, a score or more having been collected from the clays, as well as others from the lignite (Fig. 2). In only one instance have I been able to find any trace of the peduncle, in which case about

3 cm. was attached to the head, which, in all cases, represents the large fruit receptacle and does not include any true seeds.

This species of sycamore, which is a very handsome one, and not greatly different from the existing *Platanus occidentalis* Linn. of eastern North America, has only been found at the pits of the Cliffwood Brick Company, where it is very common, almost to the exclusion of other remains.

Lesquereux reported on the New Jersey clay flora to George H. Cook, and on page 29 of his report which was published in 1878, he records *Platanus Heerii* from Pettit's clay bank, near South River, although, judging from the concluding paragraph of his report, which reads: "These specimens are few and poor, and, therefore, the determinations are not positively ascertained," not much reliance need be placed in this record. During Newberry's work on the Amboy clay flora special search was made for this species, as he states on page 29, without success, and he further remarks that he had examined the collection on which Lesquereux's report was based, and its condition at the time he saw it was such that it was practically worthless, so that we may with propriety exclude Platanus from the Raritan flora in New Jersey. In any event *Platanus Heerii* is a smaller and decidedly different leaf from the Cliffwood *Platanus*, with characters that ally it with that protean group of Cretaceous leaves which have been variously referred to *Cissites, Sassafras, Credneria,* etc. Hollick has recorded two species of *Platanus* from Staten Island, both of which are sparingly represented and are from material contained in the Glacial drift, so that there is a possibility that they may belong to the Magothy, rather than the Raritan, as there are traces of the former formation in places on Staten Island. Both of Hollick's leaves are somewhat similar in size and outline and are practically unlobed. They are undoubted *Platanus* leaves, but are considerably smaller and entirely distinct from the Cliffwood leaves. Velenovsky has described two species from the Cenomanian of Bohemia—one a large Credneria-like leaf, *Platanus rhomboidea,* which name, by the way, is pre-occupied by Lesquereux's *Platanus rhomboidea,* from Golden, Col., described in 1874, or fifteen years before Velenovsky's species; the other based on several splendid fruits, entirely characteristic.

From the Dakota group numerous platanoid leaves have been collected which have been referred to ten species and varieties. These include a considerable range of form and several synthetic types, whose true relations are doubtful. These species *diminutiva, cissoides* and *obtusiloba* I would exclude entirely from this genus, although it is possible that they might with propriety be referred to a generalized genus which might be designated *Protoplatanus*, as suggested by Ward, which would include some of the apparently-related leaves which have been referred to *Sassafras, Aralia, Araliopsis,* etc. The same might be said for Newberry's *Platanus latiloba,* under which he includes Lesquereux's *Platanus obtusiloba* and *Sassafras mirabile.* The latter, it might be remarked, in venation and general form, is similar to the Cliffwood leaf, lacking, however, the deep sinuses and strongly-toothed margins of the latter. There remains from the Dakota group the series of leaves referred to *Platanus latior* (Lesq.) Kn., and its varieties *integrifolia, subintegrifolia* and *grandidentata,* as well as the two species *Platanus Heerii* Lesq. and *Platanus Newberryana* Heer, already referred to as occurring here in the East (Staten Island and New Jersey). The former also occurs in the Atane beds and the latter in the Patoot beds of Greenland.

Platanus latoir is a typical *Platanus* closely resembling some of the leaves of the modern species and including typical flowers (Fl. Dak. Group, pl. 8. f. 8, a, b), establishing beyond question their true affinity. In outline this leaf is somewhat similar to the young leaves of the Cliffwood species, which lack the trilobate form of the adult leaf. The variety *integrifolia* is a small, probably abnormal, orbicular leaf, and the variety *subintegrifolia* is very similar to the type. The variety *grandidentata,* while obviously distinct, is closest to the Cliffwood leaf in general appearance, venation and marginal characters of any fossil form known to me. It lacks, however, the deep sinuses and narrow middle lobe; the venation is almost pinnate, the lateral primaries differing but little from the secondaries and inserted some distance above the base of the leaf, while the Cliffwood leaf is decidedly tripalmately-veined from the base. The tertiary venation is identical in the two forms, as is the character of the marginal dentation. Beds of Montana age in the west include wood referred to *Platanus* by Dawson, and also two species of leaves which need not concern us here.

The Laramie formation has nine species, including the gigantic *Platanus nobilis* Newb., as well as other species of large size, beside several small-leaved forms. Five of the Laramie species persist and help to make up the seven species which have been reported from the overlying Denver beds, and four of the Laramie species occur among the six species of the Fort Union beds, one of them (*nobilis*) re-appearing in the Upper Miocene basin of the John Day, in Oregon. Another (*accroides*) not only paralleling its range, but occurring also commonly distributed in the Miocene, of Greenland, Iceland, Spitzbergen, as well at various European localities (Baden, Switzerland, Silesia, Austria, Styria, Italy and France), and represented by both leaves and typical fruit, remains, Göppert even figuring seeds from Silesia (pl. 9, f. 4–7), and Heer figuring fruits and good seeds from two localities in Switzerland.

Platanus fruits have also been detected associated with the leaves in the Tertiaries of Greenland (*P. marginata* (Lx.) Heer) and Siberia (*P. Guillelmae* Göpp.) by Heer, but the remains of fruit do not seem to have been found fossil in the United States heretofore.

In the Fort Union *Platanus basilobata* Ward and in the Miocene *Platanus appendiculata* Lesq. we have leaves with basal appendages, which, according to Ward, hint at the mode of origin of the foliaceous stipules of the modern leaves from leaf segments of their ancestors, which in time moved down the petiole. As this is the mode of origin of the stipules in *Lirirdendron* and probably in *Comptonia,* it becomes increasingly probable in *Platanus* as well.

Several of the Tertiary species, notably *accroides* Göpp., Guillelmæ Göpp., and *dissecta* Lesq., seem to be in the direct line of descent to the modern leaf, and finally we have remains of the common American *Platanus occidentalis* Linn. of the existing flora in the Pleistocene deposits of Canada and West Virginia.

Platanus does not have a great variety of species in the European Tertiary, although the individual leaves are common enough. In the modern flora it is distinctly a north temperate type, with no conspicuous outliers either northward or southward. There are six or seven species in all, the most widespread being the old world *Platanus Orientalis* Linn. and the eastern American *Platanus occidentalis* Linn., which ranges from Maine and southern Canada to northern Florida and Texas. Besides this species, we have on this continent two species of restricted range in Arizona, New Mexico and Mexico and another species in California and Southern California, all three probably relicts of the extreme southern advance of the genus during the Glacial period.

Liriodendron Morganensis sp. nov.

(Plate XXI., Figs 2-4; Plate XXIII., Fig. 1; Plate XXV.)

Leaf 7 cm. long along the midrib, about 6½ cm. across the upper lobes and 9 to 10 cm. across the lower lobes. Broadly, four-lobed, deeply emarginate at the apex, the rounded, or nearly straight-sided sinus almost forming a semi-circle, or an angle of 90°, as the case may be. Upper lobes very wide, rather oblique, with rounded, obtuse tips and rounded, lateral margins. Lower lobes almost at right angles to the midrib, moderately stout, obtusely rounded, or more conical-shaped, with the lateral margins decurrent on the petiole. Lateral sinuses deep, extending to within 1.5 cm. of the midrib, narrow, produced to a rounded point in one specimen. Secondaries simple, approximately parallel and nearly straight; those in the lower part of the leaf stouter and more oblique than those in the upper part. Two main secondaries in each of the lower lobes approximately opposite[1]. Midrib very stout, as is the petiole, which is preserved for 2.75 cm. of its length in one specimen. These specimens show that during the deposition of the Amboy clays the modern leaf-form was developed from the *simplex-primævum-Meekii* type of leaf through

[1]Some of the specimens show the characteristic tertiary venation of Liriodendron.

a series of forms approximating these species and in the above-mentioned order.

I have collected a nhmber of leaves of *Liriodendron tulipifera* practically identical in form with this leaf, and it is remarkable that, thus early, the modern leaf is represented by the two extremes of form most common at the present time, *i. e.*, the four obtuse-lobed pandurate form, like the Morgan leaves, and the several-lobed more entire form, with pointed lobes and wide, shallow sinuses, like *Liriodendron oblongifolium* Newb., from Woodbridge, N. J. In a general way the Morgan leaves are very similar to *Liriodendron prae-tulipiferum* Dawson, from the Upper Cretaceous of Nanaimo, Vancouver Island, but they are closest to *Liriodendron giganteum* Lesq., from the Dakota group of Kansas, the chief difference, a not very good character for specific differentiation, being that of size.

The western leaves are about four times the size of the Morgan leaves, and, perhaps, indicate the same species under more luxuriant conditions, or the exuberant vegetation of western saplings of the same species. In view of this disparity in size and because of other minor differences, such as the deeper and more rounded sinus at the apex of the leaf, the more rounded margins of the lobes and the narrower lateral sinuses of *Liriodendron Morganensis,* I am at present convinced that the two forms should be kept distinct. One specimen of the latter shows a rather large simple leaf of the *primævum* type, 6 cm. wide and 5.75 cm. in length along the midrib, with part of the petiole preserved, a narrow decurrent base, rounded sides, narrowly rounded tips and a deep, slightly rounded apical sinus. This leaf at first sight suggests its reference to the simple-leaved species *primævum* of the Raritan formation, but a number of considerations lead me to think that it is simply a leaf of *Liriodendron Morganensis,* that in its form had reverted to that of its Raritan ancestor. It not only was found among typical leaves of *Morganensis,* but in its size, which is larger than *primævum* and comparable with *Morganensis,* its similarly thick midrib, deep sinus and general contour, it is identical with the typical leaves of the latter species.

Sterculia minima sp. nov.

Sterculia mucronata Lesq. Berry, Bull. N. Y. Bot. Gard., 3:90, *pl. 43, f. 3,* 1903.

A characteristic of the fossil leaves which have been referred to *Sterculia* is the variation in the number of their lobes. This is well seen in the American *Sterculia Snowii* Lesq. or the European *Sterculia limbata* Velen. When I described the single bilobed specimen from Cliffwood bluff, bearing in mind this variation of lobes, I did not hesitate to consider it a leaf of *Sterculia mucronata* under which Lesquereux had included leaves exhibiting rather extreme variations of form. However, when the same sort of a leaf as the Cliffwood leaf, only trilobed, turned up in the collections at the pits of the Cliffwood Brick Company and from Grove Point, Maryland, and a similar bilobed leaf from Deep Cut, Delaware, I began to think that I was dealing with the remains of a distinct, small-leaved species. For the latter specimen, while closely resembling the former, is somewhat smaller, and compared with the small leaves of *Sterculia mucronata* Lesq. is seen to differ in having the primaries branching from above the base, in its less conical lobes, in the lobes being directed upward instead of laterally, and, consequently, in having much narrower sinuses.

In my original description attention was called to the resemblance to leaves from Woodbridge, N. J., which Newberry considered small leaves of *Sassafras acutilobum* Lesq. The latter have every appearance of immature leaves, and are undoubtedly the young leaves of the same species as Newberry's larger leaves, whatever may be the real affinity of the latter. That they are distinct from those which I have referred to *Sterculia* is, I think, unquestionable. It is probable that one of the fragments from Cliffwood bluff which Hollick referred to *Sterculia sp.* (Trans. N. Y. Acad. Sci. 16: *pl. 14, f. 4,* 1897), is referable to this new species of Sterculia.

Other small leaves of about this same age, and which have been referred to *Sterculia,* include *Sterculia vetustula* Dawson from the Canadian Cretaceous, which has rounded margins and tips, *Sterculia reticulata* Lesq. from the Dakota group, which also has obtusely rounded tips, and the somewhat more modern *Sterculia rigida* Lesq. from the Green River Eocene, which has long, linear, pointed lobes, and is obviously distinct.

Paliurus populiferus sp. nov.

(Plate XX, Fig. 1.)

Leaf orbicular, slightly emarginate at the apex and with a decurrent base, three-veined from the top of the petiole which is .94 cm. in length. Leaf 2.5 cm. long and 3.25 cm. wide.

This leaf somewhat resembles certain small orbicular leaves which have been referred to *Populus*. It is also very similar to the leaves from the Bohemian Cenomanian, which Velenovsky calls *Aralia transitiva*.[1]

The single specimen is from the pits of the Cliffwood Brick Company. *Paliurus* in the living flora has but few species, and these are confined to the southern Eurasiatic region. The fossil species are numerous, but without the fruit it is impossible to determine with certainty to which genus of the Rhamnaceæ the leaves really belong.

Santalum novæ-cæsareæ sp. nov.

(Plate XX., Fig. 7; Plate XXII., Fig. 3.)

Fragments of this species are common in the pits of the Cliffwood Brick Company, although the only entire leaf collected came from the Morgan locality. The latter specimen is 10 cm. long and 2 cm. wide, while some of the fragmentary specimens indicate a somewhat larger leaf.

The general form is oblong. In the basal third of the leaf the margins are nearly straight and the blade is gradually narrowed to the stout petiole. The tip of the leaf is broadly rounded and the midrib is rather stout. The secondaries branch from the midrib at an acute angle, and are, consequently, long and ascend-

[1] Fl. Böhm. Kreidef, Heft 1.21, *pl. 4, f. 8-10, 1882.*

ing, finally becoming camptodrome. They are somewhat massed toward the base of the leaf, where three or four branch from the midrib at a very acute angle and run parallel to the margin and to each other, 2-3 mm. apart, for a considerable distance. These features of venation and the rounded tip are constantly associated in all the specimens collected. Various modern leaves show one or the other of these features, and the fossil leaves referred to *Laurus* occasionally have rounded tips, although this character has not been observed in any of the modern leaves related to *Laurus*. Much search for modern analogues shows that this fossil species has some points of resemblance to *Eugenia camarioca* Wright from the West Indies, but is less coriaceous. Another species which is very similar, except in that it is always lanceolate in form and rather larger in size, is *Ocotea aciphylla* Mez, from Brazil. The most suggestive modern forms, however, are those of the genus *Santalum* (cf. *Santalum cognatum* as figured by von Zittel), and *Santalum ellipticum* Gaud. is especially near to its Cretaceous ancestor. So similar are the two forms that this fact has largely influenced the determination of the fossil species.

There are eight or nine living species of *Santalum*, chiefly of the Oriental tropics, ranging from Australia northward to the Philippine and Sandwich islands. Most of these have somewhat smaller leaves.

The fossil species which have been referred to this genus equal in number the living species, and are all of Tertiary age, being distributed as follows: Eocene, five, of which three continue up into the Oligocene and Miocene; there is one additional species in the Oligocene which is also found in the Miocene, and there are two additional forms confined to the Miocene. All but one species from the Green River group of the West being European or Australian.

Heterofilicites anceps gen. et sp. nov.

(Plate XXVI.)

A fern-like plant of unknown habit, apparently showing two kinds of pinnules. The smaller (Figs. 1-12) are borne upon irregularly placed, short, dichotomous branches, which are occasionally winged as if they represented the remains of extremely reduced fronds, such as are frequently seen in the existing species of *Lygodium*. At the ends of these branches occur spatulate, somewhat lax or diffuse, sporangia-like bodies. These are sometimes closely massed in the clays and they are but rarely exposed for any great distance along the plane of fracture, so that their arrangement is made out with great difficulty. These elliptical bodies range from 2.5 to 6.25 mm. in length and from 1 to 3 mm. in greatest breadth, being sometimes short and rounded and at other times long and slender, in appearance somewhat suggestive of an aquatic habitat. As a rule no details of structure are shown, although occasionally rather coarse but ill-defined longitudinal markings are faintly shown, as in Figs. 10 and 12. These are rather indefinite, but suggest wrinkles in the substance rather than indications of venation. These sporangia-like forms are excessively abundant at Kinkora, occurring almost to the exclusion of other remains, and they are also fairly common near Morgan.

The barren pinnules (Figs. 13-16) are not so abundant as the former and occur chiefly at the Morgan locality, although they are also found at Kinkora. They are 7 to 10 mm. long and 3 to 5 mm. broad, and are kite-shaped in form, with entire margins. Stipes winged, the wings becoming broad proximad, although much reduced distad, as is well shown in Fig. 15. Stipe branching shortly after entering the pinnule, the two approximately equal branches running close to the lateral margins, in a straight line to the apical margins, dividing from one to three times in this distance. The resulting branches are all approximately parallel and run directly to the apical margins.

While these characteristic *Filicinean* remains have not been found in connection with the smaller kinds, they are both associated at the two outcrops; they are entirely similar in appearance and in their mode of branching; and, in a number of instances, they possess the same winged, Hymenophyllaceous-like stipe. There can be no question but that the barren pinnules are those of a fern. With regard to what I have tentatively assumed to be sporangia, I am not at all certain regarding their real nature.

They may simply be the finer terminal portions of fronds, which basally produced the larger specimens showing venation. There is no positive evidence that they are sporangial in nature. Professor Underwood, the well-known authority on the *Pteridophyta*, is emphatic in declaring that they are not sporangia in any modern sense.

They are, however, so suggestive of certain Paleozoic genera, *Archæopteris*, for instance (cf. White, U. S. Geol. Surv. Prof. Paper 35; pl. 3, Figs. 4–6, 1905), that they might well be considered as homologous structures. Again some of the genera of the earlier Mesozoic such as *Coniopteris* and *Onychiopsis* have fructifications which suggest these mid-Cretaceous forms. Whatever their nature, as abundant and characteristic fossils, they deserve to be recorded in any account of the flora of the Magothy formation. Any more extended discussion of their probable affinity and a comparison with supposedly related forms, is reserved, pending a more complete knowledge, which it is hoped may be obtained from additional material.

November, 1905.

PLATE XIX.

Fig. 1.—Picea Cliffwoodensis sp. nov.
Fig. 2.—Picea excelsa (Lam) Link.
(From Engler & Prantl, after Willkomm.)

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PLATE XX.

Fig. 1.—Paliurus populiferus sp. nov.
Figs. 2–6.—Cinnamonum intermedium Newb.
Fig. 7.—Santalum novæ-cæsareæ sp. nov.

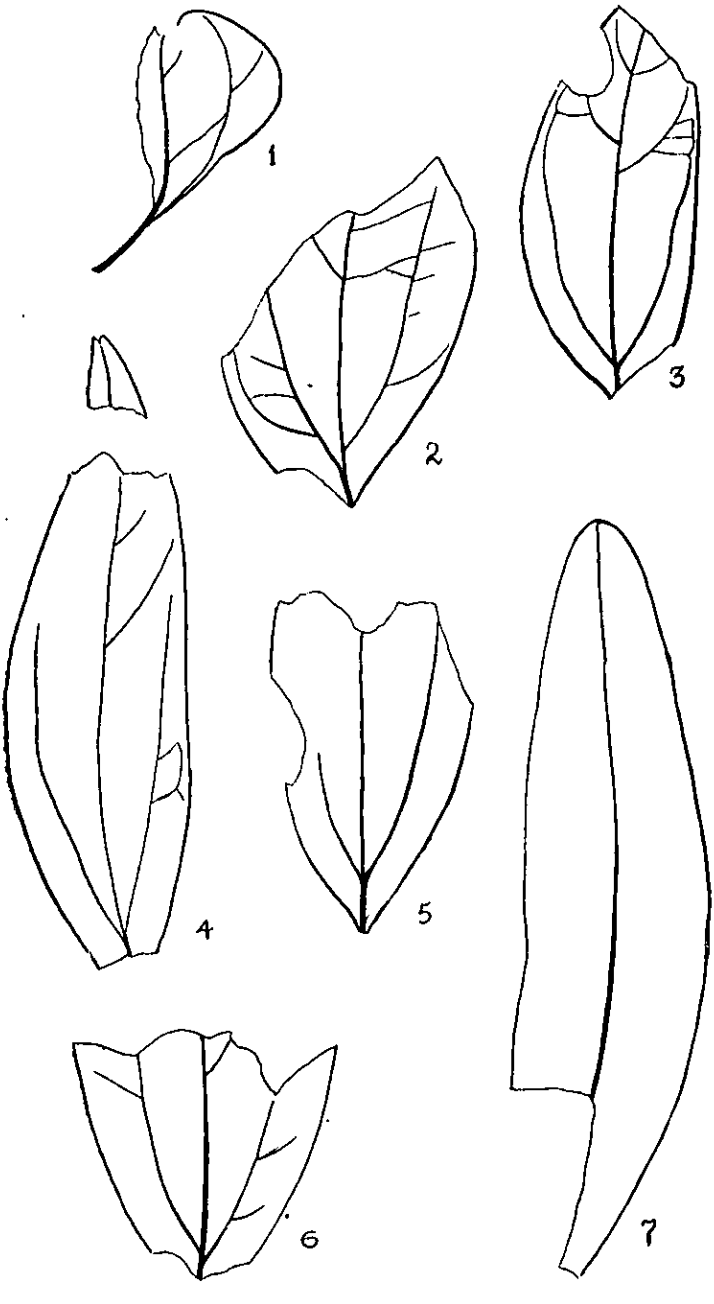
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PLATE XXI.

Fig. 1.—Juglans arctica Heer.
Figs. 2–4.—Liriodendron Morganensis sp. nov.

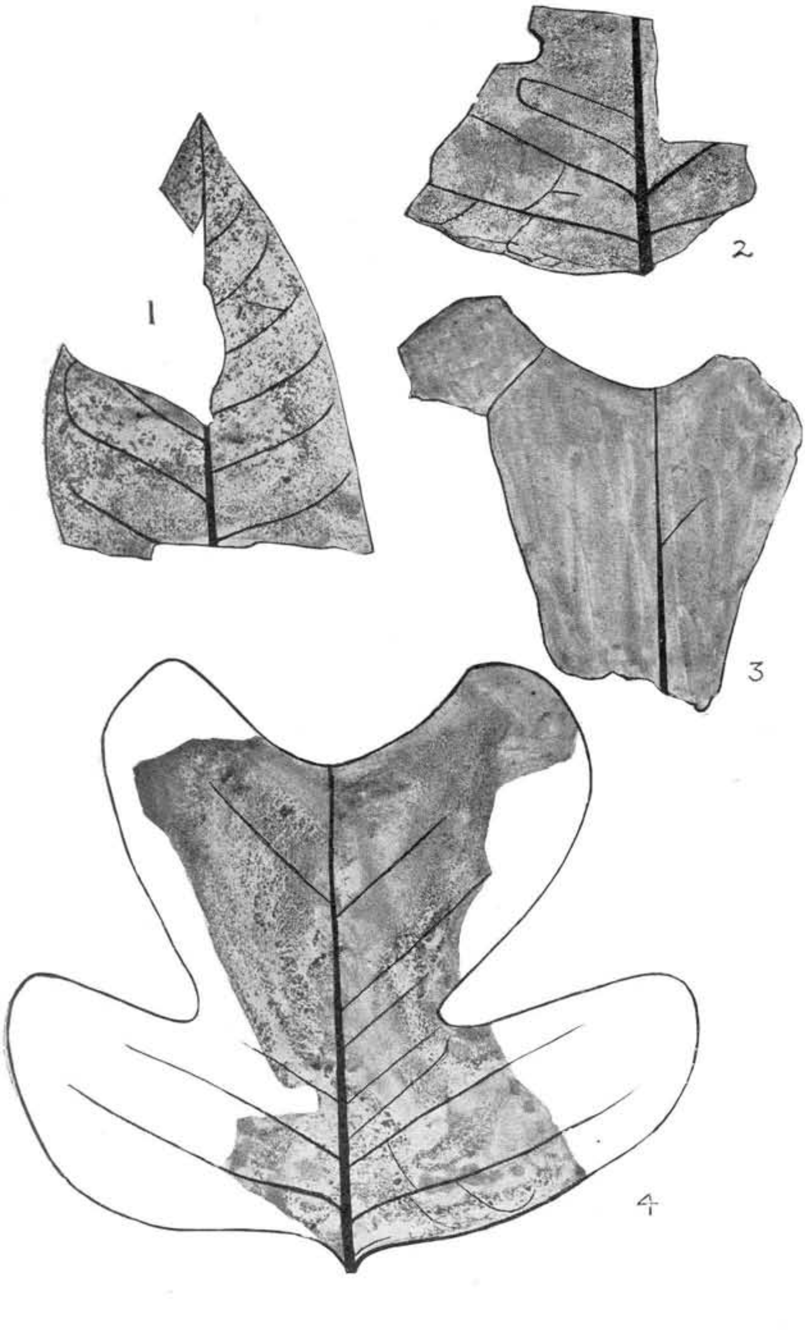
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PLATE XXII.

Fig. 1, 2.—Hymenæa dakotana Lesq.
Fig. 3.—Santalum novæ-cæsareæ sp. nov.
Figs. 4, 5.—Sassafras acutilobum Lesq.

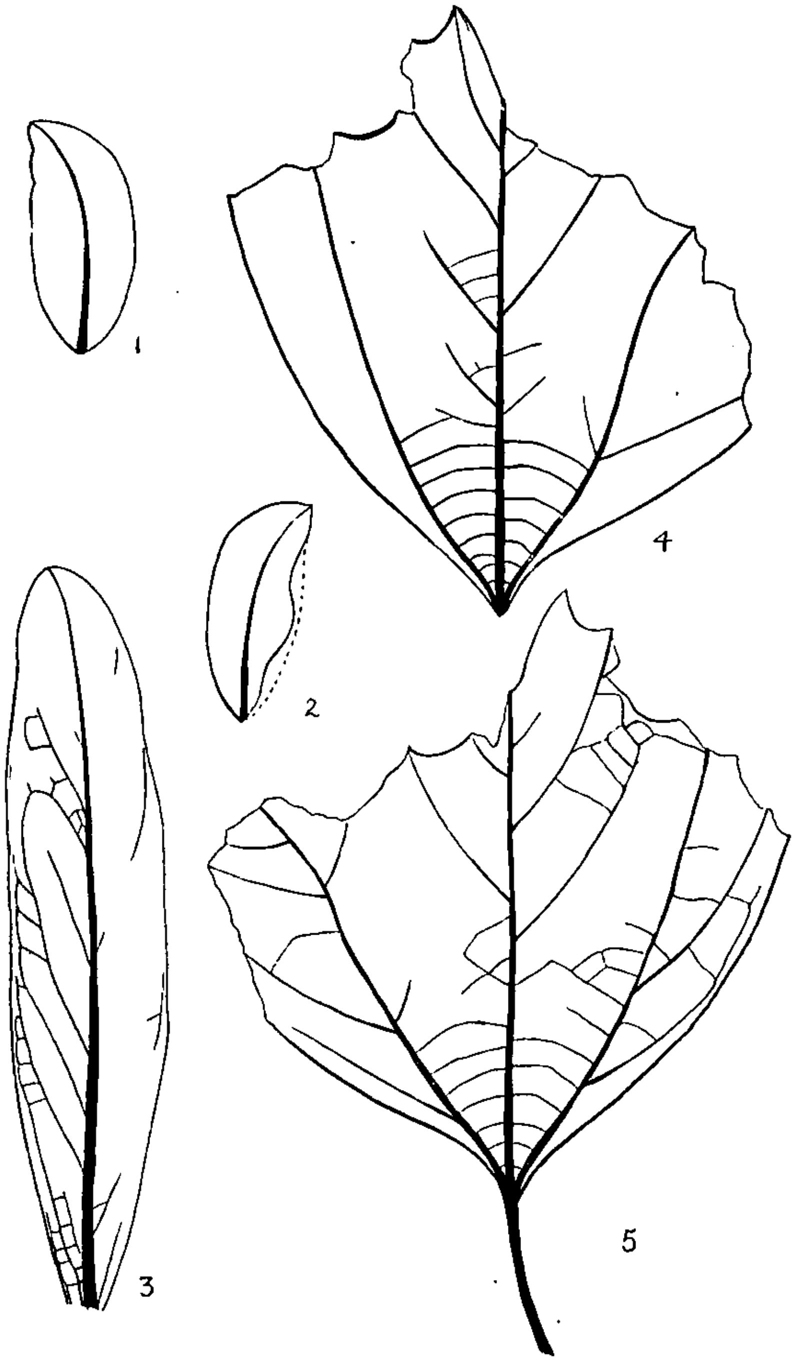
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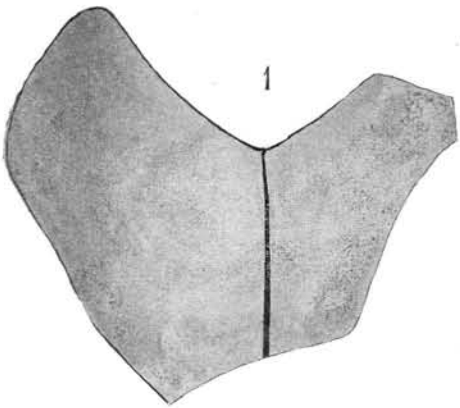
PLATE XXIII.

Fig. 1.—Liriodendron Morganensis sp. nov.
Figs. 2, 3.—Platanus Kümmelii sp. nov.



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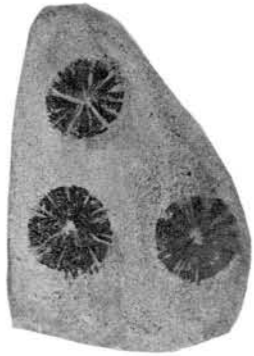

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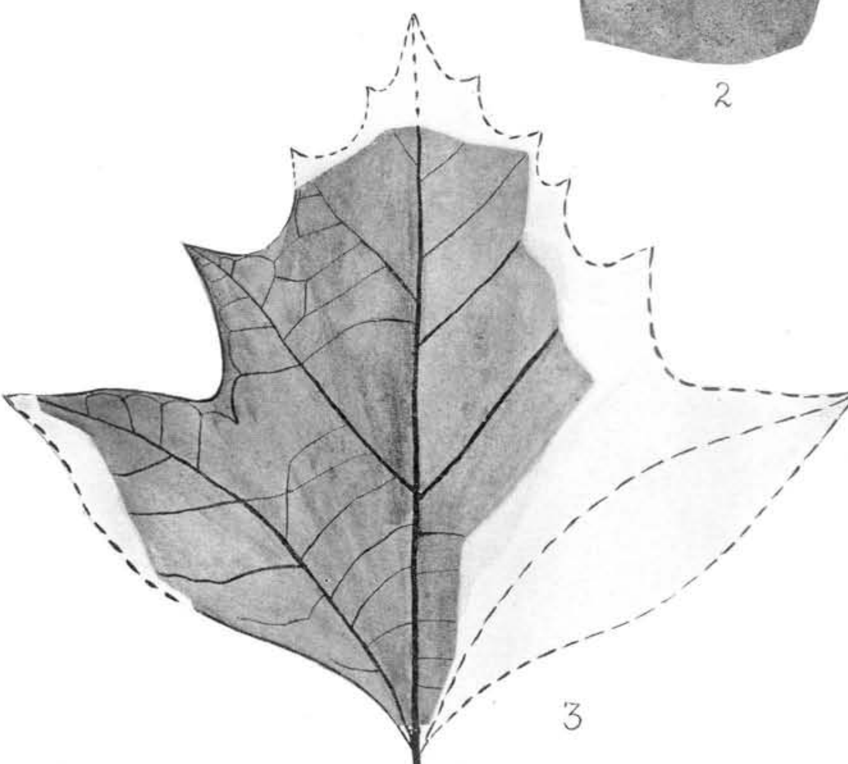

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PLATE XXIV.

Platanus Kümmelii sp. nov.

PLATE XXV.

Liriodendron Morganensis sp. nov.

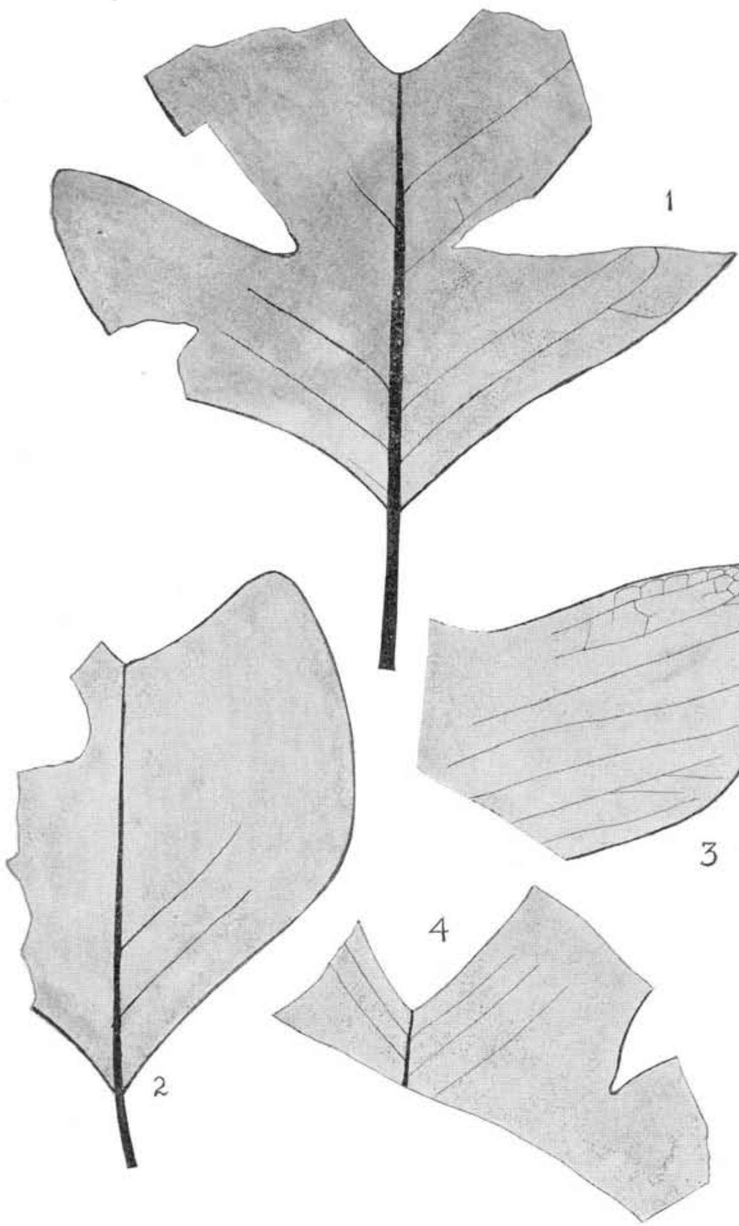
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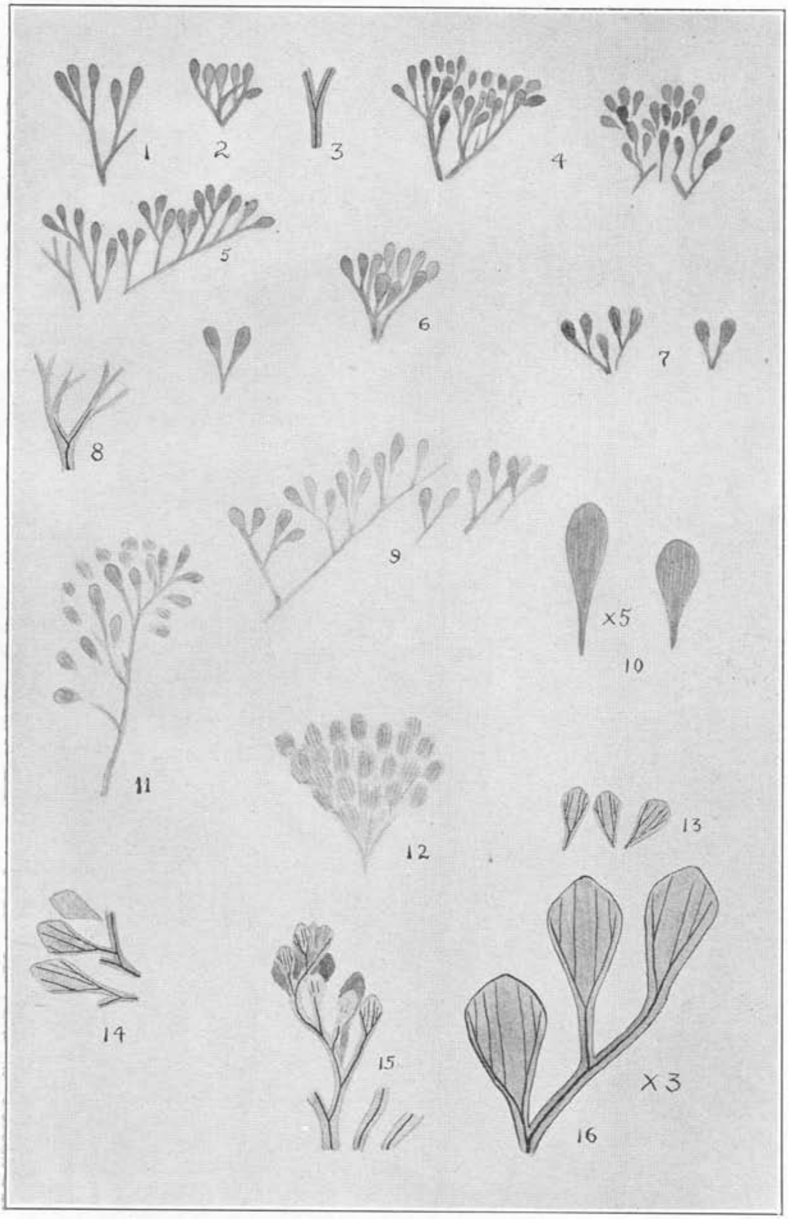
PLATE XXVI.

Heterofilicites anceps, gen. et. sp. nov.
Figs. 1–10.—From Kinkora, N. J.
Figs. 11–16.—From Morgan, N. J.
Figs. 10 and 16.—Somewhat enlarged.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PART III.

The Chemical Composition of the White Crystalline Limestones

of Sussex and Warren Counties.

By HENRY B. KÜMMEL, with Analyses by R. B. GAGE.

Chemical Composition of the White Crystalline Limestones of Sussex and Warren Counties.

HENRY B. KÜMMEL.

General distribution.—During the past year there has been a marked increase in the demand for a limestone high in carbonate of lime and comparatively free from silica and magnesia. This demand is due in part to the enormous increase in the production of Portland cement, and the necessity that compels many manufacturers of cement in the Lehigh Valley region to raise the percentage of lime in their raw mixture by the addition of varying amounts of limestone. The cement rock contains all the ingredients required in Portland cement, but they are not present in the proportions required by the best practice and the lime content has to be increased.

The demand has also been stimulated by the growing practice at blast furnaces to insist upon a non-magnesian limestone or at least a limestone very low in magnesia and silica as a flux for their ores. Then, too, the growing popularity of hydrated lime has increased the demand for high-grade limestones.

In the Annual Report for 1900, the rocks suitable for Portland cement were described and maps were published showing the location of narrow belts of the fossiliferous Trenton limestone, which contained but a small percentage of magnesia. It is the purpose of this brief paper to indicate upon the accompanying map the location of the most important belt of white limestone within the State, to present a number of analyses which this department has recently made, together with some which it has received through the courtesy of various individuals, and to draw whatever conclusions may be possible regarding the general composition of this formation.

Occurrence of the limestone.—As shown upon the map, the white limestone forms a continuous narrow belt from the State line near Glenwood, southwestward nearly to Sparta. Rarely is this belt more than a mile in width, and for much of the distance its breadth is less than half a mile. In addition to the main belt there are a number of small separate areas, southwest of Ogdensburg and west of Sparta. Beyond the limits of the map, also, there are a number of small areas of similar limestone, the most important of which are as follows:

(1) One-half mile north of Andover, (2) just east of the central portion of Cranberry Lake Reservoir, (3) along the northeastern side of Jenny Jump Mountain, (4) along Pophandusing Brook, east of Oxford Church (Hazen, P. O.), (5) one-quarter of a mile southeast of Roxburg and (6) near Lower Harmony. Of these the locality near Jenny Jump Mountain, and that near Oxford Church are the largest and most important, the former having been described in some detail in the Annual Report for 1895, and a map of that region having been published.

The white limestone does not everywhere appear at the surface within the areas marked as underlain by it. Locally the glacial and post-glacial deposits are so thick as to conceal completely all traces of the underlying rock. Nevertheless there can be but little doubt that it is at least as widespread as indicated, and there is reason for believing that connection exists between some of the isolated patches, although there is no positive evidence of it. For instance, the outcrops southwest of Sparta (Nos. 28 and 29), are probably connected with each other beneath the swamp deposits, and were it not for the heavy drift accumulations west and north of Sparta, outcrops 28 and 4 or 28 and 5 might be found to be parts of the same mass. But in default of positive evidence it is thought best not to attempt to indicate such doubtful relations on a map.

Within the areas colored, the limestone usually outcrops on the steep slopes and crests of hills, and is deeply buried in the valleys, particularly where they are swampy. There are, however, some prominent hills with steep slopes which are composed entirely of glacial deposits. Striking examples of this are the hills south of Hardystonville and McAfee.

That portion of the belt between Sand Hills on the north and Ogdensburg on the south, together with the Pinkneyville area, offers the best opportunity for quarrying, both because of proximity to railroads and the topography. The rock occurs in steep-sided hills 100 to 200 feet in height with comparatively little debris to be removed. The foliation (bedding?) is almost vertical, while the strike is parallel to the longer axes of the hills. Quarrying operations are, therefore, facilitated. The active quarries are located at McAfee, Rudeville, Franklin, and Pinkneyville, all within the limits mentioned, and in view of the great activity recently prevailing there, it is probable that most of the more valuable undeveloped properties within that area are held under lease or option for quarrying or mining purposes. In addition to the quarries in operation at the close of 1905, several new ones will soon be opened.

North of Sand Hills the limestone belt diverges from the railroad and does not afford such favorable opportunity topographically for quarrying, although fair sites might be found. The outcrops at Glenwood, although close to a railroad, are small, and owing to the drift deposits there is some doubt as to their extent. They may be larger than indicated on the map.

Character of the limestone.—Typically the limestone is a coarsely crystalline rock, the calcite (or dolomite) crystals of which often measure an inch or more in diameter. It is commonly white in color, the lustrous cleavage faces of the large crystals giving it a bright and resplendent aspect, but it often has a slight bluish tinge, and in the Jenny Jump Mountain area much of it is mottled pink. Nearly everywhere the rock contains small brilliant scales of graphite, flakes of a yellowish mica, and grains of various silicates,—diopside, chondrodite, etc. It is not possible anywhere to recognize beyond all question definite planes of sedimentation, although in many localities there is a distinct structure or foliation due to the arrangement of the accessory minerals in certain planes, or, where these are absent, to a lenticular arrangement of the crystals of calcite. In at least one quarry at McAfee there are definite belts along which the rock is found to differ in composition from that on either side. These differences are such as to suggest at least that they are the result of original sedimentation. Since in this instance these zones agree in strike and dip with the banding in the limestone, there is more reason than would otherwise be the case for regarding the latter as indicative of the stratification. While it is not impossible that this foliation may everywhere be indicative of the bedding planes, yet in default of positive evidence to this effect and the well-known fact that in many instances in other rocks foliation is entirely independent of bedding, it is not quite safe to assume their identity everywhere in this formation. Owing to the general absence, therefore, of any conclusive evidence by which planes of sedimentation can be positively identified, the structure and thickness of the limestone cannot be determined. There is evidence from drill holes, indeed, that in the vicinity of the Parker Shaft, Franklin, the gneiss underlies the limestone at a depth of from 1,190 to 1,275 feet, but there is no evidence to show whether this represents the actual thickness, whether the drill penetrated several close folds, or whether the boring was parallel to the bedding.[1]

Masses of other rock frequently occur within the limestone, in such relations as to show that they were intruded into it. These are chiefly light-colored granitic rocks and dark-colored basic dikes of various kinds. The granites in the limestones are coarse and generally pegmatitic and occur as small knobs or as sheets approximately parallel to the foliation, but sometimes cutting across it. The dark-colored rocks are later than the granitic or pegmatite intrusions and cut the limestone in various directions, and while quite common, do not in the aggregate constitute so large a mass of foreign material as the granites.

The occurrence or non-occurrence of these intrusive rocks is a matter of considerable economic importance in the development of quarries, since large masses may seriously interfere with the development of the quarry and the labor of sorting out the rock, where the intrusives are small may increase greatly the expense. The possibility of their occurrence not only on the surface but anywhere within the formation below the surface must be recognized, and thorough examination of a property both by surface exploration and by diamond drills should be undertaken before large sums are invested.

[1] The most recent view regarding the relation of the limestone and the gneiss is that the latter is intrusive in the former. (An. Rep. State Geologist, 1904, p. 250). If this is the case, the existence of the gneiss vertically beneath the limestone does not require that the bedding of the latter be parallel to the plane of contact.

Chemical composition.—A perfectly pure limestone should contain 56 per cent. of lime (CaO) and 44 per cent. of carbon dioxide (CO_2) or 100 per cent. carbonate of lime ($CaCO_3$), but a perfectly pure limestone in large masses is unknown in nature. Varying amounts of silica (SiO_2), alumina (Al_2O_3), iron (Fe_2O_3 or FeO) and magnesia (MgO), as well as other substances, may be present. In a pure dolomite, a molecule of magnesia replaces a molecule of lime in the bicarbonate $2CaCO_3$, forming $CaOMgO\text{-}2CO_2$ (CO_2, 47.8; CaO, 30.4; MgO, 21.7 or $CaCO_3$, 54.35 and $MgCO_3$, 45.65), but a pure dolomite is as rare as a pure limestone. Varying amounts of silica, alumina and iron are always present and the ratio of the magnesia to the lime may and usually does vary constantly. Although the stone when first deposited is usually a lime carbonate (with perhaps some silica, alumina and iron) dolomitization may begin while the formation is still beneath the sea, and commonly does take place to a varying degree after the limestone is elevated to the zone in which it is affected by percolating ground water.[1] Adjoining beds or even different parts of the same bed may therefore contain very different amounts of magnesia. This being the case it is necessary to test thoroughly any property by a series of analyses, when stone of any particular composition is desired.

In the following pages there is given a large number of analyses of these limestones, made in part in the laboratory of the Survey by R. B. Gage, and in part obtained from other sources. From these analyses it appears that in this formation there are all grades of limestone from rock nearly free from magnesia to that having nearly the composition of a dolomite.

The chemical composition of some of these limestones was discussed by Nason[2] in 1894, and the following analyses[3] published by him.

[1] Van Hise—U. S. G. S. Monograph XLVII, Treatise on Metamorphism, p. 798, et seq.

[2] F. L. Nason, American Geologist, Vol. XIII, p. 154–164.

[3] Other analyses published in the same article were of samples taken along the contact of the blue and the white limestone, where they were supposed to grade into each other. In reality, the two rocks have been faulted against each other, and the transition zone is a fault breccia. For this reason those analyses are not included here.

	Insoluble.	Al_2O_3 Fe_2O_3	$CaCo_3$	$MgCO_3$
I,	0.58	1.84	62.96	31.94
II,	5.75	1.80	51.12	40.52
III,	0.66	1.55	54.31	43.92
III',	0.39	4.58	63.81	29.82
IV,	10.28	2.25	50.82	36.52
V,	0.20	3.95	55.91	39.68
VI,	0.03	0.31	93.99	5.48
VII,	0.09	0.85	55.28	44.51
VIII,	0.07	1.15	55.28	44.24

I and II—Samples from the surface along the foot wall of the front (west) zinc vein covering a distance of 1,000 feet along the strike. Franklin Furnace.

III—Composition of 20 feet of limestone in the foot wall, at the 400-foot level of the Trotter mine. Sample was obtained by a diamond drill.

III[1]—A 10-foot stratum of limestone between two lenses of franklinite ore,—400-foot level. Trotter mine, from a drill core.

IV—Samples from 18 feet of core from the hanging wall of the Trotter mine, at the 400-foot level.

V—Piece of the core from drill hole No. 5, near the Parker Shaft, at a depth of 1,100 feet.

VI—The same at depth of 1,111 feet, nearly in contact with a granite dike at the bottom of the boring.

VII—Sample from the Parker Shaft, at the pumping station, 450 feet from the surface, and 500 feet above the ore body.

VIII—Sample from the south end of the old Furnace Quarry, 100 feet from the granite dike, Franklin Furnace.

Regarding the composition of the limestone, Nason concluded that "the franklinite ore body lies in a magnesian limestone, in fact a true dolomite, except in the instances named, when the limestone came in contact with the granite dikes; second, that the white limestone is generally non-magnesian *only* when in contact with granite or some other eruptive rock." The larger number of analyses now at hand do not bear out the above conclusions, but on the contrary show very clearly that a large part of the formation is a non-dolomitic limestone, and that the magnesian content is in large measure independent of the proximity of intrusive granitic dikes and bosses, although the latter may in certain cases have some slight effect. The facts on which these conclusions are based will now be given.

Detailed analyses.—Analyses numbered 1 to 31 were made in the Survey Laboratory of samples taken from localities shown upon the map (Plate XXVII) by the corresponding numbers. Each sample, except numbers 28, 29, 30 and 31, weighed from three to five pounds and was made up of small chips broken from many different points within a limited area. These analyses therefore represent the composition, not of a single piece of rock, but of the beds which might be used in opening a quarry. Several of them as noted below, represent samples taken from quarries already worked.

No. 1.—Average of samples from the old quarry, ¾ of a mile north of Andover. The quarry is located about 1,500 feet from the D., L. & W. and L. & H. railroads.

No. 2.—Average of samples from an old quarry near Cranberry Reservoir. The railroad (D., L. & W.) is close at hand, so that transportation facilities are good, but the limestone contains large amounts of intrusive rock, and judging from this analysis is not of very good quality.

No. 3.—Average of samples of rock from the quarries of the Crestmore Stone Company, along the L. & H. Railroad near Pinckneyville.

No. 4.—Average of samples of limestone from an old quarry 1 mile north of Sparta on property belonging to William Decker.

No. 5.—Average of samples from a small opening on the farm of H. G. Scudder, 2½ miles northeast of Sparta.

No. 6.—Average of samples from a ledge ½ mile west of the Stirling Hill mines, on property of E. C. Current. The ledge is locally known as Wild Cat ledge.

No. 7.—Average of samples from exposures on the Fowler property 1 mile south of Stirling Hill mine.

No. 8.—Average of samples from Nicoll's quarry west of the south end of Franklin Pond, Franklin.

No. 9.—Average of samples from Nicoll's quarry north of the pond, Franklin.

No. 10.—Average of samples from ledges on property of John Morehouse, 2 miles south of Glenwood.

No. 11.—Average of samples from ledges near the road about 1 mile south of Glenwood.

No. 12.—Average of samples from ledges of white limestone 100 yards from the Lehigh & New England Depot at Glenwood.

No. 13.—Average of samples from the Rudeville quarry of the New Jersey Lime Company.

No. 14.—Average of samples from the quarry of the Windsor Lime Company north of Rudeville.

No. 15.—Average of samples from the McAfee quarries of the New Jersey Lime Company, McAfee.

No. 16.—Quarry of the Bethlehem Steel Company. See p. 185.

No. 17.—Average of samples from the limestone at the northeast end of Jenny Jump Mountain, near the Howell Mine. (Not shown on the map.)

No. 18.—Average of samples from the marble quarry southeast slope of Jenny Jump Mountain, and 2 miles from Danville. (Not shown on the map.)

No. 19.—Average of samples from the quarry 1 mile south of Buttzville along the railroad to the Ahles Mine. (Not shown on the map.)

No. 20.—Average of samples from the old quarry ½ mile east of Hazen P. O. on north side of Pophandusing Brook, between Belvidere and Oxford Furnace. (Not shown on the map.)

No. 21.—Average of samples from the outcrops on the easterly slope of the 765-foot hill, 1 mile north of the Ogdensburg depot.

No. 22.—Average of samples from ledges south of the Hardystonville Pond and south of the Stockholm road. Stripping slight.

No. 23.—Average of samples from ledges and an abandoned quarry north of the Hardystonville Pond and near the schoolhouse. Stripping slight.

No. 24.—Average of samples from ledges on farm of C. Williams, 1 mile northwest of Sand Hills.

No. 25.—Average of samples from the Crabtree farm, 1 mile west of Sand Hills. The rock is frequently exposed for 1,000 feet or more in a belt 200 to 300 feet wide, with little or no covering. Railroad ¾ mile distant.

No. 26.—Average of samples from farm of W. C. Drew, 2 miles northwest of Vernon. Samples taken from ditch cut for a water-way.

No. 27.—Average of samples from the farm of John Madden, ½ mile south of Franklin. Samples were collected and sent to the Survey by Mr. Madden. Exact location of property not given.

No. 28.—Average of several samples from the farm of David McDavitt, ½ mile south of Sparta. Small opening at the edge of the meadow. Some layers contain considerable graphite, chondrodite and other minerals.

No. 29.—Average of several samples from farm of J. Decker, 2½ miles southwest of Sparta. Small opening at the edge of the meadow. Rock fine-grained with some graphite.

No. 30a and 30b.—Single specimens taken 4 feet and 100 feet respectively from a large granitic dike 700 yards east of the northern end of Franklin Furnace Pond.

Nos. 31a, b, c, d, e.—Single specimens taken 2 inches, 2 feet, 9 feet, 16 feet, 30 feet, respectively, west of the granite dike in the south wall of the old Furnace quarry at Franklin Furnace.

Analyses of White Limestone of Sussex and Warren Counties.

	Silica SiO_2	Iron and Alumina Fe_2O_3 & Al_2O_3	Lime Carbonate $CaCO_3$	Magnesian Carbonate $MgCO_3$
1,	9.40	0.80	88.15	0.50
2,	19.90	6.84	68.01	2.68
3,	0.34	1.04	95.93	2.71
4,	1.58	2.02	90.14	5.84
5,	.70	0.72	94.01	4.17
6,	1.12	0.40	92.00	6.34
7,	1.34	0.66	91.88	5.94
8,	0.60	0.76	93.62	4.51
9,	0.34	1.10	90.85	6.95
10,	1.32	0.58	95.97	3.13
11,	0.88	0.52	90.38	8.14
12,	0.82	0.60	96.51	2.08
13,	0.84	0.48	91.67	6.90
14,	0.44	0.46	92.31	6.36
15,	1.10	0.58	92.99	4.48

	Silica SiO_2	Iron and Alumina Fe_2O_3 & Al_2O_3	Lime Carbonate $CaCO_3$	Magnesian Carbonate $MgCO_3$
16,	Analyses	from Bethlehem	Steel Company.	See below.
17,	4.98	1.82	83.40	9.71
18,	4.36	1.98	85.90	7.97
19,	0.80	0.64	94.93	3.31
20,	1.08	0.86	94.41	3.80
21,	3.60	0.92	92.33	2.60
22,	1.58	0.74	65.69	32.18
23,	1.12	0.86	71.99	26.02
24,	0.22	0.62	96.25	2.38
25,	0.90	0.46	95.29	3.96
26,	0.66	0.36	97.16	2.20
27,	0.99[1]	1.54	86.93	11.02
28,	0.48	0.46	91.86	6.99
29,	0.47	0.32	96.14	3.14
30a,	0.37	0.30	98.18	1.20
30b,	0.51	0.17	97.89	1.15
31a,	1.10	0.40	95.68	2.76
31b,	0.21	0.32	95.12	4.24
31c,	0.63	0.30	94.11	4.90
31d,	0.74	0.34	94.66	4.37
31e,	0.28	0.35	90.58	8.87

The following analyses were received from C. A. Buck, Blast Furnace Department of the Bethlehem Steel Company. They are not analyses of particular samples, but are monthly averages of all the limestone shipped from the Bethlehem Steel Company's quarries at McAfee, and since the shipments from these quarries average 6,000 to 9,000 tons per month, and frequent analyses are made, these figures show well the composition of the limestone from this locality when considered in large amounts.

[1] The rock contained much mica. That remaining on the 80-mesh sieve amounted to 1 per cent. of sample and was omitted in the analysis. In the sample analyzed there were 2.06 per cent. insoluble residue, chiefly mica.

Analyses of Limestone Shipped During 1905 From the Bethlehem Steel Companys Quarry, McAfee.

	SiO_2	Fe_2O_3 & Al_2O_3	$CaCO_3$[1]	$MgCO_3$[1]	S	P
January, ...	1.54	1.24	94.23	4.09	.025	.005
February, ...	2.43	1.35	93.09	4.16	.031	.006
March, ...	1.80	0.80	94.37	3.44	.019	.006
April, ...	2.19	1.70	91.17	3.93	.018	.006
May, ...	2.30	0.72	92.42	4.35	.033	.006
June, ...	1.67	0.77	93.10	3.19	.030	.006
July, ...	1.92	1.10	93.10	3.51	.024	.006
November, ...	1.85	0.92	91.92	4.49	.030	.007
December, ...	1.55	0.96	93.01	4.14	.020	.009

Through the courtesy of the Alpha Portland Cement Company we are able to publish the following analyses,[2] which show the composition of the limestone in three drill holes, each about 90 feet in depth, put down on the ~~Morris-Rutherford~~ James Edsall property near Hamburg, which has recently been purchased by the Cement Company. The samples were taken for analysis at intervals of from 4 to 6 feet, and are of interest in showing the variable composition of the limestone, particularly the somewhat abrupt changes in the amount of carbonate of magnesia. They emphasize the importance of thoroughly prospecting a property not only on the surface but in depth, where the composition of the stone is of importance.

In response to a query whether any connection had been observed between the amount of magnesia and the color or size of the crystals or the proximity to granitic intrusions, Mr. Drew writes:[3] "The coarse crystalline stone usually runs in magnesia from 4 per cent. on up. The finer grained or 'compact' stone, as it is called locally, ran from 4 per cent. on down. * * * I did not notice in particular that the highest grade of limestone was nearest the granite." In the following tables the number of

[1] The analyses as received from Mr. Buck, gave the percentages of lime (CaO), magnesia (MgO), carbon dioxide (CO_2). These have been recalculated as $CaCO_3$ and $MgCO_3$ for the sake of comparison with other analyses here published.

[2] Harry Drew, Chemist, Alpha Portland Cement Company.

[3] Letter to the author.

the sample is given in the first column, its depth in feet from the surface in the second and the chemical composition in the remaining columns:

Analyses of Limestone from Drill-Hole No. 1.—James Edsall Property, Near Hamburg. Alpha Portland Cement Company.

No.	Depth in Feet.	Silica.	Oxides of Iron and Alumina.	Carbonate of Lime.	Carbonate of Magnesia.
1, ...	7	2.80	1.84	55.20	39.95
2, ...	11	0.83	0.66	74.65	24.09
3, ...	15	2.14	0.54	88.08	8.65
4, ...	19	2.08	0.72	83.12	13.97
5, ...	23	2.24	0.36	91.06	6.07
6, ...	27	1.36	0.32	91.22	6.13
7, ...	31	0.82	0.42	85.52	12.68
8, ...	35	0.90	0.40	91.75	6.66
9, ...	39	1.04	0.32	92.11	6.69
10, ...	43	1.16	0.34	91.22	6.83
11, ...	47	2.88	0.48	92.87	3.85
12, ...	51	0.80	0.34	94.72	3.96
13, ...	55	2.14	0.46	92.28	2.14
14, ...	59	2.34	0.44	94.20	2.27
15, ...	63	5.42	0.84	84.34	9.28
16, ...	67	1.78	0.56	80.11	17.04
17, ...	71	1.20	0.48	94.20	4.54
18, ...	75	2.16	0.68	94.29	2.54
19, ...	79	1.60	0.72	94.32	2.50
20, ...	83	1.24	0.62	94.72	2.39
21, ...	87	0.92	0.44	95.79	1.89
22, ...	91	1.68	0.34	94.32	2.02
23, ...	95	3.24	0.40	92.58	2.94

In this hole the high magnesia content of the samples near the surface and at a depth of 67 feet is noteworthy, particularly when contrasted with the low magnesia at other points.

James Edsall

Samples from Bore-Hole No. 2. Rutherford Property.

No.	Depth.	Silica.	Oxides of Iron and Alumina.	Carbonate of Lime.	Carbonate of Magnesia.
24, ...	2[1]	13.20	1.10	81.76	3.13
25, ...	7½	13.68	0.42	84.30	1.78
26, ...	13	23.64	1.88	71.94	2.52
27, ...	18½	3.56	0.64	90.31	5.59
28, ...	24	3.98	0.88	87.77	6.76
29, ...	29½	2.62	0.80	88.44	9.98
30, ...	35	1.94	0.34	93.25	3.97
31, ...	40½	1.32	0.28	91.51	5.68
32, ...	46	3.36	0.60	90.71	4.45
33, ...	51½	3.68	0.34	91.91	3.17
34, ...	57	2.48	0.52	94.71	1.92
35, ...	62½	4.48	1.14	87.78	5.45
36, ...	68	1.38	0.32	94.98	2.18
37, ...	73½	71.70	9.88	8.59[2]	2.46[2]
38, ...	79	19.00	0.88	78.30	1.42
39, ...	84½	2.10	0.26	91.25	5.32
40, ...	90	18.76	0.74	77.50	2.57

James Edsall

Sample from Bore-Hole No. 3, Rutherford Tract.

No.	Depth in feet.	Silica.	Oxides of Iron and Alumina.	Carbonate of Lime.	Carbonate of Magnesia.
41.	6	1.32	0.32	95.61	2.15
42, ...	12	1.98	0.30	96.33	1.36
43.	18	1.62	0.22	96.77	1.39
44, ...	24	1.62	0.30	96.69	1.18
45.	30	0.81	0.20	97.35	undet.
46, ...	36	0.66	0.26	97.78	1.00
47, ...	42	1.12	0.34	97.35	1.06
48, ...	48	1.28	0.40	97.00	1.18
49, ...	54	2.64	0.38	95.78	1.12
50, ...	60	1.52	0.50	95.87	1.35
51, ...	66	1.02	0.30	97.43	1.19
52, ...	72	1.30	0.40	97.20	0.53
53, ...	78	1.06	0.38	96.07	2.15
54, ...	84	1.16	0.42	92.00	5.87
55, ...	90	0.74	1.70	92.52	4.54

The extremely low magnesia in all the samples from this hole (No. 3), except numbers 54 and 55, as well as the small amounts

[1] Soil 2 feet deep. Sample 24 at top of the rock.

[2] These figures are for Lime (CaO) and Magnesia (MgO) respectively, and there was on ignition a loss of 6.01 per cent. The rock is evidently not a limestone.

of silica, iron and alumina in all these samples, indicate a limestone of a high degree of purity.

Parts of two of the drill cores obtained in the exploratory work in advance of sinking the Parker shaft in 1891, and representing depths of over 1,300 feet, are in the possession of the Survey. One of them cut the ore body at a depth of about 875 feet, and the other entered the gneiss at about 1,250 feet. Several pegmatitic dikes were cut by it, as well as a dark basic dike, and a bed of magnetite about 100 feet below the zinc ore body. Samples of the cores, combined to make a continuous section, were taken at intervals of about 50 feet, as well as specimens of the limestone adjoining the dikes and ore bodies. These have been analyzed for their magnesia, with the following results:

The Magnesium Carbonate Content of Samples from Limestone Cores.

Depth.[1]	*Magnesium Carbonate.*	*Remarks.*
25	20.48	(Five feet from top of the limestone.)
50	32.19	
100	43.32	
150	44.14	
200	30.51	Bluish-white color.
250	43.90	White.
300	3.75	
350	37.11	
400	11.28	
450	36.83	Grey-white color.
500	46.36	White, frequent fine mica flakes.
550	43.82	
578	20.76	Bluish-white, immediately under pegmatite dike.
588	42.59	Slightly bluish tinge, large crystals.
600	43.75	Yellowish tinge, granular crystals.
650	14.25	Dazzling white limestone.
690	2.56	
700	1.50	White, close to a 5-foot pegmatite dike.
750	6.21	White marble, just below a dike.
790	4.21	White, granular, small crystals.
800	4.14	White, no dike near in the core.
825	3.87	White, large crystals, near a dike.
873	1.62	

[1] As the depths were recorded on only a few of the samples at the time the cores were taken, these figures are in many cases only approximate.

Depth.	*Magnesium Carbonate.*	*Remarks.*
876	2.11	Dazzling white, immediately above the ore.
1,000	1.23	White, below the zinc ore.
1,050	5.53	White, large crystals.
1,110	4.89	White, between two pegmatite dikes.
1,150	5.31	Dazzling white, very large crystals, mica (1%).
1,200	7.16	Large white crystals, flakes graphite.
1,205	1.26	Pink crystalline limestone, just above hornblende gneiss.
1,245	2.12	Pink crystalline limestone, a thin layer interbedded with gneiss and pegmatite.

Summary of analyses.—Of the above analyses, twenty-eight (Nos. 1 to 29, except 16), represent average samples either from quarries actually in operation, or from undeveloped ledges. In no case do they represent individual layers, but in all instances the average composition of such a zone of rock as would be utilized in opening a quarry. To a certain extent the localities were chosen at random. Geographically they are distributed over the entire outcrop, from the State line to the Delaware River, below Belvidere. It is fair to assume, therefore, that they are representative of the great bulk of the formation, which is apparently low in magnesia and high in lime. It is evident, however, from Nason's analyses, as well as from a few of these, that some beds of highly magnesian limestone occur.

The analyses from the Bethlehem Steel Company (No. 16) represent the shipments of from 55,000 to 80,000 tons of rock made from two large quarries for a series of nine months. The working face in one of the quarries is roughly parallel to the strike of the foliation of the limestone (which perhaps represents the original bedding planes), and in the other is approximately at right angles to it, and the quarries are several hundred yards apart. The analyses, therefore, are representative of a much larger body of rock than that actually quarried.

The analyses furnished by the Alpha Portland Cement Company show that in some cases samples taken only from the surface may give erroneous impressions regarding the bulk of the rock beneath, since in their first drill hole, the samples from near the surface were high in magnesia, whereas there, as elsewhere, the majority of the samples analyzed are low in magnesia.

The analyses of samples from the cores near the Parker shaft, together with the data accumulated by Nason, and discussed at length by him[1] demonstrate beyond a doubt that some of the limestone on the surface, as well as to a considerable depth, in the vicinity of the zinc ore deposits at Franklin Furnace is dolomitic. These dolomitic beds apparently extend (perhaps not uninterruptedly) northward to the Hardystonville Pond (Nos. 22 and 23, p. 184). But at depths exceeding 650 feet near the Parker shaft the rock is in general low in magnesia, both immediately above and below the ore-body, as well as at some distances from it.

The influence of granitic dikes upon the composition of the limestone does not appear to be so great as was supposed by Nason. The analyses on p. 188 show that with one exception all the cores tested from the surface to a depth of about 650 feet were high in magnesia. The exceptional sample from 300 feet contained only 3.75 per cent. of magnesian carbonate, but so far as shown by the core there is no dike at this horizon as demanded by the hypothesis. On the other hand, a slight measure of support is given it by the fact that the specimen at 578 feet, immediately under a pegmatite dike, contained only 29.76 per cent. of magnesian carbonate, as against 43.82 per cent. and 42.59 per cent. at 550 and 588 feet respectively. From 700 feet downward the samples were all low in magnesia, irrespective of whether they occurred near granitic intrusives or not. It is recognized, of course, that the drill reveals nothing except the rock actually cut by it. Intrusive masses a few inches to one side of the hole would not be cut by it, and would not show in the core, whereas, they might effect the composition of the adjoining beds. The hypothesis might, therefore, still be true, in spite of its lack of accord with the facts as known from these drill holes.

In order to test the hypothesis still further, other analyses (Nos. 30 and 31, p. 184) were made of specimens taken at measured distances from granitic dikes. So far as any inferences can be drawn from analyses 30a and 30b it is that the dike has no effect upon the composition of the limestone. Those from the

[1] Loc. cit.

Furnace Quarry (31a to 31e and VIII) show an increase in the magnesian carbonate from 2.76 per cent immediately adjacent to the dike to 44.24 per cent 100 feet distant. While it is true that these last analyses lend some support to Nason's hypothesis, on the other hand the relationship may be purely fortuitous. In a deposit of limestone ranging from a nearly pure calcium carbonate to a dolomite and penetrated by numerous granitic or pegmatite dikes we should expect to find the intrusives in any and all positions in respect to the dolomitic and non-dolomitic beds, and this seems to be the actual fact in the case.

In the case of many of the samples (Nos. 1 to 29) granitic dikes are entirely absent from the locality or occur so far distant from the point at which the sample was taken, that it is impossible to believe that the composition of the rock has been effected by them.

As a result of these studies, therefore, it is concluded that taking the formation as a whole the granitic intrusives have had no great influence in diminishing the amount of magnesian carbonate in the limestones. But while I am forced to dissent from Nason's generalization in this respect, it is not denied that there may be a slight local effect, whereby through the development of complex magnesian minerals by contact metamorphism, the amount of magnesian carbonate has been diminished. But it is believed that this action is strictly local in extent and slight in amount and can in no way account for the low magnesia in the great bulk of the formation.

All the samples analyzed have been studied with a view of determining what relation, if any, might be traced between the color, size of the crystals, or abundance of graphite, mica and other accessory minerals and the dolomitization. But no very definite results have been obtained. Perhaps the pure white rock is more prevailingly low in magnesia and correspondingly high in lime than that of a bluish-gray tinge, but the exceptions are too numerous to make the color a very accurate guide. Nor does the size of the crystals seem to bear any definite relation to the amount of magnesia. At least striking exceptions can be cited to any statement of relationship.

Feb. 15, 1906.

PART IV.

Lake Passaic Considered as a Storage Reservoir.

By C. C. VERMEULE.

Lake Passaic Considered as a Storage Reservoir for Potable Water, Flood Control and Utilization of the Passaic River.

BY C. C. VERMEULE.

The following report has been prepared and is published for the purpose of setting forth the problems involved in one method of utilizing the surplus waters of the Passaic River and in controlling the floods thereon. The facts are given briefly and concisely, without extended argument and without prejudice either for or against the proposition, in the belief that such a method of presentation is best. Some misapprehension may arise, however, regarding the validity of the conclusions, unless a word of explanation is made. For nearly twenty years the Passaic River has been a subject of investigation by Mr. Vermeule for the Geological Survey, during the course of which a vast amount of data has been compiled and sifted. In the following pages the results of these computations are given, not the various steps by which the results have been reached.

In general all estimates regarding the flow of the river in drought and in flood are based upon data which have been fully discussed in earlier reports[1] of this department. Facts regarding the size of the reservoir, shallow-water flowage, variations in level, etc., are based on recent detailed surveys extending over the entire area affected, and may be accepted as thoroughly accurate. Estimates regarding future demands for potable water are based upon a per capita consumption considerably below that now prevailing in the larger cities of the district, and a rate of growth which cannot be regarded as excessive, when past growth

[1] Notably, in Report on Water Supply, Vol. III Final Reports. Annual Reports for 1896, 1902, 1903.

and improved methods of transportation are considered. The estimates of the cost and of the probable revenue have been made with care and in considerable detail. It may be that some will question their accuracy. Probably no two engineers would agree exactly in an estimate of this kind. Its value depends upon the experience, professional standing and knowledge of the man who makes it. The author alone is responsible for the accuracy of the calculations made in the report and the conclusions derived from them.

The fact that this investigation was authorized by the State Geologist, and is published as a part of his Annual Report does not of necessity commit the Board of Managers of the Survey, either as a body or individually, to the advocacy of the proposed plan. In fact as is stated by Mr. Vermeule, it is not the purpose of the report to urge the adoption of this plan, but "to lay the facts before the people of the State in order that they may judge for themselves of the wisdom and utility of such an improvement." It is recognized that there are serious difficulties to be overcome in carrying it into effect, some of which might be avoided by the adoption of some other plan. It is believed, however, that alternative plans which might be suggested would involve other difficulties fully as serious. After a careful consideration of all the problems involved and benefits to be gained, the plan here discussed seemed most worthy of careful investigation, and this report is accordingly submitted. H. B. K.

In the Annual Report for 1903 attention was called to the possibility of controlling floods on the Passaic River by means of either a controlling dam holding back the flood waters temporarily upon the flats above Little Falls, or by means of a permanent lake having its surface elevation at about 180 feet above mean sea level. The proposition for control by means of a permanent lake has met with general favor throughout the valley above Little Falls, and during the past year further surveys have been made in order to determine the most practicable flow line, the amount of shallow flowage and the general practicability of such a storage lake. The Geological Survey has, from time to time, presented statistics as to the various problems connected with the Passaic River and its tributaries, such as the possible reservoir sites upon the watershed, the run-off of the stream during dry, wet and average years, the discharge during floods, etc. All of these data are of value in connection with the studies which have been made as to the possibilities of the lake in question.

IMPORTANCE OF THE PROBLEMS INVOLVED.

The Passaic River presents a variety of economic problems, all of which are of great importance to the people of the State.

Potable water.—This watershed is the best and most available source for a public water supply for the large and rapidly growing urban population east of the Orange Mountains, and it is evident that the time is not far distant when its entire available yield will be needed for this purpose alone.

At the present time 64 square miles of the Pequannock watershed, which is tributary to the Passaic, has been pre-empted for the supply of the City of Newark, and it now seems probable that within fifteen years the entire available yield of that tributary watershed will be required for Newark's use. On another tributary, the Rockaway, Jersey City has pre-empted 120 square miles of watershed and controls an available supply of about 80,000,000 gallons daily, all of which is not likely to be needed for twenty-five or thirty years to come.

The area of the total watershed above Little Falls is 773 square miles, consequently the above pre-emption by Newark and Jersey City leaves 590 square miles, which is utilized only by the works of the East Jersey Water Company at Little Falls.

The Newark and Jersey City Works have large storage capacity, so that while the entire dry-season flow is held back and diverted at the intakes, it is largely added to by waters stored during the wet season. The East Jersey Works at Little Falls, however, have practically no storage, and draw a supply directly from the stream. The 590 square miles have a dry-season yield of about 70,000,000 gallons daily, of which about 30,000,000 gallons daily is taken by the East Jersey Water Company to supply the cities and towns of Paterson, Passaic, Nutley, Montclair, West Orange, Glen Ridge, Bloomfield, Kearney, Harrison, East Newark and Bayonne. While 30,000,000 gallons daily is the average draught, the water is pumped to a storage reservoir and the draught at times probably much exceeds this amount. At all events, it has been claimed that very little water is left in the stream at times.

With proper storage, however, the Passaic at Little Falls is capable of yielding a total supply of 515,000,000 gallons each 24 hours during the driest season. This, however, will require the storage of water to the amount of 100,500,000,000 gallons in all, part of which has already been provided for in the storage reservoirs constructed for Jersey City and Newark and in Greenwood Lake, and other smaller reservoirs upon the watershed. Exclusive of the portions of the watershed utilized to supply Jersey City and Newark a full development of the unused portion of the watershed will require storage to the amount of 77,000,000,000 gallons. There is no other way in which this large amount of storage can be obtained than by the construction of such a reservoir as has been proposed, flooding the central valley above Little Falls. Even if this shall be built, it will be desirable to limit the draught upon it, so that its surface will never be lowered more than 4 feet, under which conditions its available storage capacity will be 40,000,000,000 gallons.

Water power.—Another economic problem closely allied to the public water-supply question is presented by the gradual destruction of the valuable water powers upon the Passaic at Little Falls, Paterson and Dundee, due to the necessary diversion of the waters of the stream for municipal water supply. These water powers under normal conditions amounted in the aggregate to 4,460 gross horsepower, renting at from $30 to $36 per horsepower per annum, making a total rental value of $150,000. Their importance, however, is not fully measured by this rental value, as these water powers have formed an important element in the industrial development of Paterson and Passaic. If the flow of the river is conserved by storage of the surplus waters, these power developments will not only be preserved but may be increased in volume.

While it is true that the entire capacity of the stream, amounting, as above shown, to 515,000,000 gallons, daily, will be needed to supply the cities between the Orange Mountains and the Hudson River by about 1950, assuming the present rate of growth to continue; nevertheless for 15 years to come the proposed storage works could be depended upon not only to afford an ample supply for the cities, but in addition to furnish sufficient water to develop 6,000 horsepower for 24 hours or 12,000 horsepower for 12 hours at Little Falls, Paterson and Dundee. This power, at $35 per horsepower, would be easily worth an annual rental of $420,000, and a part of this income would continue beyond 15 years, although it would be gradually extinguished by the increasing demand for potable water, unless that demand could be met by the development of more distant streams.

River pollution.—Still another economic problem connected with the Passaic River which is now pressing for a solution is the defilement of the lower portion of the stream due to the discharge of sewage and other wastes from the dense population along its banks below Little Falls. A partial remedy for this will be found in the construction of the proposed trunk sewer to divert the sewage from the stream channel, but this will not be a complete remedy unless a comprehensive system of storage is adopted. The diversion of the stream for municipal water supply under the methods which now prevail will each year during the dry season, and for a steadily increasing length of time, leave the lower channel of the river a series of stagnant and offensive pools. Instead of being, as it should be, an attraction, or practically a continuous park through the populous section below Little Falls, it must continue to be what it now is, an offense and a possible source of disease.

The development of a proper system of storage, however, as is proposed, and the use of a portion of the stored water for power will greatly improve conditions in this respect, as there will always be at least 100,000,000 gallons daily flowing down the channel from Little Falls to the sea. This is more than the normal dry-season flow of the river before diversion was begun, and, consequently, it will place the lower part of the river in a better condition than it has ever been before.

Control of floods.—The fourth great economic problem connected with the Passaic River is the control of floods. I have placed this last in the present discussion, although it was the one for which the proposed reservoir was originally designed to be a remedy. This particular phase of the Passaic River development, however, has, in my opinion, received more attention than it rightfully deserves. It is not more important than either of the three previously mentioned, and is much less important than the public water-supply question. It is, however, a problem which demands a solution, since the increase of population and development of industries along the banks of the stream below Little Falls, particularly at Paterson and Passaic, have created much more valuable property subject to destruction than existed in earlier years.

The Reports of the Survey have called especial attention to three disastrous floods in recent years, viz.: That of February, 1896; that of March, 1902, and that of October, 1903. In the short period of eight years these three floods inflicted damage along the stream, which may be conservatively estimated as greater than the entire cost of the proposed reservoir. The damage was shared by the counties, the cities and the individual property owner. This loss was irretrievable, whereas, as we shall show later, an expenditure for storage works would be a profitable investment.

Those who have made a rather superficial examination of this subject have claimed that it is impossible to make a storage reservoir serve the double purpose of flood control and of economic utilization of stored waters for either water supply or water power. This point of view may be correct if applied to reservoirs of considerable depth and relatively small superficial area which are intended to be kept full most of the time, but it does not apply to a lake of large superficial area to be maintained at a level below high-water mark, such as is here proposed.

Sites for reservoirs.—There are not many points upon the watershed at which storage lakes of sufficient size to be effective for flood control can be constructed, but we have considered two such sites in the past. One of these is on Pompton Plains, to be created by a dam across the Pompton River at Mountain View. The other is at Little Falls.

The writer first called attention to the possibilities of the Pompton Plains site in "Engineering News," in 1884, when the question of an increased supply for the City of New York was being actively considered, and before the great dam on the Croton was undertaken. It is also mentioned in "Report on Water Supply," Final Reports of the State Geologist of N. J., Vol. III, page 159.

The proposed dam would be 2,200 feet long and 57 feet high, and it would form a reservoir 18 square miles in area, a considerable part of which would be over 40 feet in depth. This reservoir was proposed for municipal water supply, but for flood control later investigations have made it evident that it is less well adapted than the reservoir at Little Falls. No borings have ever been made as yet to determine the depth of foundations at the site of the proposed Mountain View dam. If the depth to rock should be very great, the cost of this long dam would be prohibitive. Such borings as have been made in the vicinity indicate that while rock appears at the surface all the way across the valley at Little Falls, the depth to rock steadily increases as we proceed westward, and reaches about 95 feet just west of Deepavaal. This is also true on a direct line between Little Falls and Mountain View; consequently, the inference is strong that the rock is at a considerable depth at Mountain View, and that, therefore, that site presents no especial attractions for the construction of a great dam, which must be of a most substantial character and not open to even a suspicion of weakness if it is to be constructed at all.

Furthermore, a dam at Mountain View would control only one-half of the watershed above Little Falls, and would not be nearly as valuable for the economic utilization of the flow of the river as the dam near Little Falls. Still another disadvantage rests in the fact that in the valley above Little Falls lie large areas of wet lands, including the Big Piece and Little Piece meadows and the Troy and Black meadows, with an aggregate area of nearly 14,000 acres. These wet lands are not only unsightly, but they are breeding places for mosquitoes, and, consequently, for malaria, and are so great a disfigurement of the otherwise beautiful Passaic Valley that their elimination is greatly to be desired, and a remedy for their condition by means of drainage has been sought and attempted from time to time for a century past.

The construction of the lake which is herein proposed will flood these lands to such a depth that they will be entirely eliminated, and will create in their place broad expanses of deep water which will greatly add to the landscape effects of the valley and to its attractiveness as a place of suburban residence. The proposed Pompton Plains reservoir on the other hand will for the most part lie within a region which is already attractive and which is being rapidly built upon at Pompton and Pompton Lakes, and will leave the larger part of the valley to be still provided for by expensive drainage works. Finally, the location chosen for the dam at Little Falls offers the very best of foundations upon trap rock and makes the building of an absolutely secure dam certain and inexpensive.

These considerations have led us to give serious consideration to the reservoir with a dam at Little Falls as being in many points superior to the one on Pompton Plains for purposes of flood control, and far more effective for the economic utilization of the river.

DESCRIPTION OF THE PROPOSED RESERVOIR.

A plan of the proposed reservoir accompanies this report (Plate XXVIII in pocket). This is based upon careful surveys made to determine the most practicable and advantageous flow line, the depth of water, amount of shallow flowage and the best means of caring for the several highway crossings and the two railroads which cross the basin at Little Falls and Mountain View.

The proposed dam at Little Falls has a total length of 6,000 feet, but as shown by the profile at the lower right-hand corner of the map it follows a ridge of trap rock and is quite low, excepting for a distance of about 1,500 feet across the river. Its maximum height above the bed of the river will be 39 feet. It will back the water up-stream as far as the village of Chatham, and up the Pompton River to the village of Pompton, the total length of the lake being very nearly 20 miles and its greatest width a little less than 4 miles. The superficial area of the lake will be 32,922 acres, or 51½ square miles. Of this area 13,891 acres is at present wet swamp land and 19,031 acres is upland. The total capacity of the proposed lake is 327,000,000,000 gallons, but it is not proposed to utilize all of this for storage.

The following is a statement of the different levels of the lake which will be necessary in order to provide for the regulation of floods and for the economic utilization of the river for water supply and water power with the area of the lake surface at the several levels:

Elevation above Sea Level.	*Area in Acres.*
Extreme flood height, 190 feet,	32,922
Ordinary high water, 188 feet,	31,320
Normal lake level, 186.5 feet,	30,200
Ordinary low water, 184 feet,	28,700
Extreme low water, 182.5 feet,	27,850
Depth at normal level of lake:	
Area less than 7 feet deep,	4,740
Area 7 to 17 feet deep,	12,900
Area 17 to 28 feet deep,	12,900

Capacities.	*Cubic Feet.*
Total capacity of lake,	43,824,000,000
Capacity between normal level and extra flood height,	5,052,000,000
Capacity normal level to extreme low water,	5,558,000,000

The average distance from the normal shore line to a depth of 7 feet will be 396 feet, and to a depth of 10 feet it will be 590 feet. The length of the shore line is 98 miles.

The above figures give a good indication of the depth of the lake and the amount of shallow flowage. It compares favorably with other artificial reservoirs inasmuch as only 16 per cent. of the area will be less than 7 feet deep, while 42 per cent. is from 7 to 17 feet, and the remaining 42 per cent. from 17 to 28 feet deep.

The broad expanses of water surface will permit a free play of winds and waves, causing a thorough agitation of the more shallow waters, which will unquestionably destroy vegetable growths which might occur in smaller bodies of water. After the construction of the lake, a dredge might be kept in operation at the more shallow parts of the lake gradually deepening and improving these portions, if such a course should be considered desirable.

The dam at Little Falls will be provided with sluices which can be opened and closed by water power. These will be constructed in duplicate and in such a way that they will be readily accessible for repairs. A quantity equal to 306,000,000 gallons daily will be allowed to discharge through the sluices at all times to furnish water supply to the cities and to provide for water power and the flushing of the stream below Little Falls. They will be so operated that the lake is maintained as nearly as possible at its normal elevation, and when it rises above that level the sluices will be opened, but never allowed to discharge a larger quantity than 12,000 cubic feet per second into the lower stream. Computations which we furnish later show that it will be possible by this means to maintain the lake within the limits shown in the foregoing table without difficulty.

STRUCTURAL FEATURES.

The dam.—The proposed dam at Little Falls will have a total length of about 6,000 feet, and be founded throughout upon a ledge of trap rock. Only 1,500 feet of its length exceeds 10 feet in height. It can be constructed with the greatest facility, as nature has already provided almost a natural dam in that location. The section will be unusually heavy, so that a large margin of stability will be provided, thereby eliminating any question as to its safety. It will be built entirely of heavy rubble masonry and concrete, the volume of which will be 68,850 cubic yards.

Changes in railroads.—It will be necessary to change the location of the New York and Greenwood Lake Railroad between Little Falls and Pequanac. The proposed new location is shown on the map. It involves the reconstruction of 9 miles of the line at a considerable expense. There is a possibility that the necessity for this might be eliminated by an arrangement to discontinue this railroad between Little Falls and Pompton Plains, the upper portion from Pompton Plains to Greenwood Lake to be operated as a branch of the New York, Susquehanna and Western Railroad, which it intersects at Pompton Junction, both of these roads being controlled by the Erie Railroad.

The main line of the Delaware, Lackawanna and Western Railroad would also have to be relocated between Little Falls and Towaco (Glenview), a distance of 6 miles. The proposed change of location is shown on the map. Where the line crosses the lake it would be raised upon a solid embankment, the slopes of which would be protected by rip-rap. This change of location would remedy the flooding and washouts to which this line is now subject at the crossing of the Pompton River, and this advantage, together with the increased travel which the lake would attract to the railroad, would be sufficient to offset any slight disadvantages involved in the proposed change of location.

The Whippany River Railroad crosses the lake basin east of Whippany, and its location would have to be modified somewhat across the Troy Meadows, and the grade raised above the level of the lake. The grade would also have to be raised somewhat at the crossing of the Passaic River.

The Morris Canal.—The Morris Canal crosses the lake basin from Little Falls through Mountain View, and would be submerged from the dam at Little Falls to a point near the foot of the plane west of Lincoln Park. It is probable that this canal will be abandoned in the near future, and, consequently, no provision for the continuance of traffic will be necessary; however, should it be necessary to continue, all that would be needed would be an inclined plane at the dam near Little Falls raising the boats into the lake, and they would then have to be towed by steam tugs through the lake to the vicinity of Lincoln Park, where they would re-enter the canal. The continuance of the canal from the lake to the Passaic River at Newark would afford communication for boats from tide water into the lake and might be very desirable.

Changes of highways.—Several highways would be flooded and eliminated by the construction of the lake. It would be desirable to provide crossings for a few of the more important highways, and provision has been made for the following: The road from Boonton to Paterson would be provided for by building a new road along the north slope of Hook Mountain and across a narrow part of the lake at Mountain View, thence along the north shore of the lake and across an arm of the same at Lower Preakness.

A new highway would also be opened along the east shore of the lake from Little Falls to Upper Preakness, and another new highway would diverge from the Boonton and Paterson road near Mountain View along the easterly shore of the lake to Pequanac. These changes would preserve a highway from Little Falls via Lower Preakness and Pequanac to Pompton to take the place of the present Pompton Turnpike.

The highway leading from Caldwell through Pine Brook to Parsippany and Dover crosses the lake basin and will be flooded for a distance of about 3½ miles. The portion across the Passaic River from Pine Brook eastward will be raised on a substantial embankment above the lake surface. West of Pine Brook a road may be substituted leading from Pine Brook to Lower Montville, which will accommodate travel from Boonton to Newark, and a branch of this road across the Rockaway River at a point about 2 miles north of Pine Brook will accommodate travel to Parsippany and beyond.

The Mount Pleasant Turnpike crosses the lake basin at Hanover and Whippany, and will be provided for on raised embankments.

The road crossing the river at Columbia Bridge will also be raised and preserved, as well as the road crossing Lower Chatham and the Morris Turnpike at Chatham. All of these changes are provided for in the estimates. All highway and railroad bridges should be at such an elevation above the lake surface as to give a clear passage-way at least 12 feet in height to permit the passage of steam yachts and other pleasure craft.

Pipe lines.—In addition to the above railway and highway changes, provision will have to be made for the pipe line of the Jersey City Waterworks, which crosses the basin of the lake near Horse Neck Bridge. A new aqueduct could be constructed by way of Pine Brook and across the raised embankment, thence back to the line of the aqueduct near Little Falls. Before flooding, the present steel pipe could be examined and put in order, and it would probably continue serviceable a long time under the bed of the lake, although it would be inaccessible for repairs, but the new aqueduct would be available at any time, and there would be practically two lines across the lake.

The Newark pipe line would also be flooded for a short distance of about 4,000 feet, where it crosses the Pompton River. Provision could be made for carrying this or a duplicate line upon the same embankment which would carry the new line of the Greenwood Lake Railroad.

Low lands on Pompton Plains.—In the neighborhood of Pequanac there is a considerable area of land on Pompton Plains where the flowage would be shallow unless some provision is made to better conditions. This may be provided for by constructing a dike following the line of the Greenwood Lake Railroad southward from Pompton Plains to Pequanac, thence westwardly along the contour of 180 to the easterly edge of the Bog and Vly Meadows, thence northwestwardly to the uplands. This dike would cut off an area of 966 acres, which would lie below the level of extreme floods in the lake, and a portion would be below the lake surface at all stages. The drainage of this 1,000 acres including some seepage would be provided for by pumping the water over the dikes into the lake. For this purpose electric power could be transmitted from the dam at Little Falls.

Waterworks.—In addition to the above some changes would be necessary at the East Orange Waterworks at White Oak Ridge for the protection of the works. These changes could be made without serious difficulty and without detriment to the supply. Similar protection would be needed at the pumping station of the water company which supplies Summit, Millburn and South Orange. The waterworks of Chatham and Madison would be near the lake borders, but would not be injured by the flooding.

The foregoing matters are all provided for in the estimate of cost which is submitted later. The work is unquestionably one of magnitude, but it involves no unusual or difficult engineering features.

RELATION OF PROPOSED RESERVOIR TO ECONOMIC PROBLEMS.

It remains to consider how the several economic problems, to which attention was called at the beginning of this report, will be solved or affected by the construction of the proposed lake.

These problems may be again enumerated as follows: 1) public water supply, 2) the preservation of water power, 3) the flushing of the stream channel below Little Falls, 4) the control of floods, and 5) the disposal of the large areas of badly-drained lands above Little Falls.

Effect upon public water supply.—The large and constantly increasing demand for potable water in the New Jersey portion of the great metropolitan district, including and surrounding New York City, was set forth in the "Report on Water Supply" in 1894. The pressure of this demand is continually being felt to an increasing extent. The City of New York is finding it quite difficult to procure a supply of water sufficient for its demands. The demands of the New Jersey portion of the metropolitan district, including the counties of Hudson, Essex, Union and the southern portions of Passaic and Bergen counties, based upon the past rate of increase of the population and a per capita consumption of 100 gallons each 24 hours may be estimated as follows:

Year.	*Gallons Daily.*
1910,	142,000,000
1920,	199,000,000
1930,	279,000,000
1940,	391,000,000
1950,	547,000,000

Included in this district are the cities of Newark and Jersey City.

We have previously pointed out that Newark is in possession of a watershed and works on the Pequanac, a branch of the Passaic, which has sufficient capacity to supply 50,000,000 gallons daily. It seems probable that Newark will require this entire amount of water by 1920. Jersey City has also acquired the Rockaway River, another branch of the Passaic, which has a capacity to supply 80,000,000 gallons daily. There is not at present sufficient storage to supply this quantity, but for present purposes we assume that the works will be developed to this extent, and estimate that Jersey City will require the entire amount in 1931. There are other sources of water supply within the district, such as the Hackensack River, one or two smaller streams and driven wells, which will be capable of furnishing eventually a total which we estimate at 40,000,000 gallons daily.

In making the above estimate we take account of the fact that some of the sources now in use must be abandoned, while others will be further developed. Beyond the water thus provided, amounting in the aggregate to 170,000,000 gallons daily, the Passaic at Little Falls and some further development of the Passaic headwaters must be depended upon to furnish the remainder. In order to estimate intelligently just how much water will be required from Little Falls for public water supply we have prepared the following table:

Water Supply of Metropolitan District.

All Quantities in Million Gallons Daily.

	1910.	*1920.*	*1930.*	*1940.*	*1950.*
Developed Sources other than Passaic, ...	17	22	30	40	40
Newark Works, ...	36	50	50	50	50
Jersey City Works, ...	39	55	77	80	80
Passaic at Little Falls, ...	50	72	122	206	206
Other Passaic Head waters, ...	..	....	....	15	79
Other Sources not yet developed, ...	..	....	....	....	92
Total requirements of Metropolitan District,	142	199	279	391	547

The Passaic at Little Falls is now called upon to supply approximately 30,000,000 gallons each 24 hours. The above table shows that this quantity will increase until in 1940 it will be called upon to supply 206,000,000 gallons each 24 hours, and this will still leave 15,000,000 gallons necessary to be developed from the headwaters. By 1950 the development of the headwaters will be increased to 79,000,000 gallons daily, which we estimate to be their ultimate capacity, and 92,000,000 gallons daily must then be provided for from still other sources not yet developed. In making this computation, we have fixed the total capacity of the works at Little Falls at 306,000,000 gallons each 24 hours; this is in addition to the 130,000,000 gallons taken from the headwaters by Newark and Jersey City, and it will still be possible to take from the headwaters 79,000,000 gallons additional. Of the 306,000,000 gallons available at Little Falls only 206,000,000 gallons are apportioned to public water supply, and the balance of 100,000,000 gallons each 24 hours is allowed to run off through the stream channel, being used to furnish power at Little Falls, Paterson and Passaic, and to flush the lower stream channel so that it may be maintained in a wholesome condition.

The general scheme of public water-supply development, therefore, which we have in mind, is to supply ultimately from the Passaic at Little Falls 206,000,000 gallons each 24 hours. This water will have a head of 184 feet above mean sea level, which will be sufficient to supply the larger part of the metropolitan district by gravity. The 80,000,000 gallons taken for Jersey City may be delivered at a higher level, or about 190 feet or 200 feet above mean sea level. The Newark supply may be delivered at a still higher level, and the later development on the Passaic headwaters may also be delivered at a higher level, so that all portions of the district may be furnished with water. Furthermore, there will be available at Little Falls, water power sufficient to pump a portion of the supply for use at high service, if required.

From the above computation it appears that we may reasonably expect that the storage lake at Little Falls would be called upon to supply the cities with from 50,000,000 to 206,000,000 gallons each 24 hours. This would leave the following amounts available for water power and for flushing the channel below Little Falls.

Balance Available for Water Power.

Year.	*1910.*	*1920.*	*1930.*	*1940.*	*1950.*
Quantity in million gallons daily,	256	234	184	100	100
Equivalent in gross horsepower for 24 hours daily,	6720	6142	4830	2625	2625

The above calculation shows that the surplus water not needed for public water supply would be sufficient to furnish 6,000 horsepower until about 1921, and 4,800 horsepower until about 1930, after which the amount would decrease to a minimum of 2,625 horsepower available 24 hours daily, this being the result of the uniform discharge of 100,000,000 gallons each 24 hours into the stream channel at Little Falls.

The least flow of the river for a two-weeks period is normally about 85,000,000 gallons daily, but this has been reduced to 65,000,000 gallons daily by the diversion of the Pequanac to Newark, and the Rockaway to Jersey City. It has been further reduced by the diversion of 30,000,000 gallons at Little Falls, so that the present dry-season flow is not more than 35,000,000 gallons daily. Consequently, the above allowance of 100,000,000 daily for the lower-stream channel will leave the water powers in a better position by far than they are at present, and will also greatly improve the sanitary condition of the stream below Little Falls.

The proposed improvement, therefore, provides for the water supply of the metropolitan district east of the Orange Mountains until 1950, and still leaves sufficient water flowing into the stream at all times to greatly improve present water power and sanitary conditions.

Water power.—Before the diversion of the Passaic waters began the natural discharge of the river passing Little Falls during the driest month averaged 98,000,000 gallons each 24 hours, and during nine months of the year it did not fall below 195,000,000 gallons daily. Since then it has been diminished 22 per cent. by the diversion of the Pequanac River to Newark, and the Rockaway River to Jersey City, so that there remains available during nine months of the year 122,000,000 gallons, and during the driest month 46,000,000 gallons daily. Occasionally it falls as low as 35,000,000 gallons. For water-power purposes, therefore, we can depend substantially upon 46,000,000 gallons during the driest months, and 76,000,000 gallons daily additional may be obtained during nine months of the year. This last, not being constantly available, is worth no more than half the amount, or 38,000,000 gallons available at all times; consequently, a full equivalent of the power now available would be represented by a uniform flow of 46,000,000 plus 38,000,000 equals 84,000,000 gallons daily.

We propose to allow 100,000,000 gallons daily to flow past Little Falls perpetually. This amount is sufficient to fully compensate the owners of water power and water supply, leaving them in quite as good a position as they are at present, in all respects.

There is at present an open question as to the legality of the diversion of 30,000,000 gallons daily from the stream at Little Falls by the East Jersey Water Company for public water supply. However this may be determined, the fact remains that such diversion has worked an injury to riparian owners upon the stream below, for which those owners should undoubtedly be compensated. This, we understand, is practically admitted by the water company.

If 100,000,000 gallons daily should be allowed to flow at all times from the proposed lake over and above the amount diverted for public water supply, this question of injury would be disposed of, because the amount flowing in the channel would be much larger than it has been in the past. We are aware that compensation in kind is not permissible under the law, but we are at present discussing the equities of the situation and the proper basis for an agreement by all parties in case the proposed storage works should be carried out.

The owners of the water powers at Little Falls, Paterson and Dundee are practically identical with the owners of the East Jersey Water Company, consequently, if we allow 100,000,000 gallons daily to flow down the channel, these owners will be benefited as to their water power, and we will also do away with the injury to property owners along the stream due to the drying up of the stream; consequently, it would seem equitable that the East Jersey Water Company should pay for the benefit of the improvement a proper amount for the right to draw water from the proposed lake at Little Falls. Any other city, town or water company should also be offered the same right at a uniform price, which, in our opinion, could properly be fixed at $20 per million gallons, the proceeds to be devoted to sustaining the improvement.

As to the water power, all power created at the new dam where the fall will be 25 feet, and all power created at Little Falls, Paterson and Dundee in excess of that due to a uniform flow of 100,000,000 gallons daily should be paid for, the proceeds to be applied to sustaining the improvement.

Quality of water.—As to the quality of the water from the proposed lake, it may be assumed that practically all of the water hereafter to be taken from the Passaic River, excepting possibly the present supply of the City of Newark, will require filtration. This being true, it may be easily shown that the water from the proposed lake, if taken from the dam at Little Falls, will be far superior in quality to the raw water taken from the stream at the same point, or at almost any other point where any considerable quantity can be obtained. This is largely due to the thorough sedimentation which will occur in the proposed lake. The volume of the lake will be fully 10 per cent. greater than the average yearly discharge of the entire river, consequently the water will ordinarily lie in storage more than thirteen months before discharging at the dam. Even the volume of the greatest known flood, that of 1903, is less than one-third the total volume of the lake, consequently, there will take place the extensive sedimentation and purification of the waters, which is now well understood to be the action of large storage reservoirs, and the water from the lake will be in better condition for filtration, if filtration is required, than the raw water from the stream.

Sanitary condition of the lower river.—It will be seen from the foregoing statements that the river is already reduced by diversion to 35,000,000 gallons daily during the driest season, and the amount being diverted is steadily increasing. The time is approaching when the river will be entirely dry at times and when it will be reduced to a series of unwholesome pools, which will be a condition intolerable to the large population living in the immediate vicinity. This will be true even if the proposed trunk sewer to divert the sewage of Paterson and Passaic to tide water shall be constructed.

The proposed storage lake will be an effective remedy for this condition, owing to the fact that we propose to allow at all times

100,000,000 gallons daily to flow down the channel, and during the next 25 years the amount will be actually almost twice this. This improvement, together with the construction of the proposed trunk sewer, will restore the river to its original attractiveness, a matter of the utmost importance to the future of the district along its banks.

Effect upon floods.—The previous Reports of the Geological Survey have dealt fully with the question of floods upon the Passaic, and especially we may refer to the Report on Water Supply of 1894 and the Annual Reports of 1896, 1902 and 1903. The following table shows the duration and volume of the six larger floods which have occurred on the Passaic at Dundee since 1876:

Floods on the Passaic at Dundee since 1876. Area of Watershed 822.7 Square Miles.

Date of Maximum Discharge.	Greatest Discharge, Cubic Feet per Second.	Time from Beginning of Rise to Maximum, to End. *Hours.*	*Days.*	Total Discharge. *Million Cubic Feet*	*Inches on Watershed.*
October 10, 1903, ...	31,410	50	11	13,619	7.12
March 2, 1902, ...	22,677	91	8	10,219	5.35
September 25, 1882, ...	18,265	66	8	7,101	3.71
February 8, 1896, ...	17,217	44	8	6,083	3.18
December, 12, 1878, ...	16,592	60	8	6,878	3.47
February 14, 1886, ...	12,452	60	8	5,729	3.00

Earlier records show that in 1865 there was a flood nearly as high as that of 1902, and in 1810 there was another, of which the estimated maximum discharge was 25,500 cubic feet per second. The flood of October, 1903, is much the highest of which we have any record. This is true both as to its greatest rate of discharge and the volume of water discharged. The flood was also of longer duration than any other. If the proposed storage lake is competent to deal with such an extreme flood as that of 1903, it may, therefore, be assumed to be ample for any flood which is likely to occur at any time. The following figures will show that such a flood would be under perfect control.

The method of operation during such a flood would be that the superintendent at the dam at Little Falls, being advised as to conditions on the headwaters of the stream, would throw open the sluices at the beginning of the flood, allowing 12,000 cubic feet per second to be discharged on the stream.

In the Report of 1903[1] it is shown that during the flood of October, 1903, the several branches of the Passaic had about reached their maximum rate of discharge 42 hours from the beginning of the flood. I estimate that the water was then coming into the valley above Little Falls at the rate of about 43,000 cubic feet per second.

In the following table data are given showing how such a flood would be controlled by a storage reservoir as here proposed. The first column shows the number of hours elapsed from the beginning of the flood which is taken to be the time when the river began to show a rapid rise at Little Falls. The second column shows the total amount of water in million cubic feet which flowed into the flats where the proposed reservoir is situated during the number of hours noted in the first column. The third column shows in million cubic feet the volume of rain falling directly upon the surface of the proposed reservoir. The fourth column shows the total of the second and third columns, being the total amount of water supply to the reservoir. The fifth column shows the total amount discharged through the sluices during the elapsed time shown in the first column. The sixth column shows the surplus waters accumulated in the reservoir, and the seventh column shows the height to which the surface of the reservoir would have been raised above the normal by the accumulated waters.

Control by Sluices Discharging 12,000 Cubic Feet Per Second.

Quantities in second to sixth columns of table are in millions of cubic feet.

1. Hours from Beginning of Flood.	2. Inflow to Reservoir.	3. Rainfall on Surface of Reservoir.	4. Total Supply to Reservoir.	5. Total Discharge.	6 Accumulation in Reservoir.	7. Height of Surface above Normal in Feet
42	4,400	1,205	5,605	1,814	3,791	2.6
102	8,020	1,438	9,458	4,406	5,052	3.5
180	10,890	1,438	12,328	7,776	4,552	3.2
264	11,936	1,438	13,374	11,325	2,049	1.4
316	12,123	1,438	13,561	13,561	0	0.0

[1]Annual Report of the State Geologist of New Jersey, for 1903, pp. 24–27.

The above table shows, therefore, that such an extreme flood as that of 1903 would have raised the surface of the proposed reservoir only 3.5 feet, and that the flood, instead of reaching the normal maximum discharge of 31,410 cubic feet per second, would have at no time exceeded 12,000 cubic feet per second. It would have been maintained steadily at this rate during 13 days and 4 hours, and after the expiration of this time the lake would have been reduced again to its normal elevation ready to control another flood of equal volume. Such a flood as that of 1903 is of very rare occurrence, and the lake would only reach this extreme height of 3.5 feet above the normal perhaps once in a century. The control of floods, therefore, is shown to be absolute and entirely satisfactory. The saving in damages to property on the lower stream, had the lake been in operation during the past ten years, would have been more than the cost of the whole improvement.

Effect upon the upper valley.—This large extent of water surface will add greatly to the attractiveness of the Passaic Valley from Little Falls to Morristown, Madison and Chatham. This valley is very picturesque and is suited in all respects to become a great suburban district, excepting for the presence of the great extent of wet lands, which are now periodically inundated by floods. The substitution of a wide expanse of water surface for these unattractive flats will unquestionably have an immediate and very beneficial effect upon real estate values west of the Orange Mountains. This effect will extend to an area quite as large as the area of the lake itself, or over 30,000 acres, and it may be easily imagined that the value of this property will be enhanced to an amount greater than the entire cost of the improvement.

This effect of the lake unquestionably appeals largely to the owners of property in the Passaic Valley, and it is possible that they would prefer that the improvement should be carried upon less utilitarian lines than have been suggested. It must be remembered, however, that this is an expensive improvement, and that it cannot be carried out simply upon æsthetic grounds. The funds needed to execute the improvement can be only provided on the grounds of public necessity or by the production of an income sufficient to carry the burden. For this reason, the present report outlines a method by which the proposed lake can be not merely ornamental, but useful, in different directions, which will provide a revenue sufficient to justify its cost and the expense of its maintenance.

FINANCIAL CONSIDERATIONS.

Estimate of cost.—The cost of the entire improvement is estimated herewith. It is assumed that enough land will be acquired to establish about the entire extent of the shore line a marginal park averaging 600 feet in width. This, together with the land needed for the reservoir, will require the purchase of 39,978 acres of land of which 13,891 acres are at present wet-meadow lands.

Table of Costs.

Meadow lands, 13,891 acres, @ $25,	$347,275
Upland, 26,087 acres, @ $100,	2,608,700
Dam, sluice gates, gate-house and machinery,	571,950
Protection of East Orange and Summit waterworks,	150,000
Re-location of New York and Greenwood Lake Railroad,	419,800
Re-location of Delaware, Lackawanna and Western Railroad,	306,440
Re-location of Whippany River Railroad,	142,655
Re-location of highways,	989,582
Re-location of Jersey City aqueduct,	662,000
Morris Canal changes,	50,000
Embankment, pumping plant, etc., at Pompton Plains,	110,000
Administration, engineering, contingencies, etc., 10 per cent.,	635,840
	$6,994,242

Carrying charges and maintenance.—The above estimate is made on a liberal basis and shows the cost of the work to be substantially $7,000,000. Assuming that it can be financed at a 4 per cent. interest rate, and that a sinking fund of 1½ per cent. is provided, which will pay off the bond issue in 35 years, the annual carrying charges and operating expenses of the entire work may be taken as follows:

Interest 4% on $7,000,000,	$280,000
Sinking fund 1½% on $7,000,000,	105,000
Operating expenses, including salaries, office expenses, pay-roll, etc.,	35,000
Repair of structures,	40,000
Total annual expenses,	$460,000

Possible income.—If this improvement could be carried out as a public trust and the incomes applied to carrying and paying for the improvement as a public benefit, the necessary income might be provided from the several sources which have already been suggested in the following manner:

The excess water power created by the improvement, as we have previously seen, is that due to all of the discharge in excess of 100,000,000 gallons daily. This excess power will amount to 437 horsepower at the new dam where there is 25-feet fall, this amount being available perpetually, and in addition to this there will be at the new dam and at the three falls below, at Little Falls, Paterson and Dundee, 2,248 horsepower available until 1920, and 1,441 horsepower additional available until 1930. All of this will be continuously available 24 hours each day and should be worth as follows:

Perpetual power 437 horsepower @ $30 per annum,	$13,110
Available until 1930, 1,411 horsepower @ $25,	36,025
Available until 1920 2,248 horsepower @ $20,	44,960
Annual income until 1920,	$94,095
Annual income 1920 to 1930,	$49,135
Annual income after 1930,	13,110

The above estimate is on the assumption that the demand for water for public water supply will be, as we have previously estimated, viz.:

50,000,000 gallons daily in 1910.
72,000,000 gallons daily in 1920.
122,000,000 gallons daily in 1930.
206,000,000 gallons daily in 1940.

The rates above charged for power are upon a low basis, as the charges in the past at Paterson and Dundee have ranged from

$31 to $36 for power available only 12 hours daily, without guarantee, whereas the above estimate for perpetual power 24 hours daily is only $30, but the estimate is made up on the assumption that the remaining income over and above the above estimates should go to the company owning the dams and race-ways, and retailing the power directly to the consumer, otherwise it would be necessary to acquire possession of these dams and race-ways, increasing the first cost of the works, in order to obtain the increased income.

Income from water supply.—As we have previously suggested, the right to take water from the dam at Little Falls should be open to all water companies and all cities desiring a public water supply. It may be reasonably charged for at the rate of $20 per million gallons. Water is now sold to several towns and cities east of the Orange Mountains at rates varying from $65 to $80 per million gallons, consequently, a charge of $20 for the right to take the water, leaving the difference between this and the prices charged at the point of delivery to cover the cost of mains, filter plants and operation would not be burdensome. At this rate we estimate the income to the works for water supply for public use as follows:

Annual Income from Potable Waters.

1910.	50,000,000 gallons daily @ $20,	$365,000
1920.	72,000,000 gallons daily @ $20,	547,600
1930.	122,000,000 gallons daily @ $20,	890,600
1940.	206,000,000 gallons daily @ $20,	1,503,800

Income from shore privileges.—The income from the rental of shore privileges cannot be accurately estimated, but it is estimated for this purpose upon the following basis: One-half of the frontage on the lake, or 250,000 feet, is to be offered for rent to private parties, clubs, etc., the remaining 250,000 feet or more to be retained for the general public use. The 250,000 feet, with an average depth of 600 feet, if rented at 50c. per foot, would produce an annual income of $125,000, but it would not all be rented for some years, it being assumed that it will all be rented by 1930, and that after that time the rentals will increase.

The foregoing assumptions and estimates produce the following total revenue for the support of the property:

Total Probable Income of Works.

	1910.	*1920.*	*1930.*	*1940.*
Income from sale of power, ...	$94,095	$49,135	$13,110	$13,110
Income from water supply, ...	365,000	547,600	890,600	1,503,800
Income from shore privileges, ...	40,000	80,000	125,000	187,500
	$499,095	$676,735	$1,028,710	$1,704,410

The above estimates are sufficient to indicate that with good business administration it may be possible to make this improvement self-sustaining from the start, and although the charges for power and for water for public use are low, the future income will rapidly increase to an amount far beyond the needs of the enterprise. If the enterprise should be constructed and administered for the public benefit with a view to merely making it self-sustaining, it would, therefore, be possible to gradually lower the price charged for water for municipal water supply to less than one-half the amount estimated. As a further indication that this improvement could be made self-sustaining, it may be pointed out that the water above suggested to be sold for water-power uses would produce a very much larger revenue if sold for water supply.

The estimates show that, assuming that we allow 100,000,000 gallons to flow down the channel from Paterson and Passaic perpetually, there will still remain, over and above the requirements of the cities of New Jersey, 134,000,000 gallons daily until 1920, and 84,000,000 gallons daily until 1930. If the right to take 80,000,000 gallons daily of this water to be used to supply the possible urgent requirements of the City of New York, pending the construction of the new water works now provided for, should be granted for a period of 20 years, as it readily could be, charging for the same the low rate of $15 per million gallons at the dam, this alone would produce a revenue of $1,200 per day, or $438,000 yearly, which would be nearly sufficient to carry the entire improvement.

No proposition to divert water from the State, even temporarily, should be entertained unless the same can be done under the direct control of the State for such a limited time that it will not interfere with the requirements of the cities of New Jersey, and under such conditions that it will not impose a hardship upon the riparian owners along the stream.

Furthermore, the income from any water so diverted should accrue to the benefit of the public, by being applied to a great public improvement, such as is herein contemplated.

CONCLUSION.

It is not the purpose of this report to advocate the construction of such an improvement as is herein proposed, but simply to lay the foregoing facts before the people of the State in order that they may judge for themselves of the wisdom and utility of such an improvement. Broadly the fact is that in the Passaic River we have a great source of wealth which at present is only imperfectly utilized, and our studies indicate that such a reservoir as is herein considered could be constructed so that it would prove a perfect means of controlling the destructive floods on the stream, that it would solve the problem of drainage of the flats in the upper valley and would provide amply for the public water supply of the cities east of the Orange Mountains for 50 years to come, and that this could all be accomplished without inflicting the hardships which are now inflicted, by diversion of the waters, upon the lower riparian owners and the cities along the course of the stream.

It furthermore appears possible that all of these benefits can be accomplished without the expenditure of public moneys, because the improvement can be made self-sustaining by very low charges for water, etc. All that would be needed would be such guarantees of the interest upon the bonds needed to carry out the improvement as would make it possible to sell those bonds and properly finance the undertaking. The whole work should be carried out as a public trust, strictly for the benefit of the public and under such conditions as we have suggested, which would make it possible for every municipality to obtain its own independent supply of water, if it shall so desire, simply by the payment of a reasonable charge for storage works and for the right of diversion.

June 10th, 1906.

PART V.

A Report on the Peat Deposits of Northern New Jersey.

By C. W. PARMELEE and W. E. McCOURT.

CHAPTER I.

Origin, Occurrence and Chemical Composition of Peat.

BY W. E. McCOURT.

The term peat has always been more or less loosely used. In some localities the name has been given to a black earthy soil which, in reality, is simply a muck. Peat is a brownish to black deposit formed by the accumulation and slow decay of vegetable matter under water, in bogs and swamps. It may be, in some cases, the incipient stage in the formation of coal and a chemical gradation can be traced from peat to anthracite. The following analyses[1] show this relation.

Substance.	*C.*	*H.*	*O.*	*N.*	*S.*	*Ash.*	*Sp. gr.*
Peat, ...	54.02	5.21	28.18	2.30	.56	9.73	.850
Lignite, ...	66.31	5.63	22.86	.57	2.36	2.27	1.129
Bituminous coal, ...	78.69	6.00	10.07	2.37	1.51	1.36	1.259
Anthracite, ...	90.39	3.28	2.98	.83.	91	1.61	1.392

Peat is often fibrous, though in some varieties but few fibres may be distinguished. The main peat-former is a kind of moss known as sphagnum, though other water plants as sedges, grasses and the like may make certain varieties. The process is one of slow oxidation, out of contact with the air, in which the amount of carbon increases as the volatile elements like oxygen and hydrogen decrease.

[1] Carter, Peat Fuel. Its Manufacture and Use. Report, Ontario Bur. Mines, XII., 194; 1903.

The following analyses[1] show the variations which take place in the change of the sphagnum to peat.

Substance.		*Analyst.*	*Carbon.*	*Hydrogen.*	*Oxygen.*	*Nitrogen.*
Spagnum,	Undecomposed.	Websky,	49.88	6.54	42.42	1.16
Peach wood,	Undecomposed.	Chevandier,	49.90	6.10	43.10	0.90
Poplar wood,	Undecomposed.	"	50.30	6.30	42.40	1.00
Oak wood,	Undecomposed.	"	50.60	6.00	42.10	1.30
Peat, porous, light brown, spagnous, ...		Websky,	50.86	5.80	42.57	0.77
Peat, porous, red brown, ...		Jaeckel,	53.51	5.90	40.59	
Peat, heavy, brown, ...		"	56.43	5.32	38.25	
Peat, dark red brown, well decomposed, ...		Websky,	59.47	6.52	31.51	2.51
Peat, black, very dense and hard, ...		"	59.70	5.70	33.04	1.56
Peat, black, heavy.	Best quality for fuel.	"	59.71	5.27	32.07	2.59
Peat, brown, heavy,	Best quality for fuel.	"	62.54	6.81	29.24	1.41

A good peat bog usually shows the following section. On the top is a layer of the living plants, below this is a mixture of partly decayed plants containing well-defined fibres and at the bottom is the typical spongy peat in which fibre may be totally absent.

Peat may vary considerably in color, structure, consistency and composition. The well-decomposed varieties are usually of a black color, more or less spongy and waxy and contain few or no fibres, while the younger peats are more brownish, fibrous and rather loose in texture.

Peat bogs are usually met with in temperate, cold and humid climates, for "as we advance towards the warmer climates, vegetable matter is more rapidly decomposed, until, at the tropical regions, the putrefaction of animal and vegetable matter is so rapid that it prevents the formation of any body of the substance and structure of peat."[2] Besides, in temperate regions, evaporation is slow and the sphagnum, which is the greatest source of peat, does not flourish in dry air.

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[1] Johnson, Peat and its Uses, N. Y., 1866, p. 24.

[2] Leavitt, Facts about Peat, Boston, 1867, p. 30.

Peat accumulates in marshes and swamps where the drainage is so hindered as to prevent complete decay of the vegetable matter which may have been deposited in the water. The various kinds of marshes and swamps may be divided into two classes:

1. Marine marshes.
2. Fresh-water swamps.

Marine marshes are formed along the coast, in bays and protected harbors. Large tracts of this type border the coast of New Jersey. These areas are covered with marsh grasses which gradually decay and accumulate with a fine mud, but the resulting deposit is not usually a good peat and is commonly of little use as a fuel, though some of the deposits may be used for packing or as a litter, or even as a fuel.

Among the fresh-water swamps the commonest and perhaps the most important is the lake swamp. In the north temperate regions there are many lakes and ponds the shores of which are lined with water plants, chiefly mosses. By the growth of these plants the motion of the waters is oftentimes retarded, the shores are kept free from the beating action of the waves and the fringe of plants may spread out over the surface. In time, the entire surface of the water may be covered by this growth. At the same time there will also be a vertical growth, for some plants will die and others will take root on their remains. With this covering of moss as a basis, other plants, like ferns and grasses, will take root and constantly add to the vegetable accumulation. The deposit will grow deeper and deeper and heavier plants and even trees will spring up to add to the mass. So the lake or pond may become entirely filled with a mass of fibrous vegetable matter, which on top will show living plants and below will pass into the waxy peat in which no fibre may be present.

There are other types of swamps in which more or less pure peat may be formed. Swamps may be formed along rivers on terraces and flood plains and, during times of high water when these depressions are covered, water plants may grow, decay and accumulate to form a deposit of muck or impure peat. Another type is the delta swamp, which may be formed in a lake in which there will be found a deposit of a black soil containing vegetable and mineral matter. Or a delta swamp may be formed along the seashore and here the deposit would be much like that which is formed in tide-marshes. Other minor types like the swamps in kettle holes and on uplands may be centers of peat accumulation.

In all these swamps the deposit will grow deeper and deeper, the process of slow oxidation will take place with the evolution of hydrogen, oxygen and some nitrogen in the form of carbon dioxide (CO_2), marsh gas (CH_4), and water and the deeper portions will become more compact and spongy. A covering of water is necessary, for if the vegetable matter were exposed to the air it would be completely destroyed.

Peat, when dug, contains a considerable amount of water. The percentage may be as high as 85 per cent., or even higher. When the peat is put out to dry it loses a large amount of this water, but never dries thoroughly. In the case of the New Jersey peats the moisture in the dried samples ranges from 4.93 per cent. to 24.30 per cent., with an average of 15.52 per cent.

All peats contain mineral matter which was deposited with the vegetable matter. This, upon the burning of the peat, is left as ash. The peats which contain a large amount of ash (50 per cent. or more) are given the name muck and are of little avail, except for agricultural purposes. The percentage of ash in good fuel peats varies from 3 to 10 per cent., though in some cases it may run as high as 25 per cent., the amount depending upon the quantity of sediment deposited while the peat was accumulating. The New Jersey samples tested ranged from 5.04 per cent. to those having over 50 per cent.

The following table shows the ash percentages in some of the peats from New Jersey and other States:

Cranston, R. I.,[1]	13.00	Rochester, N. Y.,[3]	2.15
Woonsocket, R. I.,[2]	1.80	" " [3]	3.05
Wickford, R. I.,[1]	12.00	" " [3]	5.08
Bedford, N. H.,[2]	7.00	Colebrook, Conn.,[4]	4.57
" " [2]	4.60	Poquonnock, Conn.,[4]	5.92

[1] Jackson, Rept. on Geog. & Ag. Sur., R. I., 1840.

[2] Jackson, Geol. & Min. of N. H., 1844.

[3] Fairchild & Barnum, Pinnacle Peat Marsh, Proc. Roch. Acad. Sci., III.

[4] Johnson, Essays on Peat, Muck & Commercial Manures.

Poquonnock, Conn.,[1]	8.63	Lafayette, N. J.,[4]	12.75
Welland, Ont.,[2]	4.07	Sussex, N. J.,[4]	13.61
" " [2]	7.17	Rockport, N. J.,[4]	13.83
Beavertown, Ont.,[2]	16.2	Stockholm, N. J.,[4]	6.97
" " [2]	7.03	Dunker Pond, N. J.,[4]	7.59
Beavertown, Ont.,[2]	6.68	Ironia, N. J.,[4]	16.52
" " [2]	27.67	Great Meadows, N. J.,[4]	13.97
Ardennes, France,[3]	8.3	Bog & Vly, N. J.,[4]	13.46
Allandale, N. J.,[4]	5.83	Black Meadows, N. J.,[4]	13.19
Newton, N. J.,[4]	12.03	Troy Meadows, N. J.,[3]	12.85

The ultimate analysis of various peats will also show considerable differences, but the main products are carbon, hydrogen, oxygen and nitrogen, and these are the same elements present in the entire coal series and in the plants from which the peat is formed. (See analyses, page 225.)

The average composition of peat, after deducting the ash mineral residue and recalculating, is:[5]

Carbon,	52 —56%
Hydrogen,	4.7— 7.4%
Oxygen,	28 —39%
Nitrogen,	1.5— 3%

In the following table there is given a number of analyses of peat from various sources and localities. These are published in the belief that they may be of some value to readers of the report who do not have access to previous publications on this subject. They do not include any analyses made in these investigations.

[1] Jackson Rept. on Geog. & Ag. Sur., R. I., 1840.
[2] Carter, Peat Fuel. Ont. Bur. Mines, Bull V, 18, 1903.
[3] Taylor, Statistics of Coal.
[4] Parmlee, analyst.
[5] Ries, Uses of Peat and its Occurrence in New York, Annl. Rept. N. Y. State Geol., XXI., r71, 1903.

ANALYSES OF PEATS.

LOCALITY.	Org. Matter	H_2O	Fe_2O_3 Al_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3	CO_2	SiO_2	AUTHORITY.
New Jersey												
Black Brook Meadows, Columbia Turnpike, Morris County, ...	65.61	16.16	3.19	3.86	.37	.31	......	.93	.89	.09	8.64	Cook, Geol. of N. J. 1868, p. 481.
Columbia, Morris Co.,	66.87	15.15	3.97	3.17	.39	.27	......	.1	2.46	......	7.63	" " " "
Allandale, Bergen Co.,	83.8	11.7	.42	1.46	.17	.08	......	.05	.74	.04	1.07	" " " "
Beavertown, Morris County, ...	69.8	16.8	2.92	3.34	.27	.02	......	.19	.76	.43	5.36	" " " "
Michigan—												
Meare near Bridgewater, ...	97.78	......	.536	$CaCO_3$ .855	.144	.131	.065	.053	.051	......	.403	Mich. Ag. Rept. 1865, p. 208.
Ohio—			Fe_2O_3	$CaCO_2$								
J. F. Brooks, Salem,..	......	91.31	.33	1.24	......	1.26		......	......	......	5.86	Ohio Ag. Exp. Sta. Rept., 5:281.
Wisconsin—												
Baraboo, 1st foot,....	84.28	......	......	2.16	......	.11	......	.28	......	......	8.68	
2d and 3d foot,....	92.00	......	......	1.5	......	.04	......	.1	......	......	5.39	

RHODE ISLAND.

LOCALITY.	H_2O	Ash	Veg. Matter	SiO_2	Fe_2O_3 Al_2O_3	CaO	MgO	K_2O_2 loss.	AUTHORITY.
Cranston, ...	......	13.	87.	8.	2.2	2.8	......	tr	Jackson, Rept. on Geol. and Ag. Sur. of R. I., 1840.
Block Island, ...	25.25	6.35	63.4	4.5	.75	1.1	......	......	
Cumberland Hill, ...	......	2.15	97.85	.45	.25	1.3	......	1.5	
N. Kingston, ...	......	25.6	74.4	21.2	2.4	1.5	......	.5	
Pawtucket, ...	......	11.4	88.6	9.5	1.9	......	......	......	
Wickford, ...	15.9	11.5	72.6	8.9	1.5	1.1	.2	......	
Woonsocket, ...	10.	1.8	88.2	.5	.3	.6	......	......	
S. Kingston, ...	......	17.5	82.5	12.	2.1	2.5	.5	.4	

OTHER ANALYSES.

Locality.	H_2O	Ash	Org. Matter	Authority.
New Hampshire—				
Bedford,	5.8	4.6	89.6	Jackson, Geol. and Min., N. H. 1844.
Canterbury,	13.7	23.4	62.9	" " " "
Lyndeborough,	21.	12.3	66.7	" " " "
Connecticut—				
Goshen,	20.33	8.	71.67	Johnson, Essays on Peat, Muck, and Commercial Manures.
Milford,	19.67	3.23	77.1	" " " "
Colebrook,	33.88	4.57	57.05	" " " "
Poquonnock,	17.2	8.63	74.17	" " " "
Rockville,	30.36	5.41	64.23	" " " "
New York—				
Rochester,	14.47	2.15	83.38	Fairchild & Barnum, Roch. Acad. Sci. Proc. III.
Rochester,	14.23	3.05	82.72	" " " "
South Salem,	19.43	21.27	59.3	" " " "
France—				
Ardennes,	30.5	8.3	61.2	Taylor, Statistics of Coal.

PEATS FROM ONTARIO.

Locality.	H_2O in Original Sample.	Calculated on 15% Water Content.			Authority.
		Volatile Combustibles.	Fixed C.	Ash.	
Welland,	82.2	59.27	21.66	4.07	Carter, Peat Fuel, Its Manufacture and Use.
	87.48	56.78	21.05	7.17	
Beaverton,	62.98	57.13	11.67	16.2	Ont. Bur Mines, Bull. 5, 18, 1903.
	83.31	67.58	10.39	7.03	" " " "
	84.86	73.6	4.72	6.68	" " " "
Perth,	....	54.72	19.85	10.43	" " " "
	....	57.81	18.92	8.27	" " " "
Brunner,	....	60.1	15.7	9.2	" " " "
Rondeau,	....	58.56	23.29	3.15	" " " "
Newington,	87.94	56.74	27.21	1.05	" " " "
	86.66	54.42	28.61	1.97	" " " "

These tables have been compiled from the following authors:

Ries, Uses of Peat and its Occurrence in New York, Anal. Rept. N. Y. State Geol., xxi., r63, 1903.

Parsons, Peat, its Formation, Uses and Occurrence in New York, Anal. Rept. N. Y. State Geol., xxiii, 32, 1904.

CHAPTER II.

The Technology and Uses of Peat.

BY C. W. PARMELEE.

The uses of peat grouped according to the origin of the properties may be given as follows:

I. Those due to its chemical composition:
  A. Carbon and hydrocarbon content—
    1. Directly as a fuel, raw or manufactured.
    2. Coked, the products are: Coke,
Gas,
Ammonia,
Acetic acid,
Methyl alcohol,
Tar.
    3. Gas.
  B. Nitrogen content, useful chiefly in agriculture.
II. Those due to its physical nature:
  1. As a fibrous material—
For litter,
For textiles,
For paper stock.
  2. As an absorbent.
  3. As a non-conductor of heat and sound.
III. Those due to its chemical-physical nature—
As a preservative.

PEAT AS A FUEL.

Use in Europe.—The chief value of peat undoubtedly depends upon its content of combustible matter. For economic reasons this has had little recognition in this country, and we probably use more as litter than for any other purpose. In all parts of northern Europe, of Ireland and Scotland, wherever the climate is cold and damp and fire-wood scarce or unobtainable and peat available, it has been the ordinary domestic fuel since prehistoric times. The consumption must have steadily increased up to the time that the introduction of railroads made coal a vigorous competitor. Since then, however, the production has continued steadily, as the following figures show. According to a report of a British commission, made in 1893,[1] the Netherlands consumed 280,000 tons annually in the burning of brick. A writer in the Journal of the Royal Agricultural Society, 1893, states that it is estimated that 150,000 tons are annually used for household purposes in the Grand Duchy of Oldenburg. In the year 1890 Bavaria was said to use annually 60,000 tons as fuel for railway locomotives. According to a report made by the Russian Government for the Chicago Exposition of 1893,[2] it is stated that in 1890 peat was used as a fuel in that country in the following industries: Cotton manufactures, 537,000 tons; sugar factories, distilleries, confectioners, flour mills and macaroni factories, 70,000 tons; manufacture of chemicals, 5,000 tons; candle, tallow and leather trades, 4,000 tons; woodworking, 1,000 tons; metal manufactures, 60,000 tons; glass works, 80,000 tons; paper manufactories and miscellaneous, 2,000 tons; an aggregate of 772,000 tons. Engineer Alf Larsson, in an address delivered at Stockholm[3] in 1902, said that Russia produces yearly 4,000,000 tons of peat, and the Russian Government receives annually $938,000 for leasing bogs. Germany produces 2,000,000 tons annually; Holland, 1,000,000; Sweden, 1,000,000 tons.

We can readily understand the above figures if we bear in mind the following facts regarding European conditions, namely, peat has always been recognized as a fuel; that the fuel resources are limited and the inhabitants are accustomed to utilize as combustibles all available materials, even burning grass and straw in their brick kilns.

Use in America.—In our country there have been a few scattered attempts to use peat as a fuel. These experiments have been of short duration and at present there are few persons, probably, who are sufficiently familiar with peat to recognize it or know

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[1] Report of H. M. Representatives on the Manufacture of Fuel, Moss Litter and other Products of Peat in European Countries. Blue Book Commercial, No. 2, 1893.

[2] Journal of the Society of Chemical Industry, vol. 13, pg. 596.

[3] Special U. S. Consular Report, xxvi, pg. 125.

how to prepare it for use. The early settlers of Massachusetts brought the old world practice, which, however, did not flourish where wood could be had merely for the labor of cutting. On Martha's Vineyard and Nantucket Islands, the descendants of the Indian inhabitants still continue the practice because of the lack of other cheap fuel. According to Dr. Geo. H. Cook[1] peat was "long used in Chatham Township, Morris County, and to a smaller extent in many other places." Attempts to manufacture fuel with the use of machinery were made at Belleville, Essex County, and at Allendale, Bergen County. A plant was also projected at Beaverton, Morris County. The industry did not flourish, however, either here or in New England, where similar attempts were made.

Water content.—Since peat is formed by the partial decay of vegetation at the place of its growth, we find a considerable difference between the top and bottom of such deposits. At the surface there are the growing plants, next the dead growth, then a fibrous partially decayed mass, and finally a waxy peat in which all the fibre has disappeared. These layers have different properties and, if extensive, may be separately used for various purposes. Sometimes there may be differences in various sections of the same bog. The whole mass is thoroughly wet like a sponge, as this is a necessary condition for its growth. This water content in a freshly cut sample may be as high as 85 per cent. or 90 per cent. When the peat is cut and removed from the bog, it loses a great part of this water content, but never dries out entirely. It still retains a considerable portion, which may vary with the condition of the atmosphere and character of the peat. This water content in a good air-dried peat should not exceed 25 per cent.

Ash.—Peat always contains some mineral matter which has been part of the plant structure or has accumulated through a variety of natural causes. The lower part of the bog contains the greater quantity, and it may vary in different sections of the same bog. This mineral matter we determine and describe as the ash content. It has a very important place in determining the

[1] New Jersey Geological Survey, 1866, pg. 13.

probable usefulness of the peat. If the amount is greater than 50 per cent., the material may be better described as muck, rather than peat. Twenty-five per cent. is the maximum quantity permissible in a fuel peat, and 5 per cent. is low.

The practical importance of the amount of ash is readily apparent when we consider that with every additional unit of inorganic matter we increase the cost of digging and transporting the peat, and not only lose in burning the use of the combustible material displaced, but also a certain amount of heat which is required to bring the non-combustible matter to the temperature of the fire and maintain the temperature at that point. Fortunately the ash is very light and powdery. It does not clinker the grate bars, and they are said to last much longer than with coal firing.

The chemical composition of the ash is given by Thenius[1] as follows:

"Silica, which is mechanically mixed with the peat, varies from 15 per cent. to 30 per cent., according to the character of the adjacent soil.

"Lime, occurring partly as the sulphate, partly as the carbonate in very notable quantities as much as 20 per cent., or even 30 per cent.

"Magnesia is present in almost all peats, varying from 1 per cent. to 10 per cent.

"Alumina occurs sometimes in large quantities, sometimes in small. It varies between 2 per cent. and 5 per cent.

"Ferric oxide gives the ash its red color. Often found in notable quantities.

"Phosphoric acid is present in many peats, yet seldom over 2.5 per cent.

"Alkalies occur only in small amounts, reaching at the highest 2 per cent. to 3 per cent."

Dr. S. W. Johnson[2] gives the following results as the average of his investigations of the ash of American peats:

[1] Werwertung des Torfes, Berlin, 1904, pg. 160.

[2] Peat and Its Uses, N. Y., 1866, pg. 48.

	Average.	*Minimum.*	*Maximum.*
Potash,	0.89%	0.05	3.64
Soda,	0.83%	None	5.73
Lime,	24.00%	4.72	58.38
Magnesia,	3.20%	None	24.39
Alumina,	5.78%	0.90	20.50
Ferric oxide,	18.70%	None	73.33
Sulphuric acid,	7.50%	None	37.40
Chlorine,	0.60%	None	6.50
Phosphoric acid,	2.56%	None	6.29
Sand,	25.50%	0.99	56.97

The ashes are said to be of value as a fertilizer, which explains in part the good results following the cultivation of burned moorland, a practice which has had a considerable vogue in Europe.

The composition of ash-free and dry peat is given by two writers as follows:

	Hausding.	*Websky.*	
Carbon,	60%	49.6% to	63.9%
Hydrogen,	5%	4.7%	6.8%
Oxygen,	34%	28.6%	44.1%
Nitrogen,	....	0.0	2.6%

Relation to other fuels.—The relation of peat to various fuels is shown in the following table, which also very well illustrates the progressive changes peat might undergo in a possible conversion to anthracite. According to Ost:[1]

	Wood.	*Peat.*	*Lignite.*	*Bituminous Coal.*	*Anthracite Coal.*
Carbon,	50%	60%	70%	82%	94%
Hydrogen,	6	6	5	5	3
Oxygen,	43	32	24	12	3
Nitrogen,	1	2	1	1	trace

Calorimetric tests.—The value of any fuel depends upon the quantity of heat generated and the temperature which can be obtained. The determination of the quantity of heat a fuel can furnish is called the calorimetric test, and the results furnish a very accurate means of comparison of the relative value of different kinds of combustibles. Chemical analysis of fuels will show how

[1] Tecnische Chemie, Hanover, 1903, pg. 12.

they differ in composition, but it does not furnish satisfactory data showing how they actually compare in heating power. The unit of heat which we use in reporting the results may be the calorie or the British Thermal Unit (B. T. U.). The calorie is the amount of heat necessary to raise 1 kilogram of water 1°C. The British Thermal Unit is the amount of heat necessary to raise 1 pound of water 1°F. British Thermal Units may be converted into calories by multiplying by 5/9.

Effect of ash and moisture on heating power.—The influence of the amount of moisture and ash upon the heating power of peat is very well shown in the following table according to Hausding:[1]

	Calories.
Dry peat without ash,	6,500
" " with 4% ash,	6,300
" " " 12% "	5,800
" " " 30% "	4,500
Same peat with 25% water,	4,700
" " " 30% "	4,100
" " " 50% "	2,700
" " " 0 " 15% ash,	5,500
" " " 25% " 0 "	4,700
" " " 30% " 10% "	3,700

It will be noticed upon comparison of the above figures that the difference between two samples of peat having a different content of moisture is greater than that due merely to the displacement of combustible matter. For example, dry peat has the value of 6500. That containing 25 per cent. water is not 75 per cent. of 6500, which would be 4875, but according to the table it is 4700. The explanation for this difference is that the loss represents the amount of heat consumed in vaporizing the moisture. This very well illustrates the necessity of preparing peat for use so as to contain as little content of moisture as practicable, and in such a form as to be little affected by atmospheric moisture.

Heating power of peat and other fuels.—The following table gives a comparison of various fuels:[2]

[1] Handbuch der Torfgewinnung, Berlin, 1904, pg. 333.

[2] Hausding, Handbuch der Torfgewinnung, Berlin, 1904, pg. 328.

	Water Chemically Combined. Per cent.	Water Mechanically Held. Per cent.	Ash. Per cent.	Calories
Wood, air dry,	39	20	1	3,232
" kiln dry,	49	0	1	4,040
Charcoal, air dry,	0	12	3	6,868
" dry,	..	..	3	7,837
Anthracite coal,	2	3	2	8,305
Peat,	26	25	5	3,950
" manufactured,	30.4	18	2	4,430

The calorific value of fuels furnishes the data for their comparison, but in practical operations it is not possible to realize the full value owing to such causes as imperfect combustion, radiation losses, etc. The useful heating power may be compared in terms of work accomplished under practical conditions. The following claims have been made for peat:[1]

1 pound of pressed peat will vaporize 5 to 6 pounds of water in a boiler.

250 pounds will melt 100 pounds of glass batch.

6 to 7 cwt. is required to burn 1000 brick.

100 pounds is required to burn 80 to 100 pounds of lime.

According to Hausding,[2]

1	Kilogram	of	air-dried wood	will	evaporate	3 to 3.4	Kilograms	of	water.
1	"	"	hand-cut peat	"	"	2.8 " 4	"	"	"
1	"	"	machine	"	"	4.5 " 5	"	"	"
1	"	"	best coal	"	"	7 " 8	"	"	"

Roberts-Austin says that "for equal evaporative power its (peat) bulk is 8 to 18 times that of coal." This probably has reference to the most bulky form of peat, namely, hand-cut peat.

Peat burns with the evolution of a large quantity of volatile, inflammable gases and an empyreumatic odor, which is agreeable to many persons. The evolution of these gases make it a particularly desirable fuel for some purposes as, for example, the ceramic industries. On the other hand this large volume of gas re-

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[1] Journal of the Society of Chemical Industry, 1899, pg. 1113.

[2] Handbuch der Torfindustrie, pg. 335.

quires greater flue space. This increase in size over that used in coal firing will vary[1] from 8 per cent. to 27 per cent depending upon the temperament of the gases. Attention must also be paid to the character and size of the fire mouth and grate. Dense peats do not require the same large grate area as the looser varieties.

MANUFACTURING PEAT FUEL.

Digging.—The first operation on most bogs is draining the area to be worked. It is not advisable to drain the whole bog even if feasible, for the peat will dry and become brittle or freeze in the winter rendering it in either case difficult if not impossible to work. Further, complete draining will kill the peat-forming vegetation. After the portion selected for working is sufficiently well drained, the surface growth is removed and, as will be shown later, this may be of some value. After this has been accomplished the digging may begin and we will describe the method usually followed where labor is cheap.

A trench is dug with vertical sides of sufficient width to permit a laborer to work freely in it. The cutting of the sods then proceeds either from the surface downwards or in a horizontal direction, depending upon the presence or absence of strata. In the former case, the laborer standing above, thrusts his spade, sometimes called a stane, into the peat a few inches back from the face and parallel to it. The laborer in the trench cuts this sod loose by a thrust of his spade and transfers it to a board from which it is lifted by a fork to a wheelbarrow and thus to the drying ground. The spade used by the laborer standing on the surface of the bog is a heavy tool with sharp edges and one edge turned at right angles to the blade and sometimes a sharp fin at the middle of the blade and at right angles to it. Such devices enable the user to cut one or more surfaces of a sod with a single thrust.

Cutting peat by machinery has been practised for a great many years in Germany. The apparatus in use is known by the name

[1] Bache, Proceedings of the Institute of Civil Engineers, 1900-1901, vol. cxlvi, pt. iv.

of its inventor Browsowsky, who first brought it forward in 1842. The cutting device is like the three sides of a box in arrangement and each of the lower edges is sharpened for cutting. This cutter is forced down into the peat following the vertical face of the diggings. When sunken to a sufficient depth which may be as far as twenty feet, a blade attached to the cutter is made to cut under severing the prism of peat which may be raised. The apparatus can only be used along the face of trenches already dug. Such a machine operated by two men can cut 3,000 cubic feet in 10 hours. The prism so cut is about 1½ by 2 feet in cross section and from 10 to 20 feet long. This is then cut into convenient sized pieces.

Peat sods are dried by exposure to the air which of course renders the industry wholly dependent upon favorable weather conditions. Consequently the digging of peat can be carried on only during the late spring, summer and early autumn. It cannot be continued very late in the autumn, for the cut peat must have time to dry before frost, otherwise great loss will be occasioned by the freezing. In order to facilitate drying, the sods are generally loosely piled on a flat, dry piece of ground. Sometimes they are piled on elevated racks, which may be protected by a roof, or the drying ground may be thickly set with poles furnished with spikes projecting outwards, upon which the sods are transfixed. The advantage of such methods lies in the fact that drying always proceeds more rapidly above the surface of the ground. If the peat is deficient in fibre, or crumbly on drying, or to be had only in a pulpy condition, the above described process is wholly unsuitable, and recourse must be had to other methods which will give a more solid product. This result is readily attained by kneading and mixing. A number of different methods are in use abroad which we will briefly describe.

Trodden peat.—The peat is dug in irregular lumps and thrown into a vat or pit, and water is added if too dry. The mass is trodden by barefooted men or women, or by horses or oxen, until it is reduced to a paste. This paste may be filled into moulds and, when sufficiently solid, emptied on the drying floor. Or the pulp may be run into a many-celled frame. It is compressed by pounding, and when sufficiently firm is emptied out. Or the pulpy mass is spread out on a smooth surface, allowed to dry somewhat and then compacted by rolling, beating or treading by men or women wearing boards on their feet. It is then cut with a long knife into bricks and removed to the drying floor. This method is very general in Holland. If it is impracticable to drain the bog, and the peat can be removed in a pulpy condition, it is frequently dredged out of the trenches by laborers using nets of close mesh or bagging.

All these methods are unsuited for use in this country owing to the high cost of labor. Besides, the product has many faults. It is loose, brittle, and bulky, and consequently it does not bear transportation well. The burning of it in industrial establishments requires much labor and attention, and the use of very large fire mouths and grates. The space for drying and storing must be considerable owing to the bulk. The season for cutting and drying is very limited and the chance of loss because of unfavorable weather is great. To avoid these difficulties and to secure a useful fuel has been the goal of many inventors, and a great variety of mechanical devices has been tried both in this country and abroad with varying success.

The most successful systems are those which are designed to secure a combination of crushing and tearing of the fibre and a thorough mixing of the mass. This not only insures a destruction of all roots and fibre but, according to a theory, breaks down certain compounds called protozane. These particles have a nature similar to starch or glucose and when ruptured act as a binder.

The various methods which have been employed for the purpose of condensing peat are too numerous to discuss in detail. The following methods are in successful operation. They are given as typical processes.

Pulped peat.—This method is similar to one already described as "trodden peat" with this difference, that the peat is prepared by machinery. It is very successfully used at Sparkjer in Denmark, and very generally in Holland. The operation as conducted in a latter country requires the use of a scow, upon which is placed the necessary machinery, consisting of a dredge, a kneading and mining machine and a pump. The kneading and mixing machine is essentially a metal trough through which passes one or more shafts bearing knife-like blades. These shafts revolve and disintegrate the material raised by the dredge. The pulpy mass is delivered by the pump upon cleared ground, on the moor or on nearby land, where it dries until firm and is then cut into bricks, which are removed for more complete drying. The scow floats in one foot of water. The stripping or accumulation on top of the peat is used as filling or for building dikes. A similar method was used in Canada in 1864 which produced dried peat at 92c. per ton, it is said, but operations were subsequently discontinued.

Compressed peat.—Attempts which have been made to drive out the water mechanically held in peat by subjecting the raw peat to pressure have resulted in failure. At a Canadian plant, operated from 1900 to 1902, the moss was subjected to a pressure of two tons per square inch. An average sample of the raw material contained 77.71% water. On leaving the press it contained 63.48%, whereas drying under ordinary atmospheric conditions will remove 30 to 40% moisture. If the peat is first broken and dried better results may be had. A plant located at Beaverton, Canada, at which this method has been employed is of interest not only for the process but also for the fact that it has been in successful operation for four years. The digging of the peat is done mechanically by an electrically-driven scraper which cuts and elevates the peat from any depth of the pit. The fragments are delivered before a paddle-wheel, which throws them in a shower over the cleared surface of the bog 30 to 50 feet, forming a layer of a depth of ½ inch, where it is dried by the air and sun. This layer may be built up by further increase to a thickness of 6 inches. The drying goes on rapidly if the weather is good, and a layer of 1 to 2 inches thick will lose 40 per cent. in moisture in 2 to 3 hours. The material after drying is raked together by hand and loaded into electrically-driven cars, which carry it to the bins or hopper. From the hopper it goes to the "breaker" where it is further broken and delivered to the drier. This is a steel cylinder 30 feet long 3 feet in diameter with a pitch of 14 inches. It turns at the rate of 1½ revolutions per minute. The interior surface is furnished with projections which assist in mixing the charge and preventing its sliding. The cylinder is surrounded at a little distance by a brick wall. The space between the wall and the cylinder is the flue for the passage of the hot gases. The peat passes through the drier in 20 to 30 minutes and falls as a pulverized mass upon a conveyer, which delivers it into a hopper at the briquetting press. The plant operates only in the summer time. It has a capacity of 12 to 15 tons per day, at a cost of $1.80 per ton.

Ex-pressed peat.—The typical machine used is similar to the auger brick-machine. It consists essentially of a horizontal or a vertical cylinder in the axis of which is a shaft furnished with broad blades having cutting edges. The size of the cylinder, the number and the dimensions of the blades are determined by the character of the peat and they in turn influence the amount of output. As the shaft rotates the peat is crushed, torn and mixed, and moved forward by the blades which are arranged nearly as a spiral. The comminuted mass is finally forced out as a continuous bar through a die having one or more openings. It is cut into briquettes of convenient length and carried to the drying floor. The dry briquettes have one-fifth of the volume of a similar weight of raw peat. Small machines are operated by horse power, the larger by steam. Sometimes auxiliary rollers for a preliminary crushing and cutting are placed above the main shaft. These machines are often mounted on trucks, which move along tracks on the bog, and a leg provided with a chain elevator reaches down into the trench. The laborers feed the cut peat on to the elevator, which conveys it to the hopper of the machine. The capacity claimed for the horse-driven machines varies from 8,000 to 20,000 bricks a day. The power machines deliver as high as 80,000, with a maximum consumption of 13 h. p.

This type of machine has been in use for upwards of fifty years and hundreds are said to be in use on the continent of Europe. On the great bogs of Russia it is reported that 50 to 70 may be seen at work at a time,[1] each machine being driven by a locomobile of 12 h. p., requiring the labor of 30 men, with

[1] Engineering Magazine, vol. 24, 1902, pg. 204.

a daily output of 40 to 60 tons in the dry state. The cost of production in Germany, with wages at $1.00 per day, is stated by Hall and Tolman[1] to be $1.70 per ton.

The American Peat Coal Company, situated at Lincoln Park, N. J., the only plant in the State engaged in the manufacture of this fuel, uses the process described above (See also p. 284).

At New Rochelle, N. Y., an attempt was recently made to utilize local peat beds. The peat was prepared in this manner, but the machine in this instance was mounted on a track at one side of the trench and the bricks were distributed about the surface of the bog for the drying. Subsequently these were gathered and stored for sale. A number of tons were disposed of for local domestic use, and it was found very satisfactory when burned in open fire-places, and in some instances in kitchen ranges.

Other plants in operation during the year 1905 using similar methods were:[2]

Lamartine Peat Light & Power Co., Fond du Lac, Wis.
Michigan Peat & Marl Co., Grand Rapids, Mich.
J. M. Cheney, Orlando, Fla.
Wolverine Peat Co., Vicksburg, Mich.

Plants using other methods:

American Peat and Fuel Co., Capac, Mich.
Boston Fuel Co., Boston, Mass.
Michigan Peat Co., Eaton Rapids, Mich.
National Peat Co., Chelsea, Mich.
Illinois Peat Fuel Co., Chicago, Ill.

Partly operating or organizing:

Aurora Peat Co., Aurora, Ill.
Capital Peat Fuel Co., Detroit, Mich.
Indiana Peat Fuel Co., Tyner, Ind.
Kandiyohi Peat Coal Co., Willmar, Minn.
Mankato Peat Fuel Co., Mankato, Minn.
Northern Peat Co., Minneapolis, Minn.
Northwestern Peat Co., Minneapolis, Minn.

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[1] Engineering Magazine, Feb., 1905.

[2] Julius Bordollo, Peat Fuel Production, The Engineer, May 15, 1906.

Peat Gas and Coal Co., Portland, Me.
Van Buren Peat Co., Gobleville, Mich.
Western Peat Co., Marshall, Wis.
Wisconsin Brick Co., Madison, Wis.
Amalgamated Peat Fuel Co., 80 William Street, New York.

The quality of the peat produced by any of the above methods will depend primarily upon the completeness of the preliminary disintegration. Peat molded either by compression or expression is a very superior article as compared with the hand cut. It is so tough as to resemble wood in its resistance to cutting by saw or knife. It will not soil the hands nor crumble, which, together with its greater density, renders it suited for transportation. It resists weathering, as it is quite waterproof, and moreover it is not damaged by frost. As a fuel it burns slowly and steadily. Such methods of manufacture make peat a more available fuel, but do not increase its power to do work, since this is dependent upon the chemical composition alone. A pound of cut peat does not make as good a fuel as the more compact form, for reasons already mentioned, but it has the same heating power.

The drying of pulped or of ex-pressed peat is usually and most economically done by the action of the sun and air, either in the open or under sheds. A great deal of ingenuity has been displayed in the many devices put forward for the manufacture of peat fuel. For the most part they have been failures both in this country and abroad. It is estimated that fully $400,000 was spent in futile experiments in Canada in the space of seven or eight years prior to 1902. The fact remains, however, that the industry has been made profitable abroad, where the economic conditions are somewhat different. In general, without respect to location, certain conditions must be met in order to insure success. Bogs are not alike, and what is suitable for working one will not necessarily do on another. Advice from an experienced or competent person should be had in the selection of the bog, the method of operation, the choice of machinery and its installation. A preliminary survey of the bog will determine whether its extent and depth are sufficient to justify mechanical working, and physical and chemical examinations will settle the question of its usefulness and for what purpose. Bogs suitable for working with a permanent plant should have an area of at least 100 acres and a depth of at least 4 feet. Such a bog will yield about 70,000 tons of dried peat.

Kiln-dried peat.—Experiments made for the purpose of removing the moisture held mechanically even by the driest peat by heating it in ovens or retorts have not produced a product of sufficient value to justify the expense. The early efforts were in the line of heating the peat in retorts either by applying the heat externally or by conducting the hot gases through the charge. It has recently been proposed to heat the peat electrically, either by piling the briquettes about a resistanse coil in a closed chamber or by putting the peat in the circuit, with the expectation that a charring will follow.

Peat coke.—For many years peat coke has been used in Europe for metallurgical operations, although at present there are only a few plants, owing to the close competition of coke. The Russian Government has been reported as having recently built a factory between St. Petersburg and Moscow, in a region where coal and wood are scarce, for the purpose of providing fuel for locomotives. Owing to the normally low content of sulphur, peat coke has been highly esteemed in metallurgy, either alone or mixed with charcoal.

The methods used in coking may be classified as follows:

1. In heaps, as charcoal is made. A portion of the charge is burned to furnish heat for the coking.

2. In permanent kilns. A portion of the charge is burned.

3. In retorts. The peat is protected from contact with the flame or gases, and there is no loss by combustion.

Coking in retorts is the most important of the above methods, since it furnishes a greater yield of coke, and the by-products, such as gases, tar, acetic acid, etc., may be recovered. The Ziegler process, in operation at Oldenburg, Germany, is the most conspicuous example of this type. This plant with its five kilns has been in operation for several years, and has been reported favorably by German Government experts. Another plant of the same kind is in operation at Redkino, in Russia, and at Beuerberg, Germany. The oven consists of vertical retorts made partly of iron and partly of fire-clay. These are heated by an upper and a lower bank of fire-places. The temperature maintained is 600° C. The gas generated in the process is partially consumed under the retorts for coking, and the excess is used under the boilers. This gas furnishes enough fuel save that needed in beginning. The waste heat of the flue gases is used to dry the wet peat preparatory to use. The products of the coking are:[1]

27 per cent. coke.

4.5 per cent tar, contains { Oil, Creosote, Parafin.

31 per cent tar water, contains { Ammonia, Acetic acid, Methyl alcohol.

37 per cent. gas, which contains 15 per cent. methane and 24 per cent. hydrogen.

About 18 tons of coke can be produced in 24 hours. Three tons of peat are required to yield 1 ton of coke. The coke is jet black, resonant when struck, firm, columnar, free from phosphorus and sulphur. Its thermal value is 6776 to 7042 calories. It sells for $9.52 to $11.90 per ton, and is highly prized for smelting iron, copper refining and similar purposes.[2]

An electrical process of coking was in operation in 1898 at Stangfiorden, Norway. The peat briquettes were loosely piled in an iron cylinder about a resistance coil. The dimensions of the cylinder were 3 feet by 1 foot. Nearby water-power was the source of the electric current used in raising the temperature of the coil. The peat was first partially dried and pressed into briquettes, and then thoroughly dried in a tunnel drier before going to the retorts. The by-products recovered were:[3]

Coke, 33 per cent.; tar, 4 per cent.; tar water, 40 per cent.; gas, 23 per cent.

Peat coke or semi-coke has been prepared by passing the air-dried material between heated iron rollers or plates or through hot presses.

[1] Engineering Magazine, 27:821.

[2] Special Consular Report, xxvi, pg. 81.

[3] Hausding, Handbuch der Torfgewinnung, Berlin, 1904, pg. 392.

Peat suitable for the production of coke for metallurgical purposes should be of the dense variety with an ash content not exceeding 10 per cent. The ash, moreover, should not contain either sulphur or phosphorus, both of which, however, are only occasionally found in peat. Hand-cut peat furnishes a brittle product, and in general the greater the condensation peat can undergo in the process of manufacture the better the quality of the coke. The following table gives a comparison of various coked fuels:[1]

	Calorific Value.	*Calorific Intensity.*
Pure carbon (8,080 calories)	1	....
Peat coke,	0.33 — 0.85	2,050 — 2,400
Wood charcoal,	0.64 — 0.97	2,100 — 2,450
Coke, 5% ash,	0.84 — 0.97	2,350 — 2,450

Results of the determinations of fixed carbon or coke of a number of samples of peat from this State are given in Chapter III.

The only place known to the writer where coking of peat is being done in this country is at New Haven, Conn. There a small plant is offering its product at $9.00 per ton for household use, in competition with cannel coal at $12.00 per ton.

Peat gas.—This is said to have been used for the past thirty years at the Notala Steel Works, Sweden. From 13,000 to 16,000 cubic yards of dry-kneaded peat are annually consumed. It costs somewhat more than coal gas, but has the great advantage of containing little, if any, sulphur or phosphorus. It is also reported that gas is used at several places in Europe for heating purposes, and in some glass-melting furnaces. One of the advantages offered by this use of peat is the opportunity to utilize material having a high content of ash. The usual method employed produces what is known as generator gas. The operation is so conducted that a very thick bed of fuel is always present and the combustion takes place in such a way that it is incomplete. Instead of the gaseous products being consumed, *i. e.*, oxidized, a large portion escapes in a combustible form and is

[1] Hausding, Verwetung des Torfes, Berlin, 1904, pg. 408.

conducted to the place where it is to be used as a fuel. In the following table there is a comparison of generator gas made from different fuels.[1]

	Peat.	*Lignite.*	*Bituminous Coal.*
Carbon monoxide,	21%	22%	22%
Hydrogen,	8%	8%	9%
Hydrocarbons,	2%	2%	2%
Nitrogen,	60%	62%	61%
Carbon dioxide,	9%	6%	6%

It has also been proposed to use peat for the generation of water gas, since the large amount of moisture present in the raw material would be a positive advantage. It also seems probable that by the use of the Mond gas process the nitrogen present in peat may be profitably recovered. By this method coal containing 1.45 per cent. of nitrogen will yield 70 to 75 pounds of sulphate per long ton.[2] Peats may readily be had containing this quantity of nitrogen.

The use of peat for the suction gas engine is said to have given satisfactory results. This may prove a most important field of usefulness for this fuel. According to Dr. Gradenwitz, "Even very low grade of material containing 50 per cent. of water proved quite available, warranting the same safety of operation as any other solid material."[3]

The peats used for experiment had the following composition:

	Hannover.	*Grengen in Wurtenburg.*
Water,	32.30	4.78
Ash,	3.26	44.42
Calories,	3,596	2,392
Gas per Kilogram	1.86 cu. meter	1.32 cu. meter
Calorific value of the gas,	1,429	1,350

The consumption of fuel, per effective horse-power hour, was 1.82 pounds and 2.71 pounds, respectively.

[1] Hausding, Verwertung des Torfes, pg. 415.

[2] Journal of the American Chemical Society, Vol. XXVII, 1905, Review of American Research, pg. 578.

[3] Lignite Producer Plants, Scientific American Supplement, Oct., 1905, pg. 24900.

USES IN AGRICULTURE.

The agricultural status of peat of forty or fifty years ago is best given by Dr. S. W. Johnston. According to him, the usefulness of the raw peat depends upon two things: 1, as an amendment, improving the texture of the soil.

a, By its power of absorbing water.

b, By its power of absorbing ammonia.

c, By promoting disintegration and solution of mineral ingredients.

d, By its influence upon the temperature of the soil because of its moisture content.

2, The nitrogen content.

Modern practice, however, would refrain from the direct application of peat to arable soils. It is considered preferable to compost the peat before its application to the land. Occasionally, however, the direct use of peat on the soil may be justified, as, for instance, under circumstances mentioned by Storer, that is to say, on land in a limestone country. Generally, for direct application, it must be weathered for some time in order to destroy its antiseptic qualities and break down its gummy texture. The abundance of concentrated commercial fertilizers renders the use of peat, as it was formerly employed, decidedly unprofitable in most localities.

As a filler.—Of late a number of manufactories have been established for the purpose of preparing peat powder for use as a filler in commercial fertilizers and for mixing with dried blood. This use of peat is quite legitimate for it enables the manufacturers to produce a fertilizer of superior mechanical condition. Fertilizers, and especially those made up of hygroscopic materials, show a strong tendency to form lumps. Under such circumstances it becomes difficult to distribute the fertilizer uniformly on the soil. Where peat is used as a filler, the formation of crusts or lumps is more readily prevented. From the consumers standpoint, the use of peat as a filler is objectionable when the manufacturer includes the peat nitrogen in his guarantee and charges for it the same price paid for high-grade organic nitrogen. Peat furnishes an especially tempting material to use because of the fact that nitrogen is almost always found present. Dr. S. W. Johnson found in the examination of 30 samples from Connecticut that there was a variation from 0.4 per cent. to 2.9 per cent., with an average of 1.5 per cent. In our examination of 123 samples from this State, all contained some nitrogen. The lowest was 0.74 per cent.; the highest was 2.83 per cent. The average is 1.75 per cent. The nitrogen of peat, when the latter is directly applied to the soil, yields but slowly to the various agencies of decay, so that it is clear that its value as a source of food to plants is quite limited. A number of authorities, among them Stutzer, go so far as to deny any value whatever to peat nitrogen when so used. Storer, on the other hand, is inclined to think that a portion of the peat nitrogen may become available within a year. He says:[1] "Generally speaking, by far the larger part of the nitrogen in peat exists in a form which is insoluble in water and comparatively inert, considered as a plant food. In spite of its inertness, it is a matter of familiar observation and experience that the peat nitrogen may be made to contribute to the support of crops, and that it has consequently a considerable money value." According to Nessler,[2] "Although the nitrogenous constituents of peat decompose in the soil more slowly than the altered ossein in meal from steamed bones, they do, nevertheless, in some cases decompose more quickly than the nitrogenous component of wool, or than the ossein in coarse meal from raw bones, or than those in leather meal, either that or from torrified leather." Summing it up, it appears that it is neither better nor worse than many other low-grade nitrogenous materials now freely used by the manufacturers of fertilizers. There are three factories in this State located on Great Meadows, Warren County, engaged in preparing peat for filler in fertilizers.

As a litter.—The surface layer of many bogs consists of the fibrous remains of the vegetation which has grown there. When this material is of a suitable nature and of sufficient thickness it is frequently prepared for use as a litter for stables or as a pack-

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[1] Agriculture, New York, 1897, vol. iii, pg. 79.

[2] Storer, Agriculture, New York, 1897, vol. ii, pg. 85.

ing material, and for many other purposes for which a soft, elastic, absorbent, fibrous material may be used. It is a general practice in Germany, Holland and other peat-producing countries to combine the manufacture of peat litter with the preparation of peat fuel, if both kinds are found in the same bog. According to the official report of the Hannoverian and Oldenburg Railroad administration, about 21,873 tons were sent from stations on that road during the year 1882. This country imports a considerable quantity for use in the stables of large industrial establishments. It sells in New York for $10 to $16 per ton. There is only one factory in this country engaged in the manufacture of this product. This is located at Garret, Indiana. The litter is sold at $1.40 per bale of 225 pounds. A considerable quantity of the peat moss is cut by florists and nurserymen for their own use from convenient bogs, and some is shipped from New Jersey to the nearby cities for the same purpose.

The peat is cut in sods with spades in the same manner as already described. The best time for cutting is in the fall or early winter in order that the freezing may assist in disintegrating the lumps and leave the fibre loose and elastic. In northwest Germany the bog is plowed and harrowed in the fall, after first removing the top growth by burning. Another harrowing is done in the spring. After the peat has been sufficiently dried in the air it is shredded in a machine called a "wolf." This contains a drum covered with teeth, which tear the fibre asunder. The fine stuff, sieved out and called peat mull, has a number of uses. The fibrous material is compressed and baled.

Peat moss suitable for this purpose should be loose, without hard earthy or solid lumps, with a moisture content in the air-dried material not exceeding 20 to 30 per cent., and it should possess a high absorptive power.

The largest present use of the product which we call peat litter is in the stable. Its value depends upon the following properties:

1. It is highly absorbent. A good litter will absorb eight times its own weight of urine. Whereas straw will absorb only three times. Wollny,[1] in a comparative study of equal vol-

[1] Storer, Agriculture, pg. 273.

umes of different litters, found that peat stood first, rye straw fifth.

2. Peat litter not only prevents the waste, but also conserves the value of the urine and excrement by either preventing decomposition or by retaining the ammonia set free. Professor Fleischer is quoted as saying that by the use of such litter in a stable of 10 head of cattle, soluble nitrates to the value of $35 would be retained, which would be lost with straw. The portions of the liquor which are not absorbed have been found to contain less solubles than the original.
3. By reason of its own nitrogen content plus that from the excrement, the litter makes a superior material for manure or for composting.
4. It furnishes a soft, elastic, dry bed, which will keep the animals clean.
5. It keeps the feet of horses in better order, and according to the "Report on the Use of Moss Litter by the Stables of a Prussian Regiment of Uhlans,"[1] "catarrh of the nose and eyes, generally the result of bad air in the stables, are less frequent. Wounds on the legs heal more quickly, inflammation of the glands very seldom occurs and rotting of the frog is almost entirely prevented."
6. Less litter is required than in the case of straw in about the ratio of 1 ton of peat litter equals 2 tons of straw.
7. The air of the stable is kept sweeter. There is less moisture, and leather trappings remain in a better condition.

TEXTILES.

Repeated efforts have been made to utilize a particular kind of a fibrous peat as a raw material in the textile industries. For this purpose the so-called wool-grass is best suited. This growth, the Eriphorum vaginatum, is only occasionally found, and then sometimes at a little depth below the surface. There is no question of the possibility of preparing a soft, flexible, bleachable fibre which will dye well, but of the many methods which have been

[1] Journal of the Royal Agricultural Society, 1893, 763.

advanced it does not appear that any have been able to produce a fibre at a sufficiently low cost. A practical demonstration of the application of this fibre in the arts was made at the Vienna Exposition of 1898, where a building was furnished with carpets and curtains made from this material. Further, at one time the French Government was supplied with mattresses, saddle cloths and blankets of this fibre.

When prepared for surgical uses it is said to have the considerable advantage of possessing a very high absorptive power, which is more gradual than cotton, besides being cheaper and possessing antiseptic properties. According to a writer in the London Lancet,[1] "when peat dressings were used, serum and blood were all absorbed, and even after many days the peat thus soaked was perfectly free from decomposition."

Peat fibre has been suggested as a substitute for cotton waste for oiling machinery.

Attempts to use peat fibre as a paper stock have met with similar difficulties as in its use in fabrics. It has to compete with very cheap raw materials, such as straw and wood. It is troublesome to clean of its dirt, it is difficult to bleach, and requires the addition of fibre from old bagging, ropes, etc. A factory for the manufacture of cardboard has recently been established at Capac, Mich., and is now producing experimentally. The product contains 10 per cent. wood fibre. It is not bleached, but is of a brown color.

Fibrous peat is highly recommended as a packing material because it is elastic and highly absorptive. The latter property is of advantage in packing breakable containers holding liquids.

AN ABSORBENT.

The highly absorbent power of peat in the form of litter has already been mentioned. The powder or mull which separates from the litter during the process of the manufacture of litter possesses this same property in the same high degree. It has a general use in Europe as an absorbing, deodorizing and disinfect-

[1] U. S. Consular Report, 182:262.

ing material for privy vaults. During the cholera epidemic in Hamburg, Germany, in 1892, the use of the mull was made compulsory in the city of Christiania, Norway.

The charred peat powder is said to have been on the market in this country for a number of years as a deodorizing powder.

Owing to the properties mentioned, the mull is an excellent material for packing, especially for perishable articles. It is also recommended for propagating beds either for seedlings or for mushrooms, because it retains its moisture for a long time, and retards putrefaction. Plants may be protected against frost by its use without danger of rust or mildew. Since peat litter is recommended for use in fowl houses because of its deodorizing properties and its power of banishing vermin, it appears that the powder would be equally efficient.

The powder treated with carbolic acid and iodoform has been filled into bags and used for surgical purposes.

It has also been used to absorb the waste molasses of the sugar refineries and the product fed to cattle. Or the mass may be used for a fertilizer, enriched as it is by the presence of a considerable quantity of mineral salts, notably the salts of potassium. Twenty-five parts of the powder will take up one hundred parts of liquor and still be in an easily transportable condition.[1]

The powder has also been used as a filtering medium for oil.

A NON-CONDUCTOR OF HEAT AND SOUND.

The fibre or powder may be used advantageously as a filling between walls wherever sawdust is used, as ice-houses, etc., or between the walls of telephone booths.

A PRESERVATIVE.

This power of peat has been frequently demonstrated in many strange ways. For example, in the year 1830, two human bodies were found in a moor near Halfsleben, Thuringi, who, according to the dress and gold ornaments, must have lived at the time of

[1] Thenius, Verwertung des Torfes, Vienna, 1904, pg. 222.

Julius Cæsar. The flesh and hair were well preserved. In the year 1747, in Lincolnshire, England, the body of a woman was found in a bog at a depth of seven feet. The only change that the flesh had suffered was a brownish discoloration. The sandals on her feet and her clothing bore unmistakable evidence of the centuries that had passed since her body had sunk into the bog. This preservative power in a living moor has been ascribed to the protection from the action of atmospheric oxygen and the presence of humic acid. This interesting property has been utilised in a practical way. Perishable articles, such as fish and fruits, have been packed in peat and sent on long journeys, and after many days, upon arriving at the destination, they have been found in a perfect condition. It is said that potatoes so packed will not sprout.

MISCELLANEOUS USES.

A great number of uses other than those mentioned have been proposed which are interesting, but of little importance. Other and cheaper raw materials are at hand. Among the proposed uses we find the manufacture of alcohol. The process suggested is that of treating the material with sulphuric acid and fermenting the sugar formed and distilling off the spirits. A yield of 62 to 63 litres of alcohol is claimed for 1000 kilograms of peat.

An Austrian inventor proposes to use the fibre in the manufacture of paving material.[1] It is claimed that the artificial wood hardens steadily in moist soil and is well suited for sleepers, holding screws and nails well, and resisting rotting.

A brown dyestuff may also be separated from peat in the process of the manufacture of paper.

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[1] U. S. Consular Report, 66:248, p. 50.

CHAPTER III.

The Testing and the Valuation of New Jersey Peats.

BY C. W. PARMELEE.

The value of a peat as a fuel, and to a certain degree for other purposes, may be determined by three laboratory tests, namely, moisture, ash and calorimetric. If the peat is to be used for litter, providing, of course, that it has the necessary physical conditions, *i. e.*, fibrous, absorbent and free from lumps, the first two tests are applied, while the calorimetric is limited solely to the consideration of the heating power. Further tests of value for specific purposes are those determining the amount of coke to be had and the amount of nitrogen present.

The methods applied in the study of the New Jersey deposits and the results were as follows.[1]

Moisture test.—As previously stated, peat, when taken from the bog, contains a large amount of water, frequently as high as 85 or 90 per cent. When exposed to the air a large portion of this water evaporates, but there still remains some which cannot be driven out, except at a high temperature. The method used in the laboratory was to air dry the samples by spreading them out in thin layers, exposing them for several days to the room temperature. A small portion, representing an average sample, was carefully taken and ground through a mill to such a fineness that it would all pass through a 100-mesh sieve. Two watch glasses ground on the edges to fit tightly together, with a brass spring to hold them firmly, were accurately weighed, and then five grams of the powdered sample were weighed and placed in one glass. This was placed in an oven which was kept at a temperature of 105°C and the sample left there until, by repeated drying and weighing, no further loss of moisture was found. This

[1] In this work, credit is given to Mr. Robt. W. Cobb and Mr. Geo. B. Ford, students of Rutgers College, who furnished valuable assistance.

operation generally required 96 hours. The weighings were always undertaken with the cover glass securely clamped over the sample by means of the spring. This was found necessary because of the very hygroscopic nature of the dry powder. The samples showed a wide range. The lowest amount of moisture in an individual sample was 6.09 per cent. The highest was 28.14 per cent. Considering the whole number of samples, it may be said that as the ash content increases the moisture content is lower; although the converse is not true, that a high moisture content indicates a low ash. It is not safe to apply the general rule to particular cases. The average moisture content of 107 samples, having 50 per cent. or less of ash was found to be 15.52 per cent. Hausding[1] reports the average of 16 European varieties, as determined by various chemists, as 16.58 per cent. The moisture content of a good air-dried peat should not exceed 25 per cent.

Ash test.—The oven-dried sample was kept in a tightly corked test tube, and for the ash test approximately 1 gram was emptied into a weighed platinum crucible. The exact amount taken was determined by the difference in weight of the test tube before and after emptying the small portion. The ignition was carried out over a gas flame in the usual way, and the residue weighed as ash. From the result was calculated the amount of ash on the basis of the air-dried material. The samples examined varied from 5.04 per cent. to over 50 per cent. ash. Those containing 50 per cent. or above may be considered as muck, rather than as peat. A good fuel peat should not have over 25 per cent. of ash, although those having a greater amount may still be found useful for use in gas producers. Thorp[2] gives the average of ash as 6 per cent. to 12 per cent. Roberts-Austin[3] says that it rarely falls below 10 per cent.

Calorimetric test.—The purpose of the calorimetric test is to determine the actual amount of heat which any fuel will furnish. The method of operation is to burn completely a small sample of fuel under such conditions that the heat generated will be ab-

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[1] Handbuch der Torfgewinnung, Berlin, 1904, pg. 18.

[2] Dictionary of Applied Chemistry, vol. II, pg. 158.

[3] Introduction to the Study of Metallurgy, London, 1902, pg. 223.

sorbed by a known volume of water. The rise in temperature is observed and used as the basis of calculation. The unit of heat which we use in reporting the results may be the calorie or the British thermal unit (B. T. U.). The calorie is the amount of heat necessary to raise 1 kilogram of water (2.2 pounds) 1°C. The British thermal unit is the amount of heat necessary to raise 1 pound of water 1°F. The British thermal units may be converted into calories by multiplying by 5/9.

The calorimetric tests of the New Jersey peats were obtained by the use of the Standard or Parr calorimeter. This apparatus consists of a hollow cylinder or bomb which may be tightly closed at either end. For a test, the bomb is charged with a small quantity of the powdered dry sample, crushed to pass through a 100 mesh. The quantity varied from ½ to ¾ of a gram. This was mixed with sodium peroxide and potassium chlorate which furnished oxygen for combustion. The bomb, after filling, was immersed in a large cylinder containing a quantity of water—two liters. The large cylinder was placed in a fibre bucket having a wall between the large cylinder and the outer wall of the bucket. This arrangement provided an insulating air space between the large cylinder and the wall, and another between the wall and the bucket, which provision prevented temperature changes due to external causes. The bomb, when immersed, stood vertical, centered upon a pin so as to rotate easily. Four vanes attached to the sides, and an axle or stem of small size projected from the top of the bomb upwards. On the upper part of the stem a small pulley was attached, which was driven by a belt from a small motor. Within the bomb there were two metal poles attached to the cover and connected by a loop of fine iron wire of sufficient length to dip into the charge. This loop was heated to incandescence by the passage of an electric current, which thus ignited the charge. The completeness of the combustion is assured by the presence of the oxidizing chemicals mixed with the sample. The heat generated by this reaction radiates from the bomb and heats the surrounding water. By means of a delicate thermometer the rise in the temperature of the water could be noted and the calorific value calculated.

Since the determinations were made on samples dried at a temperature of 105°C, the results are higher than may be expected from the air-dried peat. The advantage of this method however is that all the samples may be more accurately compared since the amount of moisture remaining after air drying is dependent upon local conditions. Only those samples having 25 per cent. or less of ash were tested. All tests were run in duplicate and the results in all but two instances differed by less than one division on the thermometer used. That is, less than $^1/_{20}$ of 1° F. In many instances the calculated difference was less than $^1/_{200}$ of 1° F.

The results obtained by the use of this apparatus have not been checked by comparison with the results on the same sample using other types of the calorimeter. Since however it is known that this instrument gives accurate results with very similar fuels, such as lignite, brown coal, napthalene, etc., it is quite unlikely that the error from this source is greater than the experimental.

In the table given below the results are gathered into three classes according to the ash content. It will be noticed that high calories accompany low ash with few exceptions. These exceptions would probably be explained by an ultimate chemical analysis.

Coking test[1].—This test was made for the purpose of securing data which may be of use in selecting suitable material for the production of a substitute for wood charcoal and for the information which they furnish regarding the fixed-carbon content. The results may be grouped under the same classes as arranged according to the ash content. Upon inspection of the table, it will be seen that peats with high-ash give high coke, which of course is due to the fact that the coke contains the ash.

The method employed was to heat one gram of the air-dried powdered peat in a platinum crucible for 3½ minutes over a bunsen burner with a low flame. At the expiration of that time the flame was turned on full for a like time and then the crucible was cooled and weighed.

The results of these tests are given in the tables below. The first group includes those in which the ash was less than 10 per cent; the second group, those with ash between 10 and 15 per cent; the third group those having between 15 and 25 per cent.

[1] These tests were made by Mr. R. B. Gage, chemist of the Survey.

of ash. The numbers in the first column are the same as those used on the map accompanying the report. In Chapter IV the various peat bogs here enumerated are described.

High-Grade Peat. Ash Ranging Between 0 and 10 Per Cent.

Locality.[1]	*Locality No.*	*Sample No.*	*Ash.*	*Calories.*	*Coke.*
Allendale,	5 ab	3	5.04	5876	29.20
Sussex,	20 o	44	7.27	4589	36.11
Stockholm,	26 a	58	5.75	5284	35.31
Dunker Pond,	26 o	59	6.24	5265	34.30
Mt. Hope,	29 d	68	5.14	5645	43.85
" "	29 m	70	9.47	5159	38.76
Ironia,	32 i	72	9.34	5488	37.64
Bog & Vly,	47 g	102	7.28	5378	37.08
Southtown,	58 a	112	6.54	5098	34.36
Westwood,	4 c	115	7.30	5203	33.51
Kerr's Corner,	58 e	117	8.01	5120	32.62
" "	58 k	118	7.72	4982	36.70
Danville,	56 a	119	8.62	4953	33.14
Franklin Lake,	63 f	130	8.34	5521	36.28

Medium-Grade Peat. Ash 10 to 15 Per Cent.

Locality.	*Locality No.*	*Sample No.*	*Ash.*	*Calories.*	*Coke.*
East Newton,	12 d	15	10.34	5187	33.09
Lafayette,	15 j	22	10.45	5004	34.91
Sussex,	19 m	34	11.38	4946	37.95
"	25	46	14.59	4878	39.77
Van Sickle,	22 a	47	13.04	4986	40.01
Rockport,	22 b	48	11.36	4908	37.53
Vernon,	23 q	54	14.40	4707	36.92
Ironia,	32 j	73	14.26	5193	41.78
Rockaway,	33 g	75	10.54	5057	32.25
Black Meadows,	37 d	83	12.43	4791	38.81
Great Meadows,	37 e	84	10.84	4885	37.45
Great Swamp,	38 l	89	13.86	4947	40.09
Troy Meadows,	41 s	92	10.60	5272	37.80
" "	41 d	93	13.44	4901	38.96
Pequannock,	45 c	98	12.69	4789	39.15
Danville,	56 g	110	11.04	5234	36.90
"	56 z	111	13.31	4562	40.26
Southtown,	58 b	116	13.42	4795	36.83
Woodbridge,			10.40	4926	34.40
Buttsville,	61 e	125	10.41	4863	34.51
Pompton Plains,	63 e	128	13.64	4767	41.55

[1] The location of the peat swamps is shown on the map, Plate XXIX, accompanying this report.

Low-Grade Peat. Ash 15 to 25 Per Cent.

Locality.	*Locality No.*	*Sample No.*	*Ash.*	*Calories.*	*Coke.*
Allendale,	5 a	2	18.89	4388	41.57
Hackensack,	9 c	9	20.74	4312	46.75
Springdale,	10 e	11	24.43	4041	
East Newton,	12 e	16	23.78	4212	43.73
Lafayette,	15 e	19	23.29	4092	44.85
Sparta Junction,	15 j	23	20.88	4026	40.20
Sussex,	19 g	31	20.11	4165	41.90
Beemersville,	21 a	35	17.23	4814	41.40
"	21 e	36	20.82	4199	39.38
"	21 e	40	23.03	4212	44.35
Wykertown,	21 i	42	22.81	4377	44.18
Harmonyvale,	25 g	57	23.25	4027	42.60
Wyckoff,	27 b	60	24.70	4049	45.90
Berkshire Valley,	27 h	61	18.21	4387	46.26
" "	28 b	63	24.95	4276	47.10
" "	28 c	64	23.24	4456	46.01
" "	28 c	65	20.10	4800	41.95
" "	28 h & l	66	24.38	4300	45.20
Mount Hope,	29 c	67	16.44	5117	42.65
Kenvil,	31 h	71	19.27	4285	42.94
Rockaway,	33 g	76	16.46	5049	41.10
Chester,	32 l	94	17.61	4575	42.29
Dismal Swamp,	50 b	105	20.43	4335	42.35
Newark Meadows,	53 k	108	20.06	4347	43.55
Johnsonburg,	57 a	120	15.82	4317	36.35
Mt. Herman,	60 e	124	16.71	4568	36.46
Pigeon Swamp,	62 k	126	20.40	4539	37.25

Nitrogen test.—All the samples were examined by the Kjehldahl method for the total nitrogen present. Three grams of the powdered air-dried sample were found sufficient. These results may be useful for the manufacturer of filler for fertilizer, and the gas manufacturer using peat either in a by-product coking oven or with the Mond producer or similar systems for the recovery of the nitrogen. In our examination of 123 samples from this state, the lowest amount of nitrogen found was 0.74 per cent., the highest figure was 2.83 per cent. The average was 1.75 per cent. The results of the analyses are given in the table below.

Litter peat.—Only one sample of peat was received at the laboratory which appeared at all suitable for this purpose. This was sample No. 112, from Southtown and this is rather brittle.

The following samples seemed suitable for use as packing material:

No. 36, Beemerville,
No. 75, Rockaway,
No. 61, Berkshire Valley,

TABLE SHOWING ALL TESTS OF NEW JERSEY PEATS.

Locality.	Locality Number.	Sample Number.	Moisture, 105° C, Per Cent.	Ash, Air-dried Sample, Per Cent.	Calories.	British Thermal Units.	Nitrogen, Per Cent.	Coke, Per Cent.	Fixed Carbon, Per Cent.	Volatiles, Per Cent.
Pequannoc,	....	1	18.09	10.91	4966	8938	2.18	38.23	27.20	61.77
Allendale,	5 a	2	15.00	18.89	4388	7898	2.13	41.57	22.68	58.43
Allendale,	5 ab	3	14.11	5.04	5896	10611	2.17	29.20	24.16	70.80
Sprout Brook,	8 a & b	4	16.42	64.17	.....	.....	1.60	.....	.....	.....
Sprout Brook,	8 b	5	30.70	29.12	.....	.....	1.90	.....	.....	.....
Sprout Brook,	8 c	7	9.08	50.43	.....	.....	0.95	.....	.....	.....
Hackensack,	9 b	8	4.93	72.49	.....	.....	.....	.....	.....	.....
Hackensack,	9 c	9	14.20	20.74	4312	7761	1.87	46.75	26.01	53.25
Springdale,	10 b	10	7.25	57.55	2238	4028	1.31	.....	.....	.....
Springdale,	10 e	11	13.28	24.43	4041	7274	2.40	.....	.....	.....
Buckmire Pond,	11 a	12	6.31	67.70	.....	.....	0.82	.....	.....	.....
Newton,	12 a	13	7.20	64.24	.....	.....	1.05	.....	.....	.....
Newton,	12 a	14	11.89	30.54	.....	.....	1.70	.....	.....	.....
East of Newton,	12 d	15	14.16	10.34	5187	9338	2.24	33.09	22.75	66.91
East of Newton,	12 e	16	12.84	23.78	4212	7582	2.06	43.73	19.95	56.27
Sparta,	13 ef	17	8.77	53.87	.....	.....	1.52	.....	.....	.....
Roseville,	14 e	18	7.49	61.80	.....	.....	0.88	.....	.....	.....
Lafayette,	15 e	19	12.26	23.29	4092	7365	2.01	44.85	21.56	55.15
Lafayette,	15 e	21	9.64	26.12	.....	.....	1.58	.....	.....	.....
Lafayette,	15 b	22	18.27	10.45	5004	9007	2.83	34.91	24.46	65.09
Sparta Junction,	16 a	23	27.56	20.88	4026	7247	1.99	40.20	19.32	59.80
Sparta Junction,	16 a	24	22.34	32.76	.....	.....	1.65	.....	.....	.....
Sparta Junction,	16 d	25	9.73	29.22	.....	.....	2.37	.....	.....	.....
Sparta Junction,	16 e	26	6.66	46.83	.....	.....	1.53	.....	.....	.....
Washingtonville,	17 a	27	16.06	37.26	.....	.....	1.42	.....	.....	.....
Washingtonville,	17 e	28	14.28	33.72	.....	.....	1.20	.....	.....	.....
Sussex,	20 e	29	13.84	26.23	.....	.....	2.34	.....	.....	.....
Sussex,	20 f	30	9.73	46.24	.....	.....	1.78	.....	.....	.....
Sussex,	20 g	31	24.30	20.11	4165	7496	1.78	41.90	21.79	58.10
Sussex,	20 h	32	12.89	51.06	.....	.....	1.30	.....	.....	.....
Sussex,	20 l	33	10.14	49.09	.....	.....	1.59	.....	.....	.....
Sussex,	20 m	34	15.99	11.38	4946	8902	2.34	37.95	26.57	62.05
Beemerville,	21 a	35	14.12	17.23	4814	8667	1.53	41.40	24.17	58.60
Beemerville,	21 e	36	14.20	20.82	4199	7558	1.86	39.38	18.56	60.62
Beemerville,	21 e	40	12.50	23.03	4212	7582	1.77	44.35	21.32	55.65
Beemerville,	21 g	41	10.69	38.08	.....	.....	1.65	.....	.....	.....
Wykertown,	21 i	42	14.55	22.81	4377	7879	1.71	44.18	21.37	55.82
Sussex,	20 o	43	14.45	28.69	.....	.....	2.10	.....	.....	.....
Sussex,	20 o	44	7.57	7.27	4589	8260	2.00	36.11	28.84	63.89
Sussex,	20 st	45	9.50	56.35	.....	.....	1.48	.....	.....	.....
Sussex,	20 t	46	16.66	14.59	4878	8779	2.13	39.77	25.18	60.23
Van Sickle,	22 a	47	14.01	13.04	4986	8975	2.25	40.01	26.97	59.99
Rockport,	22 b	48	17.52	11.36	4908	8834	2.02	37.53	26.17	62.47
Vernon,	23 a	49	12.98	38.69	.....	.....	1.71	.....	.....	.....
Vernon,	23 e	50	12.55	46.27	.....	.....	1.76	.....	.....	.....
Vernon,	23 h	51	11.09	50.15	.....	.....	1.04	.....	.....	.....
Vernon,	23 j	52	13.74	36.91	.....	.....	1.79	.....	.....	.....
Vernon,	23 r	53	17.74	25.26	.....	.....	2.46	.....	.....	.....
Vernon,	23 o	54	18.55	14.40	4707	8473	2.73	36.92	22.52	63.08
Beaver Run,	25 d	55	15.70	25.86	.....	.....	2.03	.....	.....	.....
Beaver Run,	25 e	56	14.42	28.08	.....	.....	1.90	.....	.....	.....
Harmonyvale,	25 g	57	16.66	23.25	4027	7249	2.20	42.60	19.35	57.40
Stockholm,	26 a	58	17.40	5.75	5284	9510	2.10	35.31	29.56	64.69
Dunker Pond,	26 d	59	17.80	6.24	5265	9482	2.11	34.30	28.06	65.70
Wyckoff,	27 b	60	16.77	24.70	4040	7287	1.98	45.90	21.20	54.10
Berkshire Valley,	27 h	61	15.43	18.21	4387	7897	1.80	46.26	28.05	53.74
Berkshire Valley,	28 a	62	11.87	37.42	.....	.....	1.78	.....	.....	.....
Berkshire Valley,	28 b	63	13.87	24.95	4276	7697	1.79	47.10	22.15	52.90
Berkshire Valley,	28 c	64	14.69	23.24	4456	8021	1.61	46.01	22.77	53.99

Locality.	Locality Number.	Sample Number.	Moisture, 105° C., Per Cent.	Ash, Air-dried Sample, Per Cent.	Calories.	British Thermal Units.	Nitrogen, Per Cent.	Coke, Per Cent.	Fixed Carbon, Per Cent.	Volatiles, Per Cent.
Berkshire Valley, ...	28 c	65	14.04	20.10	4800	8640	1.54	41.95	21.85	58.05
Berkshire Valley, ...	28 hl	66	13.63	24.38	4300	7739	1.48	45.20	20.82	54.80
Mt. Hope, ...	29 c	67	14.32	16.44	5117	9211	1.54	42.65	26.21	57.35
Mt. Hope, ...	29 d	68	15.26	5.14	5645	10162	1.27	43.85	38.71	56.15
Mt. Hope, ...	29 k	69	13.60	27.46	.....	.....	1.60	......	......	......
Mt. Hope, ...	29 w	70	16.27	9.47	5159	9287	1.87	38.76	29.29	61.24
Kenvil, ...	31 h	71	15.79	19.27	4355	7803	2.34	42.94	23.67	57.06
Ironia, ...	32 i	72	14.59	9.34	5488	9877	1.17	37.64	28.30	62.36
Ironia, ...	32 j	73	13.69	14.26	5193	9347	1.30	41.78	27.52	58.22
Chester, ...	32 q	74	11.80	31.40	.....	.....	1.42	......	......	......
Rockaway, ...	33 g	75	16.20	10.54	5057	9102	2.11	32.25	21.71	67.75
Rockaway, ...	33 g	76	14.17	16.46	5049	9088	1.88	41.10	24.64	58.90
Mountain View, ...	46	77	10.44	51.65	.....	.....	1.22	......	......	......
Chatham, ...	35 l	80	15.21	33.07	.....	.....	1.50	......	......	......
Chatham, ...	35 lk	81	14.82	53.87	.....	.....	0.98	......	......	......
Great Swamp, ...	36 i	82	12.88	34.68	.....	.....	1.59	......	......	......
Black Meadows, ...	37 d	83	17.80	12.43	4791	8624	2.05	38.81	26.38	61.19
Great Meadows, ...	37 c	84	17.81	10.84	4885	8794	1.88	37.45	26.61	62.55
Troy Meadows, ...	41 h	85	11.42	49.18	.....	.....	1.25	......	......	......
Great Swamp, ...	38 b	86	7.58	66.40	.....	.....	0.74	......	......	......
Great Swamp, ...	38 f	87	9.59	50.48	.....	.....	1.26	......	......	......
Great Swamp, ...	38 i	88	11.80	45.92	.....	.....	1.34	......	......	......
Great Swamp, ...	38 l	80	16.19	13.86	4947	8905	2.07	40.09	26.23	59.91
Troy Meadows, ...	41 i	90	13.27	39.02	.....	.....	1.36	......	......	......
Troy Meadows, ...	41 l	91	13.94	32.61	.....	.....	1.65	......	......	......
Troy Meadows, ...	41 s	92	17.54	10.60	5272	9490	1.46	37.80	27.20	62.20
Troy Meadows, ...	41 b	93	17.86	13.44	4901	8820	1.98	38.96	25.52	61.04
Long Meadow, ...	42 a	94	17.89	17.61	4575	8237	1.80	42.29	24.68	57.71
Hatfield Swamp, ...	42 q	95	13.15	39.89	.....	.....	1.40	......	......	......
Hanover	43 a	97	14.94	29.41	.....	.....	1.74	......	......	......
Pequannoc, ...	45 c	98	19.84	12.69	4789	8620	1.61	39.15	26.46	60.85
....	....	100	11.68	36.87	.....	.....	1.33	......	......	......
Bog and Vly, ...	47 e	101	15.26	25.19	.....	.....	1.58	......	......	......
Bog and Vly, ...	47 g	102	17.25	7.28	5378	9680	2.16	37.08	29.80	62.92
Cranford, ...	48 c	103	14.18	32.37	.....	.....	1.50	......	......	......
Rahway River, ...	48 f	104	14.73	26.66	.....	.....	1.76	......	......	......
Dismal Swamp, ...	50 b	105	19.02	20.43	4335	7803	1.70	42.35	21.92	57.65
Newark Meadow, ...	52 b	106	21.33	50.86	.....	.....	0.86	......	......	......
Newark Meadow, ...	52 b	107	11.00	44.34	.....	.....	1.24	......	......	......
Newark Meadow, ...	53 k	108	18.59	20.06	4347	7833	1.92	43.55	23.49	56.45
Elizabethport, ...	54 e	109	9.02	64.66	.....	.....	0.78	......	......	......
Danville, ...	56 f	110	20.84	11.04	5234	9421	1.98	36.90	25.86	63.10
Danville, ...	56 z	111	27.70	13.31	4562	8213	1.96	40.26	26.95	59.74
Southtown, ...	58 a	112	24.07	6.54	5098	9177	1.62	34.36	27.82	65.64
Bear Swamp, ...	3 g	113	9.03	55.01	.....	.....	1.28	......	......	......
Westwood, ...	4 b	114	12.79	33.38	.....	.....	1.82	......	......	......
Westwood, ...	4 c	115	16.90	7.30	5203	9365	2.11	33.51	26.21	66.49
Southtown, ...	58 b	116	20.90	13.42	4795	8632	2.52	36.83	23.41	63.17
Kerrs Corners, ...	58 e	117	22.13	8.01	5120	0215	2.35	32.62	24.61	67.38
Kerrs Corners, ...	58 k	118	21.89	7.72	4982	8968	1.59	36.70	28.98	63.30
Danville	56 a	119	28.14	8.62	4953	8915	2.45	33.14	24.52	66.86
Johnsonburg, ...	57 a	120	21.63	15.82	4317	7772	2.27	36.35	20.53	63.65
Greenville, ...	59 d	121	16.39	42.11	.....	.....	1.58	......	......	......
Greenville, ...	59 g	122	6.09	42.80	.....	.....	1.88	......	......	......
Febletown, ...	60 a	123	14.72	40.81	.....	.....	1.56	......	......	......
Mt. Herman, ...	60 e	124	22.68	16.71	4568	8224	2.13	36.46	19.75	63.54
Buttsville, ...	61 e	125	16.82	10.41	4863	8753	2.65	34.51	24.10	65.49
Pigeon Swamp, ...	62 k	126	24.25	20.40	4539	8169	1.72	37.25	16.85	62.75
Pompton Plains, ...	63 c	127	13.82	38.50	.....	.....	1.48	......	......	......
Pompton Plains, ...	63 e	128	19.17	13.64	4767	8579	2.11	41.55	27.91	58.45
Pompton Plains, ...	63 e	129	11.36	52.19	.....	.....	1.34	......	......	......
Franklin Lake, ...	63 f	130	12.50	8.34	5521	9938	2.03	36.28	27.94	63.72
Woodbridge Mfg. Co., Danville, ...	....	.....	18.82	10.40	4926	8865	2.62	34.40	24.00	65.60
Monmouth Junction, ...	....	.....	7.64	46.71	.....	.....	0.94	......	......	......

CHAPTER IV.

Distribution of Peat in Northern New Jersey.

BY W. E. MCCOURT.

All the swamps in the northern part of the State were visited, with the exception of those in the mountainous sections of Passaic and Sussex counties. These were omitted because of their great distance from a railroad. There are a number of peat bogs of a good quality, as the laboratory tests on the samples collected have shown (p. 261), especially some of the areas in Bergen, Morris, Sussex and Warren counties. Some of these larger areas are the Sprout Brook Meadow in Bergen County; Black Meadows, Troy Meadows, and the Bog and Vly Meadows in Morris County; the Vernon and Sussex Meadows in Morris County and the Pequest Meadows in Warren County. One company was in operation on the Bog and Vly Meadows, manufacturing fuel, and three companies are located on the Pequest Meadows, using the peat as a filler in fertilizer.

Detailed descriptions of all the swamps visited, with the results of the laboratory examination of the samples collected, are given on the following pages. The location of all swamps examined is shown on the map, Plate XXIX, accompanying this report.

BERGEN COUNTY.

There are a number of swamps in this county, small ones scattered over the northern and western parts and the large marshes between Hackensack and Newark, bordered by the Hackensack and Passaic rivers.

Loc. 65. This includes a few very small swamps scattered between Franklin Lake and Midland Park, in the southwestern part of the county. The small wooded area just west of Franklin Lake and bordering a small stream showed a 5-foot deposit of an excellent peat, brown and fibrous, the laboratory examination of which gave the following results:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
130	65 f	12.50	36.28	27.94	63.72	2.03	8.34	9.51	5521	9938

The other few areas at the border line of the county, 2 miles west of Midland Park, gave no evidence of the presence of peat.

Loc. 27. This locality, also, includes a number of small swamps scattered from Crystal Lake to Wyckoff, along the New York, Susquehanna and Western Railroad, and bordering small streams 1 mile north and northeast of Camp Gaw. In the two areas west of the road 1½ miles north of Wyckoff, 2 feet of a fibrous brown peat was encountered. The results of the tests on a sample from this locality are listed below:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
60	27 b	16.77	45.90	21.20	54.10	1.98	24.70	29.66	4049	7287

Three-fourths of a mile west is another small peat swamp. The other areas showed no peat, with the exception of a very small swamp just west of Camp Gaw, where there is a deposit of a very fibrous material, 1 foot in depth, which gave the results in the laboratory examination as follows:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash oven dry.	Calories, Oven	B.T.U. dried.
61	27 h	15.43	46.26	28.05	53.74	1.80	18.21	21.54	4387	7897

Loc. 6. This locality centres about Ramseys, where there are some wooded lowland areas along the streams. All the swamps were visited, but in none was there any indication of anything else but a clay soil.

Loc. 5. This is a peat bog just northeast of Allandale, covering about 160 acres, in which there is a deep deposit of an excellent brown, fibrous variety, the upper 12 inches of which, however, is quite black. The owner of the bog, Mr. H. J. Appert, estimates its greatest depth at over 15 feet. At one time the peat from this bog was cut and used as a fuel. The peat was put into a mill, where it was beaten and ground in water until its fibres were thoroughly broken up, and the whole reduced to a fine pulp. The pulp was drawn off and allowed to settle and drain, and it was then dried in the sun. The operations were not very extensive, and the bog has not been worked since 1875 or thereabouts. An analysis of this peat is given below:[1]

Organic matter,	83.80
Water,	11.70
Oxide of iron and alumina,	0.42
Lime,	1.46
Magnesia,	0.17
Potash,	0.08
Phosphoric acid,	0.05
Sulphuric acid,	0.74
Carbonic acid,	0.04
Silica,	1.07
	99.53
Elements of ammonia,	2.2
Ash,	4.50

The results of the laboratory examination on two samples from this bog are given below:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
2*	5 a	15.00	41.57	22.68	58.43	2.13	18.89	22.24	4388	7898
3†	5 a	14.11	29.20	24.16	70.80	2.17	5.04	5.83	5896	10611

* Upper 1 foot, black. † Lower 4 feet, brown.

Loc. 3. Bear Swamp, 1½ miles west of Montvale, and the swamp area along Pascack Creek from Westwood to Montvale

[1] Cook, Geology of New Jersey, 1868, pp. 699, 700 and 481.

are included in this locality. This latter is merely a floodplain swamp, and no peat was found, the soil being sandy down to 4 feet.

Bear Swamp, owned by Michael White, is densely wooded, and at times some of the muck has been dug and used to spread over other land as a fertilizer or enricher. The sample taken from this locality appears to be a fibrous, gray clay, and gave the following results in the laboratory examination:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
113	3 g	9.03	1.28	55.01	60.48

Loc. 4. This locality embraces the swamps along Musquapsink Creek, from Westwood west 2 miles and 1½ miles along the northern branch of this creek. A sample was taken at the junction of the creek with the Washington township line, where the section showed 2 feet of muck underlain by a sandy clay. The dry sample, however, proved to be merely a gray clay containing some fibre, as the tests listed below indicate. The entire area is but a clayey floodplain.

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
114	4 b	12.79	1.82	33.38	38.26

The elongated swamp lying in the hills 2½ miles west of Westwood is a densely wooded clay swamp, and the small area along the Saddle River, 1½ miles east of Ridgewood, is another clayey floodplain area.

Loc. 2. This embraces a rather large swamp area along a branch of the Hackensack River from Randell, east of Closter, northward past Norwood and Neuvy to the State line. The area to the east of Closter is a rather wet swamp, containing about 2 feet of muck, too earthy, however, to be a peat. The area from Randell to Norwood showed a covering of black sandy muck soil. The extensive area to the northward was quite dry, and all borings showed only a sandy soil, while the wetter and more mucky portions are limited to the immediate borders of the stream. The large area marked as swamp on the map along the Hackensack River at the State line was not visited, but the character of the other swamps in the vicinity leads us to suspect that no peat is present.

Loc. 8. This includes the immediate wet areas bordering the Saddle River from the fork of Hohokus Creek south to near Rochelle Park, the Sprout Brook area from New Milford road to Rochelle Park and a small area northeast of Lodi. Along the Saddle River no peat was found; the areas are merely clayey floodplains. The entire area north of the River Edge road, which includes about ¼ of a square mile, and lies in a hollow through which flow the head waters of Sprout Brook, is covered to a depth exceeding 5 feet by a good variety of peat. A sample taken from a boring at the extreme north of this area gave the following results:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
115	....	16.90	33.51	26.21	66.49	2.11	7.30	8.76	5203	9365

South of the River Edge road the peat seems to be more of a muck than a true peat, as the following results show:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
4 just no. of road	8 a	16.42	1.60	64.17	76.94
5 north of 4	8 b	13.70	1.90	29.12	33.69
7 ¼ mile s. of road	8 c	9.08	0.95	50.43	54.47

The rest of the area along this brook, from Spring Valley to Rochelle Park, seemed to be made up of a clay soil. In the small swamp north of Lodi the soil is very wet, but it is merely a sandy muck.

Loc. 9. In this locality are included the meadows extending from Hackensack south to Woodridge and east to within 1 mile of Hackensack River and the swamps along the west side of the river. This large area covers about 2 square miles, is grown over with grass and cat-tails, and seems to be entirely underlain by a slight deposit of white sand, under which there is a blue clay. There is, however, a varying thickness of a black muck on top, in some places reaching a depth of 3 feet. A sample taken near the Lodi, Little Ferry road, in the swamp, gave results as follows:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
9	9c	14.20	46.75	26.01	53.25	1.87	20.74	24.17	4312	7761

The areas along the river are clay swamps.

Loc. 52. This locality includes the Newark-Hackensack marsh lands, bounded on the south by the Passaic River, on the east by the Hackensack River, on the north by the road from Woodridge to Little Ferry, and on the west by the high land. This area is similar to the Newark-Eliazbeth Meadows in Essex County, and the Jersey Meadows in Hudson County. Along the waterways the marsh is mainly a fine bluish mud, and near the shore this mud contains a large amount of grass stems and roots.

Loc. 53. This is a small portion of the large Jersey Meadow east of the Hackensack River, from Dellman's Creek to Nordhoff, made up of a bluish mud covered by the characteristic marsh grasses.

ESSEX COUNTY.

Loc. 51. The Newark-Elizabeth Meadow, bordering Newark Bay, is another example of the marsh-swamp type. Near the margins the soil is mainly a blue clay containing some grass fibre while further out it is largely made up of the accumulated vegetable remains, with some mineral matter. A section about ½ mile north of Elizabethport and east of the Newark Branch of the Central Railroad of New Jersey showed 2 feet of a deposit consisting mainly of a mass of this grass, underlain by 2 feet of a more compact mass containing considerable clay. The two samples listed below are from this place;

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
106 upper 2 feet	51 b	21.53	0.86	50.86	64.67
107 lower 2 feet	51 b	11.00	1.24	44.34	49.83

The other swamps in this county border the Passaic River from Chatham to Two Bridges. We shall discuss them in the order of localities along the river from Chatham.

Loc. 35. This embraces the areas from Chatham to ½ mile north of Columbia Bridge. This entire area can be said to be practically void of peat, for most of the borings showed a blue clay, with the exception of a small area at Columbia Bridge where there are 4 feet of a mucky soil containing some fibre. The laboratory examination, however, showed these to be a muck;

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
80 upper 4 feet	35 l	15.21	1.50	33.07	39.00
81 lower 1 foot	35 l	14.82	0.98	53.87	63.26

Loc. 43. This includes the swamps from ½ mile north of Columbia Bridge to 1 mile south of Swinefield Bridge. The small swamp east of Hanover, used for pasture land, contains a deposit of what seemed a good peat, brown and fibrous and over 5 feet in depth, but the results of the tests in the laboratory show that it is not a good fuel variety;

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
97	43 a	14.94	1.74	29.41	34.48

The narrow areas bordering the river showed only a clay.

Loc. 42. This locality includes Hatfield Swamp, from Swinefield Bridge to Pine Brook, Long Meadow east of Pine Brook, and Little Piece Meadow from Pine Brook to Horseneck Bridge. Hatfield Swamp is densely wooded in places and only at the southern end was there encountered any muck. The soil for the most part is a clay. The muck at the southern end is 3 feet in depth and overlies a clay. The sample collected at this place gave the following results:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
95	42 q	13.15	1.40	39.89	45.90

Long Meadow is a swamp about 2 miles long and ½ mile wide, east of Pine Brook, partly wooded and the rest overgrown with brush. The meadow is made up of a brown, fibrous variety of peat, running deeper than 5 feet, with a 1-foot covering of black peat. A sample from the southeastern corner gave the following results in the laboratory:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
94	42a	17.89	42.29	24.68	57.71	1.80	17.61	21.44	4575	8237

In the Little Piece Meadow all of the borings showed a sandy loam of varying depth, underlain by a blue clay.

Loc. 46. In the Great Piece Meadow, which occupies a large tract from Horseneck Bridge to Two Bridges, none of the borings gave any evidence of peat. The soil is more or less clayey and is in most cases underlain by a sand. There are some low areas, however, in which the top soil is black and mucky, but it is not a peat.

HUDSON COUNTY.

In this county we have the Jersey Meadows, bordering the Hackensack River as far north as Dellman's Creek and bounded on the east by the Jersey Heights. (Loc. 53). This marsh is just like the other marshes in this vicinity and contains no fuel peat; it is largely a blue mud which, near the margins, contains the grass fibre as in the other marshes.

A sample collected in the small marsh at Fairview gave the results listed below;

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
108	53k	18.59	43.55	23.49	56.45	1.92	20.06	24.64	4347	7833

MERCER COUNTY.

There are, probably, no deposits of any note in this county. The only swamp visited is Bear Swamp, along the tracks of the Pennsylvania Railroad, south of Lawrence Station and about five miles northeast of Trenton. (Loc. 1.) This is a tract embracing about 500 acres, partly wooded and the rest covered with grass and cat-tails. All of the borings showed a dark humus sandy soil of 6 inches depth underlain by a white sand. Where the railroad crosses the center of the swamp there is a wet area covered with moss, and here peat may be in the process of formation.

MIDDLESEX COUNTY.

Loc. 54 and Loc. 55. Along the Raritan River, Arthur Kill and Rahway River there is a tract of shore-marsh swamp covered with marsh grasses. The soil is a blue clay containing some fibre from the accumulation of the roots and stems of these grasses, but of little use as a peat.

Loc. 50. In the northwestern part of the county, Dismal Swamp extends along Bound Brook, northwest of Metuchen to within a mile of South Plainfield. A sample taken from the southern wooded portion of this swamp showed the following tests:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
105	50b	19.02	42.35	21.92	57.65	1.70	20.43	25.23	4335	7803

This is a fibrous, brown peat, limited to 5 or 6 feet in depth, and found in only a limited area. The northern portion of this swamp is higher ground, and showed a clay loam in the borings. A small swamp along Cedar Brook, south of Plainfield, is heavily wooded and gave no evidence of peat, though some small muck holes were encountered.

Loc. 62. In the southwestern part of this country there are swamp areas south and southeast of Monmouth Junction. Most of this region is wooded and none of the borings showed the presence of peat. The scattered areas east of the Trenton and New Brunswick Railroad, from Dayton to Milltown, all of which are wooded river-swamps, likewise gave no evidence of peat, with the exception of one boring in the northern end of Pigeon Swamp, where there is a 2-foot layer of a brownish peat, which gave the following results in the laboratory tests:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
126	62k	24.25	37.25	16.85	62.75	1.72	20.40	26.92	4539	8169

Along the line of the Camden and Amboy division of the Pennsylvania Railroad, from Jamesburg to Spotswood, is another series of river swamps, for the most part heavily wooded, the borings in which showed gravel and sand, though north of Jamesburg, in a cranberry swamp, 12 inches of a brownish peat was found in a few borings, and a number of muck holes were encountered in the wooded swamp west of Spotswood.

Loc. 63 and 64 are included under Loc. 62.

MORRIS COUNTY.

In Morris county we find a number of peat deposits, the location of which is shown on the map and detailed descriptions of all the swamps are given below.

Loc. 31. In this locality have been included the area along the High Bridge branch of the Central Railroad of New Jersey, from Careys to Succasunna Station, and the small swamp west of Kenvil. The area along the railroad is barren of peat, the soil being a clay loam of 1 to 2 feet in depth underlain by white sand. The wooded swamp west of Kenvil contains a fibrous black peat of 2 to 3 feet in depth overlying a white sand. A general sample from this latter swamp showed up as follows:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
71	31h-i	15.79	42.94	23.67	57.06	2.34	19.27	22.88	4285	7714

Loc. 32. This embraces an elongated swamp along the Black River, from Succasunna to the place where the river crosses the Chester branch of the Delaware, Lackawanna and Western Railroad, with a narrow strip just south of Succasunna.

To within ½ mile north of Ironia the large swamp showed only a sandy soil, with a slight covering of muck. The small section north of the Ironia road, for a distance of ½ mile, is covered by a deep deposit of a good brown fibrous peat.

Samples from the east side of the creek, ½ mile northwest of Ironia (72), and from the west side 1 mile northwest of the village (73) gave these results:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
72	32i	14.59	37.64	28.30	62.36	1.17	9.34	10.93	5488	9877
73	32j	13.69	41.78	27.52	58.22	1.30	14.26	16.52	5193	9347

Again, from Ironia to a point 1 mile south of Hortons, in the wooded part peat was not encountered; the soil is sandy. However, at a point 3¼ miles south of Ironia a boring showed a fibrous material over 5 feet in depth, and this covers the area as far south as the Chester road, below which the soil is again sandy. A sample taken from the boring mentioned above gave the following results:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
74	32 q	11.80	1.42	31.40	35.59

In the small arm of the main swamp, south of Succasunna, no peat was found in any of the borings, the soil being a yellowish clay 1 foot in depth overlying a yellow sand.

Loc. 28. This area embraces a narrow swamp bordering the Rockaway River from the point where it crosses the Delaware, Lackawanna and Western Railroad north to Berkshire Valley and the area along Green Pond Brook, from the Morris County Railroad crossing north to the Picatinny Powder Magazine. The Rockaway River swamp, though narrow, contains what seems to be a fair peat deposit, better near the north end than the south end; but the percentage of ash is too high to admit of its being used as a fuel. At the south end it is shallow, not more than 1½ feet in depth, and it contains a large amount of mineral matter, as the following tests of a sample from the extreme south end show:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
62	28 a	11.87	1.78	37.42	42.47

The sample from a boring ½ mile north of the railroad crossing, where there is a depth of over 5 feet of this material, gave these results:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
63	28b	13.89	47.10	22.15	52.90	1.79	24.95	28.98	4276	7697

The entire north end, from a point 1 mile south of the Berkshire Valley road, contains peat over 5 feet in depth, brown and fibrous, underlain by a blue clay. The figures given below show the results of the tests on samples from this part:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
64[1]	28c	14.69	46.01	22.77	53.99	1.61	23.24	27.23	4456	8021
65[2]	28c	14.04	41.95	21.85	58.05	1.54	20.10	23.28	4800	8640

[1] Upper 6 inches. [2] Lower 4 feet.

Green Pond Brook swamp, which is partly wooded, toward the southern end showed 2 feet of a brown fibrous clayey material overlying a white gravelly sand. The results of the tests on a general sample from this locality are given below:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
66	28h-1	13.63	45.20	20.82	54.80	1.48	24.38	28.22	4300	7739

Loc. 29. A number of small swamps, from Dover to Mount Hope, are included under this locality number. The only large swamp is that at Mount Hope, occupying a flat valley among the hills east of the village.

The southern end of this swamp contains a fibrous brownish peat, high in ash, underlain by a white gravel. Borings in the centre showed this to be over 5 feet in depth. The northern end is stony and wooded, but contains a fibrous brown muck of a poorer variety than that at the southern end. The following results are given for a sample collected at the south end:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
69	29 k	13.60	1.60	27.46	31.78

Some of the small swamps in this vicinity contain good peats, but the deposits are very limited.

A small swamp at the cross roads, ¾ mile south of Mt. Hope, contains a peat, over 5 feet in depth, which gave these figures in the laboratory examination:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
68	29d	15.26	43.85	38.71	56.15	1.27	5.14	6.06	5645	10162

No. 67, from the swamp 2 miles north of Dover, on the west side of the road, is brownish-black, somewhat fibrous, and gave the following results:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
67	29c	14.32	42.65	26.21	57.35	1.54	16.44	19.17	5117	9211

No. 70, from a 1-acre swamp on the south side of the road from Mount Hope to Rockaway, 1 mile from Mount Hope, is brownish, with a little fibre, and gave these results:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
70	29w	16.27	38.76	29.29	61.24	1.87	9.47	11.32	5159	9287

Another 1-acre swamp ½ mile farther east along the road contains the same sort of peat.

Loc. 30. The swamps along the Rockaway River from Rockaway to Dover are discussed under this heading. In all the borings in this locality no peat was encountered. For the most part the soil is a blue clay, varying in depth from 1 to 3 feet, underlain by a white gravel and sand. In the wooded portions the decaying leaves and other vegetable matter have given the clay a mucky character.

Loc. 33. In this locality there have been included a number of small swamps; those bordering Beaver Brook, from Meriden to Rockaway, those along the tributary to this brook from Hibernia to its mouth, a small group of areas 1 mile north of Denville, the small area at Denville, and another small patch at Mount Tabor.

The swamp along Hibernia Brook is merely a floodplain into which the brook is cutting, displaying sand and gravel, while that along Beaver Brook seems to be a clay soil about 3 feet deep, overlying a sand.

The small swamp 1 mile north of Denville looks very promising. Here there is a covering of a moss peat 6 inches deep, underlain by a good brown fibrous variety over 5 feet in thickness. The following figures are the results of the examinations of samples from this swamp:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
75[1]	33q	16.20	32.25	21.71	67.75	2.11	10.54	12.47	5057	9102
76[2]	33q	14.17	41.10	24.64	58.90	1.88	16.46	19.17	5049	9088

[1] Upper 6 inches. [2] Lower 5 feet.

Both the areas at Denville and Tabor are made up of from 2 to 3 feet of a blue clay overlying a sand.

Loc. 34. This lies along the Whippany River from the terminus of the Rockaway Valley Railroad to a point 1 mile southwest of Washington Valley. In all cases the borings showed a blue clay 3 to 4 feet deep under which there is a sand.

Loc. 7. This is the Lee Meadows, lying in the triangle formed by the roads joining Malapardis, Littleton and Parsippany. This is rather high ground, with a few muck holes, and in none of the borings was there anything but a blue clay encountered.

Loc. 39. This is the extreme western part of the Great Swamp, included between the Passaic River and the road from Stirling, through Pleasant Plains, across to Pleasantville. All the borings showed a striking similarity, being in yellow clay, with blue below. Here and there there are patches of sandy soil.

Loc. 38. This is what might be termed the central portion of the Great Swamp, bordering Locality 39 on the east and separated from Locality 36 by the road from Long Hill to Green Village.

In this locality, as in 39, most of the borings showed a yellowish clay, which in some places was quite fibrous. This is especially true of the small wing 1 mile east of Pleasantville and along the brook 1¼ miles southwest of Green Village. However, a variety of brown fibrous peat occupies the central portion of this locality, embracing ½ square mile. A sample collected from a boring 1¼ miles south of Pleasantville and ½ mile east of the road, contains a rather high percentage of mineral matter, and gave the following results:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
88	38 i	11.80	1.34	45.92	52.03

In a small area 1 mile southwest of Green Village there is a deposit, 3 feet thick, of a brown material, which looked like a peat, but the results, given below, show it to be a muck:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
86	38 b	7.58	0.74	66.40	71.44

In the northern part of this central area of the Great Swamp a boring brought up a fibrous clayey material, which gave the following results in the laboratory tests:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
87	38 h	9.59	1.26	50.48	55.83

A sample from a boring 1½ miles north of Long Hill and ¼ mile east of the road gave these results:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
89	38l	16.19	40.09	26.23	59.91	2.07	13.86	16.52	4947	8905

Loc. 36. This is the large swamp along Black Brook, enclosed in the triangle formed by the roads between Long Hill, Green Village and the junction of the roads from Green Village and Long Hill to Chatham. It is very thickly wooded and quite inaccessible in most places. As far as borings were made there did not seem to be any peat in this area, though prospecting in the centre of the swamp might bring some to light. The soil is a yellowish or blue clay in most places, though areas of sand are frequent. If any peat is present, and it is reported to be by residents, it probably occupies small areas and is confined to the portion of the swamp west of the brook. A sample taken 1¼ miles north of Long Hill and ½ mile east of the road to Green Village

looks like a fiber-bearing clay. The results of the laboratory examination are given below:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
82	36 i	12.88	1.59	34.68	39.81

Loc. 40. This area lies along the Passaic and Delaware Railroads from 1 mile east of Millington to Berkeley Heights. It is merely a floodplain swamp made up of a bluish clay.

Loc. 37. Black Meadows, 3 miles east of Morristown, is the area included under this locality number. The entire swamp area includes about 2 square miles, but all of this is not peat land. It is mostly free from woods and covered with grass. In times of heavy rains it is quite inaccessible in some places. At the north end of the swamp, south of the Whippany River for a distance of ½ a mile or more, there is no peat, the borings showing only a yellow clay 5 feet in depth. In the eastern side of the swamp, especially in the arm extending out towards Afton, the surface soil is a muck underlain by a bluish yellow clay. However, the part of the swamp west of Black Brook, from below the Afton road to within ½ mile of the Whippany River, contains an extensive deposit of a good fuel peat, embracing possibly 800 acres or more. The borings north of the Afton road and in the center of the swamp showed this black fibrous peat to be over 8 feet in depth. The two samples following were collected in the center of the swamp north of the road from Morristown to Afton;

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
83	37d	17.80	38.81	26.38	61.19	2.05	12.43	15.12	4791	8624
84	37e	17.81	37.45	26.61	62.55	1.88	10.84	13.19	4885	8794

Near the place where these samples were collected, Mr. Canfield of Morristown some years ago carried on experiments with the fuel, but no permanent operations were established.

It was reported by Dr. Cook[1] that peat was at one time cut for fuel at Columbia, in the Black Brook Meadows. The following analyses are taken from his report:

	1.	2.
Organic matter,	65.61	66.87
Water,	16.16	15.15
Oxide of iron and alumina,	3.19	3.97
Lime,	3.86	3.17
Magnesia,	0.37	0.39
Potash,	0.31	0.27
Phosphoric acid,	0.93	0.10
Sulphuric acid,	0.89	2.46
Carbonic acid,	0.09	...
Silica,	8.64	7.63
Total,	100.05	100.01
Elements of ammonia,	Not tried.	2.10
Combustible matter,	65.61	66.87
Water,	16.16	15.15
Ash,	18.22	17.98
Total,	99.99	100.10

No. 1 was taken north of the Columbia turnpike, probably in the immediate vicinity of where Specimen 84 was collected. No. 2 was a peat cut for fuel at Columbia, near No. 1, but 2 to 3 feet beneath the surface.

Loc. 41. This is the Troy Meadows, immediately north of the Black Meadows, covering 2 to 3 square miles, but not all of this is peat land. In the part south of the Troy Hills-Hanover Neck road there is a brownish-black, somewhat fibrous peat, the results of the laboratory examination of which are given below:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
93	41d	17.86	38.96	25.52	61.04	1.98	13.44	16.36	4901	8820

[1] Geology of New Jersey, 1868, 481, 700.

Along this road the peat seems to occur in limited areas and then only to a depth of 1 to 2 feet. The following sample was taken from several borings along this road:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
90	41 j & k	13.27	1.36	39.02	44.99

Along the Whippany River and bordering both sides of it the soil is a clay. North of the east-west ditch the peat seems to be of a fair quality though the sample taken in the middle of the swamp runs high in mineral matter:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
91	41 l	13.94	1.65	32.61	37.89

The northwest portion of the swamp contains a good peat which is brown and quite fibrous. The following sample was collected from a boring just south of the Parsippany-Pine Brook road:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
92	41s	17.54	37.80	27.20	62.20	1.46	10.60	12.85	5275	9490

To sum up, then, in this swamp the peat seems to be limited to the western portion. The sample for which the following results are given was taken from a boring in the extreme south end of the swamp and shows the high percentage of mineral matter at this place:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
85	41 b	11.42	1.25	49.18	55.50

Locs. 35 and 42. These border the Passaic River and have been discussed under Essex County.

Loc. 47. In this locality have been included the Bog and Vly Meadows lying north of the Delaware, Lackawanna and Western Railroad north of Lincoln Park and a small area still farther north, and 1 mile west of Pompton Plains.

The small swamp west of Pompton Plains is rather high ground and is made up of sand and gravel.

The Bog and Vly Meadows, embracing 800 to 900 acres, looks very promising. The whole area is covered by a good depth of a fibrous, brownish-black peat. Just south of the road from Pequanac it is 3 feet deep, underlain by a clay layer of 1 foot, in turn underlain by a sand. Still farther in the swamp the peat is 8 to 10 feet deep and overlies a white sand, with no intervening layer of clay. One-half mile south of this road and just west of the west ditch is located the plant of the American Peat Coal Company, the only company in northern New Jersey producing peat for fuel. The following samples are from this locality:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
1[1]	....	18.09	38.23	27.20	61.77	2.18	11.03	13.46	4966	8938
101[2]	47e	15.26	47.30	22.11	52.70	1.58	25.19	29.72	....	......
102[3]	47g	17.25	37.08	29.80	62.92	2.16	7.28	8.79	5378	9680

[1] Raw material, A. P. C. Co. [2] North of road. [3] Pit of A. P. C. Co.

The American Peat Coal Company or Pompton Fuel and Developing Company was established in 1904 and at the time visited (summer 1905) was in operation, but later in the season was shut down, perhaps only temporarily. This plant is located 2 miles west of Pequanac. A general view of the plant is shown in Plate XXX, fig. 1. The peat is dug by hand, by means of the specially-formed spade known as a slane, and a pit 35 x 75 feet has already been opened to a depth of 3 feet, and is drained by means of a pump attached to a 25-H. P. engine. From the pit, the peat is conveyed in steel cars to the bins in the second story of the main building, which is 35 x 100 feet, where there

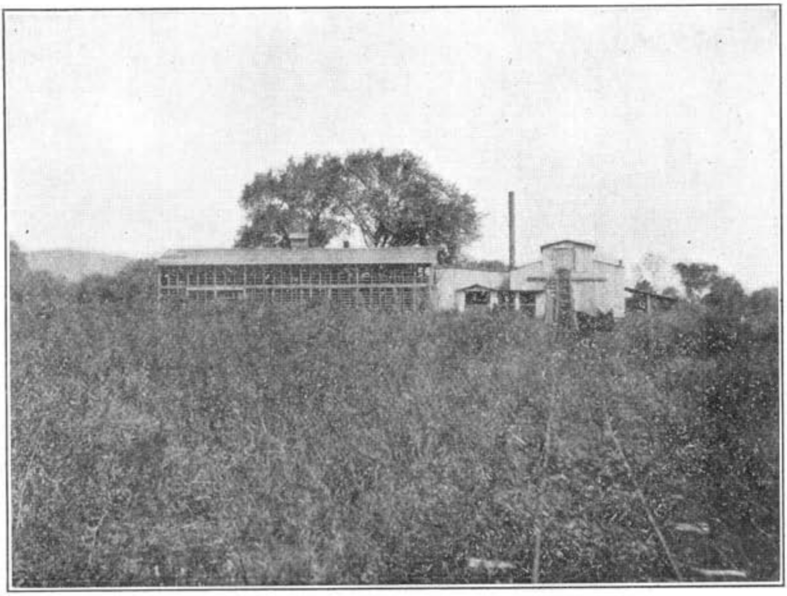

Fig. 1. General view of plant of American Peat Coal Company. The drying house, main building and track from the pits to the bins are shown.

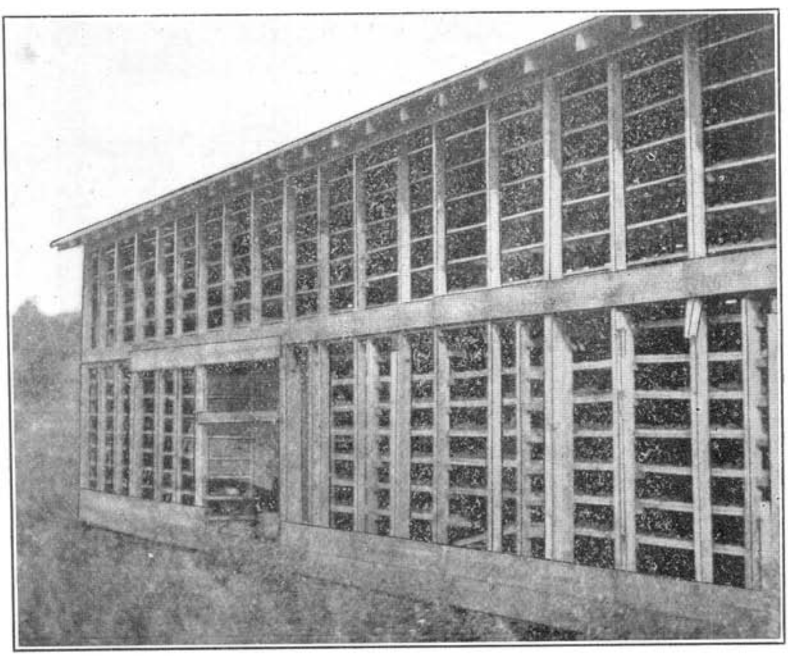

Fig. 2. A nearer view of the main-drying house, showing the peat bricks on the screens.

is a large boiler, a 50-H. P. engine and the other machinery. The peat machine is the type known as the Heinen Double Breaker, having a daily capacity of 50 tons of peat bricks. In the first breaker the peat is roughly broken and in the second it is more thoroughly kneaded so that when it leaves the tube it is quite plastic. It issues in the form of a double bar 4½ inches by 9 inches, which, as it emerges, is cut into 2 bars with a square cross-section of 4½ inches. These bars are cut into suitable sizes by hand, transferred on trays to the carrying belt which conveys the bricks to the drying houses. There are two such houses. The main drying-house, Plate XXX, Fig. 2, has 2 stories with rows of screen shelving, having, it is said, a capacity of 1,000 tons. The peat is allowed to air-dry on these shelves for 2 to 4 days, when it becomes hard and brittle and is stored in the bins at the end of the drying house. There is also a smaller drying house, or hot dry-room, with a blower and a coil of 1½ inch pipe, in which hot air is mixed with cold air to hasten the drying.

The product was sold at $3.00 per ton, and the cost is claimed to be sufficiently low to leave a good margin of profit. At the time of the visit 6 men were employed. The market is mainly local, the fuel being used for domestic purposes.

Loc. 45. This borders the Pompton River, on the west side, from a point west of Wayne to ½ mile north of Pequanac. The southern part of this locality, from Wayne to Pequanac, though quite heavily wooded, seems to give good indications of a fair peat. Almost all of the borings show a fibrous, brownish-black peat, deeper than 5 feet, though in some places there are ridges of sand and gravel rising through the peat. The results given below are tests of a sample taken just east of the road 1½ miles north of Lincoln Park:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
98	45c	19.84	39.15	26.46	60.85	1.61	12.69	15.84	4789	8620

This same kind of material is found in the eastern side of the swamp along the railroad.

East of the railroad, at Pequanac, there is a small wooded swamp in which the borings showed a peat, much like the above, but only 2 feet deep, underlain by a clay.

PASSAIC COUNTY.

The few swamps in this county are very small ones.

Loc. 26. A small swamp north of Dunker Pond, at the extreme southwest corner of the county, gave evidences of a very good peat over 5 feet in depth. It is a good fibrous, brown variety, and showed the following results on testing:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
59	26d	17.80	34.30	28.06	65.70	2.11	6.24	7.59	5265	9482

It is said that at one time a water company was intending to buy this pond for a reservoir, but borings showed that the peat was too deep to serve as a good bottom.

Though there are a number of swamp areas in the western half of the county, they were not visited because of their being located in the mountains, and their being very heavily wooded.

Loc. 65. About 2½ miles east of Pompton Plains there is a small swamp occupying a lowland in the hills. Three samples were taken from this locality; the figures below show the results of the laboratory tests:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
127	65c	13.82	......	......	....	1.48	38.50	44.68	....	......
128[1]	65e	19.17	41.55	27.91	58.45	2.11	13.64	16.87	4767	8579
129[2]	65e	11.36	......	......	....	1.34	52.19	58.87	....	......

[1] Upper 4 feet. [2] Lower 1 foot.

Loc. 44. This embraces a number of small swamps north of the Passaic River, between Mountain View and Totowa, most all of which are wooded lowland areas bordering small streams.

Those along the brook running through Preakness showed but a clay soil, and the area 1 mile north of Little Falls showed a sandy soil.

SOMERSET COUNTY.

No peat deposits were found in this county. The only swamp area of any note is the extreme western portion of Great Swamp, north of White Bridge. (Loc. 39.) Here the borings showed only yellowish and bluish clay, with here and there patches of a sandy soil. In some of the wet spots the top soil is a black clay material.

Part of Loc. 40, along the Dead River, south of Millington, is in this county; but this is merely a floodplain, which showed nothing but a bluish clay.

SUSSEX COUNTY.

This county contains a large acreage of swamp land and a number of these swamps contain peat. A detailed description of the swamps follow.

Loc. 14. This includes a group of swamps extending in a north-south direction in the mountains from Stanhope reservoir to Roseville. Most of these are densely covered with woods, and the soil is gravelly or sandy. In but two places muck was struck, 1½ miles south of Roseville, between the road and Lubbers Run, and at a point ½ mile farther north. This muck is merely a clay containing some grass fibre, as the following results of the tests on the sample from the former locality show:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
18	14 e	7.49	0.88	61.80	66.79

Loc. 11a. In order to determine the character of some of the heavily-wooded mountain swamps, this locality, including three small swamps on Alamuchy Mountain, north of Waterloo, was

visited. The soil is a muck made up of decaying leaves and other vegetable matter. Even if a good peat were present it would hardly be worth exploitation because of the limited extent, the inaccessibility and the dense forest covering.

Loc. 10. In this locality have been included a large swamp, containing about 600 to 800 acres, extending from Springdale for 2½ miles southwest, and a number of small swamps among the hills between this large swamp and Andover. These small swamps are barren of peat, the soil being a clay. A sample taken along the Pequest River ¾ of a mile south of Springdale proved to be a gray clay containing some grass fibre. The results of the tests on this sample are given below:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
10	10 b	7.25	1.31	57.55	62.06

In the large swamp, however, the conditions are different. In the north end, at Springdale, the borings showed 1 foot of muck underlain by hardpan. One mile south of Springdale, and west of the stream, there is a deep deposit of a wet muck, the sample from which is brownish, contains some fibre, and gave the following results in the laboratory:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°	Calories oven	B. T. U. dried.
11	10 e	13.28	2.40	24.43	27.50	4041	7274

On the east side of the stream, 1 mile north of the southern end of the swamp, the section shows 2 feet of muck overlying a sand, and at the extreme south end the soil is clayey. The peat, or rather muck, is limited to the center of the swamp, and is of a poor variety.

Loc. 13. This includes the large swamp lying in the valley south of Sparta and the smaller areas among the hills between Sparta and Mulford Station. The large swamp contains no peat, but has a covering of muck varying in depth from 6 inches to 2 feet, overlying a white sand, and this white sand is underlain by a blue clay. A sample of this muck proves to be a gray clay, with some grass fibre, as the following results testify:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
17	13 f	8.77	1.52	53.87	59.06

In the small swamps no peat was encountered.

Loc. 16. In this locality have been placed the small swamps at Germany Flats, Sparta Junction and the area along the railroads, 1½ miles west of the junction. In the swamp, 1 mile southwest of the junction, along the Lehigh and Hudson Railroad, the section is as follows: 6 to 8 inches of a black muck, 3 feet of a black fibrous material, 2½ feet of a brownish clay-like material, underlain by a blue clay. The samples collected 1 mile south of the junction and ¼ of a mile west of the railroad gave results in the laboratory as follows:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
23[1]	16a	27.56	40.20	19.32	59.80	1.99	20.88	28.83	4026	7247
24[2]	16a	22.34	......	....	....	1.65	32.76	42.16	....	......

[1] Upper 3 feet, black. [2] Lower 2½ feet, brown.

In a small swamp, where the road crosses the railroads 1 mile west of the junction, the following section was observed: 6 inches of sandy black soil, 1 foot of a fibrous black material, 2 feet of a brown deposit underlain by a white sand. The samples from this swamp showed up as follows:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
25 upper 1 ft., black	16 d	9.73	2.33	29.22	32.34
26 lower 2 ft., brown	16 e	6.66	1.53	46.83	50.17

Loc. 18. This is a very small swamp bordering the stream east of Branchville Junction. The borings showed nothing but a slight covering of clay muck overlying a blue clay.

Loc. 12. This is the large swamp extending from Newton north to Branchville Junction, along the Sussex Railroad, and embracing about 2 square miles. The borings along the west side of this area gave no evidence of peat. At a point 1 mile north of Newton and just east of the road the section is 6 inches of a clayey soil containing grass fibre and 4 feet of a black muck with some fibre. The samples from this boring showed up as follows in the laboratory examination:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
13 upper ½ ft.	12 a	7.20	1.05	64.24	69.18
14 lower 4 feet	12 a	11.89	1.70	30.54	34.61

The other borings along the west side, especially those near the north end, showed a black soil of a slight depth, underlain by a clay. On the eastern side of the swamp we find a deposit of a good peat, for the most part over 5 feet in depth and covering, possibly, 300 to 400 acres. It is a brown variety, somewhat fibrous, and is covered by a thin deposit of a black muck. A sample collected 1 mile south of Branchville Junction and west of the railroad gave the results as follows:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
15	12d	14.16	33.09	22.75	66.91	2.24	10.34	12.03	5187	9338

Another sample from a boring 1½ miles north of Newton, between the Kill and the railroad, showed up as follows:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
16	12e	12.84	43.73	19.95	56.27	2.06	23.78	27.22	4212	7582

Loc. 17. This includes two small swamps, one lying south of Washingtonville and the other 1½ miles north. In the former swamp there is a 2-foot deposit of a muck which overlies a blue clay. A sample from a boring on the east side of the area 1 mile south of Washingtonville gave the following results:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
27	17 a	16.06	1.42	37.26	44.38

In the north swamp the borings showed 1 foot of a brownish, sandy, fibrous material, underlain by a blue clay, the upper layers of which are weathered and contain some fibre.

Loc. 15. This locality takes in a 300 to 400-acre swamp north-east of Lafayette, and some small swamps farther west and north-west. Four miles north of Lafayette, and just west of the road to Harmonyville, there is a small swamp, of only a few acres extent, owned by Jonas Simmons, where there is a 2-foot deposit of a black fibrous peat, underlain by over 5 feet of a brown fibrous peat. However, the amount of mineral matter is too high to admit of their being used as fuel peats. The results of the tests on these samples are given below:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
19[1]	15e	12.26	44.85	21.56	55.15	2.01	23.29	26.55	4092	7365
21[2]	15e	9.54	......	....	....	1.58	26.12	28.87	....	......

[1] Upper 2 feet, black. [2] Lower 5 feet, brown.

The small swamp bordering the stream west of this same road and 1 mile north of Lafayette contains no peat, but has a 1-foot deposit of marl underlying a slight depth of muck and overlying a blue clay.

The large area north of Lafayette contains a good variety of a brownish-black, fibrous peat over all its extent, embracing about 400 acres. The peat, in all the borings, was over 5 feet in depth, excepting near the edges, where it is underlain by a blue clay.

The top soil is gritty to a depth of about 6 inches. A general sample taken throughout the length of the swamp, from a number of different borings, gave the following results:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
22	15ijkl	18.27	34.91	24.46	65.09	2.83	10.45	12.75	5004	9007

Loc. 19. This is the narrow swamp bordering the stream between the Sussex and the Lehigh and Hudson Railroads, from Monroe Corners to Franklin Junction. All the borings showed a covering of 6 inches of a black, sandy soil, underlain by a blue clay. In some places the rock is close to the surface.

Loc. 25. The small swamp along Beaver Run, north of the village of the same name, and those north and south of Harmonyvale, are included under this locality number.

The area along Beaver Run gave no evidence of peat, the soil is a clay loam covering a sand.

One mile west of Beaver Run and northwest of Harmonyvale there is a small swamp of 80 to 100 acres, which seemed to contain a good variety of peat, but the laboratory examination showed a high percentage of ash. There is an upper layer of 1 foot of a black fibrous kind and a lower layer of a very fibrous brown variety, exceeding 5 feet in thickness. It is said that in the centre of this bog the depth of the deposit is over 20 feet. Samples from the southeast end of the swamp showed up as follows:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
55	25 d	15.70	2.03	25.86	30.68
56	25 e	14.42	1.90	28.08	32.81

In the small swamp 1½ miles southwest of Harmonyvale there was encountered 1 foot of a peat material, of a brown fibrous nature, underlain by a thin seam of marl, under which there is a blue clay. The sample taken at the south end looks fair, but the swamp is so small as to be hardly worth mentioning. Below are given the results of the tests on this sample:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air.dry.	Ash 105°	Calories, Oven	B.T.U. dried.
57	25h	16.66	42.60	19.35	57.40	2.20	23.25	27.90	4027	7249

Loc. 24. This group of swamps, lying along the stream from ½ mile northeast of Rudeville south to Hardystonville, is on rather high ground, partly wooded, but for the most part covered with grass. All the borings were in a blue clay, in some places underlain by a white sand.

Loc. 26. This includes the small swamp at the north end of Dunker Pond, 2 miles east of Stockholm, discussed under Passaic County, a rather dry swamp at Stockholm, bordering Pacack Brook, and a very small area along the New York, Susquehanna and Western Railroad, where it crosses the road from Stockholm to Two Bridges.

The Stockholm swamp is high ground, the soil is a covering of clay loam on a clay, and some of the borings struck a sand and gravel underneath a 4-foot clay layer.

The swamp along the railroad, west of Stockholm, though containing only 15 or 20 acres, has an excellent deposit of peat over 6 feet in depth. It is of a brown color, and is quite fibrous. A sample collected at the extreme east end, just south of the railroad, gave the results that follow:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
58	26a	17.49	35.31	29.56	64.69	2.09	5.73	6.97	5284	9510

Loc. 23. In this locality has been included a more or less continuous strip of swamp land along the Lehigh and Hudson Railroad, from a point 1 mile south of McAfee to Vernon Station, and from there, following Pochuck Creek, to the New York State line. Below McAfee the borings showed nothing but a blue clay,

and the ground is rather high and dry. This is true also of the narrow strip extending ¾ mile north of McAfee. However, between Sand Hills and a point ½ mile south, and on the west side of the little stream which the railroad follows, the borings showed over 5 feet of a black-brown peat, containing some fibre. The samples taken here gave these results:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
53	23r	17.47	......	......	....	2.46	25.26	30.59	....	......
54	23q	18.55	36.92	22.52	63.08	2.73	14.40	17.68	4707	8473

From Sand Hills to Maple Grange there is a deposit, over 5 feet deep, which seemed to be a good peat, but the laboratory examination shows it to contain a high percentage of mineral matter. The soil on top is more or less gritty, beneath this there are 6 inches of a black variety, and below is a fibrous brown. The following samples were collected and tested:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
52 south of Vernon, Glenwood road	23 j	13.74	1.79	36.91	42.78
49 1 mile s. e. of Maple Grange	23 a	12.98	1.71	38.69	44.46

From the Maple Grange-Glenwood road north to the State line the swamp is more or less wooded, and in it are islands of gravel. Most of the soil is a bluish clay, though here and there are patches of muck. Samples were taken north of this road (50) and ½ mile east of Glenwood (51). Both of these are mucks rather than peats, as the following results testify:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
50	23 e	12.55	1.76	46.27	52.60
51	23 h	11.09	1.04	50.15	56.40

This swamp along Pochuck Creek, as also the swamp along the Wallkill River, are the southern extremities of the Drowned Lands in New York State, where peat is found in depths up to 18 feet.

Loc. 20. This area is the strip of swamp land bordering the Wallkill River, from the State line south to Hamburg, tapering from 1 mile in width at the State boundary to a point 1½ miles north of Hamburg. The small area along the little tributaries, southwest of Hamburg, is underlain by blue clay, and on both sides of the river up to a point about 2½ miles north of Hamburg the borings were all in a blue clay.

One mile southeast of Papakating, and 100 feet from the railroad, a sample was taken. Here there is a black fibrous clay-like material over 5 feet in depth, which gave these results:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
29	20 e	13.84	2.34	26.23	30.41

At Papakating, and west of the railroad, a sample from a deep mire proved to be a fiber-bearing clay, as these figures below show:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
30	20 f	9.73	1.78	46.24	51.20

Two samples from borings 100 feet apart and 200 feet from the point where the Lehigh and New England Railroad enters the swamp to cross the Wallkill gave these results:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories. Oven	B.T.U. dried.
31	20g	24.30	41.90	21.79	58.10	1.78	20.11	26.54	4165	7496
32	20h	12.89	......	....	....	1.30	51.06	58.64	....	......

The former is brown and fibrous, but somewhat sandy looking, while the latter seems to be a brown fibrous clay.

From the point where the railroad crosses the Wallkill the partly wooded swamp, for a distance of 1 mile northward, seems to be made up of clay, and a sample from a boring 200 yards east of the railroad and ½ mile from the crossing, in which boring the muck was 2 feet deep, proved to be a fibrous clay, as these results show:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
33	201	10.14	1.59	49.09	54.54

From a point about 2 miles north of Independence Corner northward to the State boundary the swamp furnishes a good amount of peat. However, immediately bordering the river the soil is clayey, and in the swamp there are a number of gravelly and sandy islands. The area is, for the most part, grown over with trees and bushes. The depth of the peat varies from nothing up to probably 10 feet or more. It seems to be deepest just over the State line, where at several points a sapling was pushed down into the bog for a distance of 12 feet. A number of samples were collected from different borings. These are listed below, as are also the results of the laboratory investigation:

No. 34. Three and one-half miles south of Owens, 200 feet east of the railroad, black, some fibre, over 5 feet in depth.

No. 43. Upper foot, black, fibrous, somewhat sandy looking, taken just north of the road from Owens to Sussex and ¼ mile west of the bridge across the Wallkill.

No. 44. Lower 3 feet, brown, fibrous, same locality as 43.

No. 45. One-fourth mile north of the State line and ½ mile east of the river, upper 6 inches.

No. 46. Same locality as 45, brownish-black, fibrous, over 10 feet deep.

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
34	20m	15.99	37.95	26.57	62.05	2.34	11.38	13.61	4946	8902
43	20,0	14.45	......	....	....	2.10	28.69	33.46	....	......
44	20,0	7.57	36.11	28.84	63.89	2.00	7.27	8.03	4589	8260
45	20t	9.50	......	....	....	1.48	56.35	62.27	....	......
46	20t	16.66	39.77	25.18	60.23	2.13	14.59	17.51	4878	8779

These come from a part of the Drowned Lands of the Wallkill, where, in New York State, Parsons states a fair average of the depth of peat is 18 feet. Two analyses from Parsons' report[1] will serve for 43 and 44.

North side of road, 150 feet west of Owens Station.	*Organic matter.*	*Ash.*
Sample taken 6 inches below the surface, ...	90	10
Sample taken 3½ feet below the surface, ...	89	11

In this locality, then, the good peat will be found in the territory lying between the State line and the line drawn east from Papakating.

Loc. 22. In this locality have been included the small swamps west of the New York, Susquehanna and Western Railroad, at Van Syckles, and the irregular area south of Rockport, covering about 200 acres. The Van Syckles bog, though small, is a good peat swamp in which the deposit is of a brownish fibrous character over 5 feet in thickness. Near the edges of the swamp a layer of marl was found beneath the peat. The following data show the results of the laboratory investigation of the sample from this locality:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
47	22a	14.01	40.01	26.97	59.99	2.25	13.04	15.15	4986	8975

The Rockport swamp is another good peat bog in which the peat is quite fibrous and brownish, and runs over 5 feet in depth.

[1] Peat, Its Formation, Uses and Occurrence in New York Annl. Rept. of N. Y. State Geol. XXIII, p. 71, 1904.

The results of the tests on the sample from a boring west of the road 1½ miles south of Rockport are given below:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
48	22b	17.52	37.53	26.17	62.47	2.02	11.36	13.83	4908	8834

Loc. 21. This includes the small swamp ½ mile east of Plumbsock, a larger area ½ mile south of Beemerville and a smaller area 1 mile southwest of Wykertown. The small swamp east of Plumbsock has the following section, 6 inches of black peat, 3½ feet of brown fibrous peat underlain by a blue clay. The sample taken ½ mile east of Plumbsock and south of the stream, in the centre of this bog of 30 to 40 acres gave these tests in the laboratory examination:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
35	21a	14.12	41.40	24.17	58.60	1.53	17.23	19.97	4814	8667

In the north end of the large area south of Beemerville the borings showed clay in the partially wooded and somewhat dry swamp. Just south of the road there is an area of about 10 acres which contains over 5 feet of a good peat, the upper 8 inches of which is black and very fibrous and the lower portion is brown. The following results were obtained from samples taken along the stream:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
36[1]	21e	14.20	39.38	18.56	60.62	1.86	20.82	24.27	4199	7558
40[2]	21e	12.50	44.35	21.32	55.65	1.77	23.03	26.31	4212	7582

[1] Upper 8 inches. [2] Lower 4 feet.

In the small area southwest of Wykertown the borings showed a deposit over 5 feet deep of a brown, fibrous, claylike material, which contains too much mineral matter to be used as a peat, as the following tests show:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
41	21 g	10.69	1.65	38.08	42.58

In a 5 to 10-acre bog 2 miles east of Wykertown there is a brownish-black, fibrous deposit over 5 feet in depth and overlain by 6 to 8 inches of a blacker variety. The percentage of ash is a little high for a fuel peat. The tests on a sample from the centre of the swamp are given below:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
42	21i	14.55	44.18	21.37	55.82	1.71	22.81	26.59	4377	7879

The swamps in the mountains of the western part of this county were not visited. Even if peat be present, which is improbable, the limited extent of the swamps, the inaccessibility, the distance from railroads and the heavily timbered character of the swamps would all combine to prevent any exploitation.

UNION COUNTY.

Loc. 49. On the south central border line of the county, along the Lehigh Valley Railroad from Goodmans to Potters, is Ash Swamp, embracing something less than a square mile of marshy ground. The outlook for peat does not seem to be very promising. The area is very densely covered with brush and wooded. In places there is a depth of 2 to 4 feet of muck which is more of a black loam than a peat. Other borings showed a clay loam underlain by a gravel.

Loc. 48. In the north central part of the county there are two small swamps. One of these, along the west branch of the Elizabeth River, from Union to New Orange, is a very wet area, covered densely with brush and scrub oak, in which there is a 3-foot deposit of brown muck, underlain by gravel and sand. The deposit contains too much mineral matter to be a good peat. A sample taken at Union gave the results:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
103	48 c	14.18	1.50	32.37	37.71

The other swamp, along the Rahway River and Normahiggin Brook from Branch Mills to New Orange, has a very similar deposit of 3 feet, also underlain by a gravelly sand. The sample from a boring ½ mile east of Branch Mills showed the following tests:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
104	48 f	14.73	1.76	26.66	31.24

Loc. 54. Bordering the shore, along Arthur Kill, from Elizabeth to the Rahway River, there is an area of coastal marsh covered with grasses. All the borings showed a mass of grass stems and roots mixed in with a blue clay to a depth of 3 feet, underlain by a blue clay. The following results are from a sample taken from a boring east of the New York and Long Branch Railroad 2 miles south of Elizabeth:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
109	54 e	9.02	0.78	64.66	71.05

The southern portion of the Newark Bay Swamp (Loc. 51) comes into this county, but it is discussed under Essex County.

WARREN COUNTY.

The only peat area of any large size in this county is the Great Meadows, or the Pequest Meadows, in the northeastern part. There are also some other small localities, all of which, besides the barren areas visited, are discussed in detail under the respective locality numbers.

Loc. 61. This is a small swamp at the south end of Green Pond, 1 mile northeast of Buttzville. It is almost entirely wooded and though of small extent, embracing not more than 90 acres, contains a fair grade of peat. A sample from a 5-foot boring 200 feet south of the road at the southern end of Green Pond gave the results noted below:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
125	61e	16.82	34.51	24.10	65.49	2.65	10.41	12.51	4863	8753

Loc. 60. This embraces 3 small swamps, the first along Beemer Brook, at Febletown, 1½ miles north of Hope, another along Muddy Brook 1 mile south of Mount Herman and the third along Honey Run and Muddy Brook just south of Swayze's Mills. A sample taken at Febletown, in the wet marsh, proved to be a grayish clay, as these figures show:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
123	60 a	14.72	1.56	40.81	47.86

A sample was taken from a boring in the swamp below Mount Herman where the peat is a fair grade containing some fibre, having a brownish-black color and a depth of 2 to 3 feet. The results of the examination of this sample follow:

Lab. No.	Loc. No.	Moisture 105	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
124	60e	22.68	36.46	19.75	63.54	2.13	16.71	21.61	4568	8224

The swamp south of Swayze's Mills is underlain by a clay loam and is thickly grown over with bushes and scrubby trees.

Loc. 58. This includes some very small swamps in the northern part of the county. A small swamp 1 mile west of Southtown shows a fair peat 4 feet deep, of a black color with a little fibre. A rather interesting section was noted at the south end of this swamp. Below 2 feet of a muck there was observed a 6-inch layer of peat moss below which there was a clay layer 1½ feet thick. The peat sample from this swamp gave the following results and the sample of moss peat is also listed below:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
116	58b	20.90	36.83	23.41	63.17	2.52	13.42	16.96	4795	8632
112[1]	58a	24.07	34.36	27.82	65.64	1.62	6.54	8.61	5098	9177

[1] Moss peat.

In a small swamp of a few acres extent just south of the road 2½ miles south of Paulina, there is a good fibrous peat 5 feet deep. The results of the examination of a sample from the swamp are listed below:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
117	58e	22.13	32.62	24.61	67.38	2.35	8.01	10.29	5120	9215

In another small swamp 1 mile east of Kerr's Corners, beside the road to Johnsonburg, there is a 2- to 3-foot deposit of a very fibrous brownish-black peat, underlain by a clay. The figures below show the results of the tests on this peat:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
118	58k	21.89	36.70	28.98	63.30	1.59	7.72	9.66	4982	8968

Loc. 59. In this locality have been included some small swamps lying near the county line, north and northeast of Johnsonburg. In none was there any peat encountered; the one just north of Johnsonburg showed gravel while the others showed clay. The sample taken on the county line ½ mile southwest of Greensville (121) and the one taken 1 mile farther south (122) proved to be very clayey in nature, as the figures given below show:

Lab. No.	Loc. No.	Moisture 105°	Nitrogen.	Ash, Air-dry.	Ash, 105°
121	59 d	16.39	1.58	42.11	50.36
122	59 g	6.09	1.88	42.08	45.57

Loc. 57. In this have been included a number of swamps lying to the north of the Pequest Meadows, included in the triangle formed by Alamuche Station, Johnsonburg and Southtown. Most of these swamps are covered with bushes and trees, and the soil seems to be a clay loam containing more or less mineral matter. A sample taken on the east side of the swamp, 2 miles west of Alamuche Station, seems to be a fair peat, having a thickness of 2 to 3 feet. Below are given the results of the tests on this sample:

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
120	57a	21.63	36.35	20.53	63.65	2.27	15.82	20.19	4317	7772

Loc. 56. This area is the Pequest Meadows, covering about 6 square miles and lying to the west of the Lehigh and Hudson Railroad, from Danville to 1½ miles south of Alamuche Station.

In this swamp there are a number of islands which rise up through the peat. The eastern and southern parts are under cultivation, while the northern end and the part along the river are densely covered with woods. The entire swamp, with the exception of the islands and the northern end, contains a good deposit of peat, probably 2,000 to 3,000 acres in extent, and of variable depth, with a maximum of over 7 feet. At the time of my visit (August, 1905) the Woodbridge Manufacturing Company had a plant located at Danville, at the south end of the swamp, where they were digging the upper foot, to be used in the manufacture of fertilizer. This plant was established in the summer of 1904, and has been in operation since that time, with a force of 20 men. The sod is cleared off the swamp, the upper layer of peat is dug out, hauled in cars to the plant, and there put into a cylindrical drier 4 feet in diameter and 30 feet long, slightly raised at one end. It moves through this drier and comes out at the lower end pulverized, hard and thoroughly dried. It is then put into 100 to 200-lb. bags and shipped to the company's plant, where it is used in the manufacture of fertilizer. The capacity of this plant is 11 to 12 tons per 24-hour day, and the peat is dried in 15 to 20 minutes. Over 1,000 tons had been produced since the beginning of operations, and at the time of the visit the plant was being enlarged.

The American Agricultural Chemical Company has leased and tested property on the west side of the swamp about 4 miles north of Danville, where it is understood they will begin operations to dig the peat to be used in the manufacture of fertilizer. The ammonia content of their peat is said to be 3.2 per cent. at the top and 2.3 per cent. at the bottom of a 4-foot boring. The Alphano Company had already started to build on the east side of the meadow, 3 miles north of Danville.

The following samples were collected and tested, and the results of these tests are listed below:

No. 110. East side of swamp, 3 miles north of Danville and 200 yards west of the railroad, on property of the Alphano Company.

No. 111. West side of swamp, 4 miles north of Danville and 200 feet east of the road, black, fibrous; property of American Agricultural Chemical Company.

No. 119. South end of swamp, ¼ mile north of Danville, black, some fibre, property of Woodbridge Manufacturing Company.

Lab. No.	Loc. No.	Moisture 105°	Coke.	Fixed Carbon.	Volatiles.	Nitrogen.	Ash Air dry.	Ash 105°	Calories, Oven	B.T.U. dried.
110	56f	20.84	36.90	25.86	63.10	1.98	11.04	13.94	5234	9421
111	56z	27.70	40.26	26.95	59.74	1.96	13.31	18.41	4562	8213
119	56a	28.14	33.14	24.52	66.86	2.45	8.62	12.00	4953	8915
*	†	18.82	34.40	24.00	65.60	2.62	10.40	12.81	4926	8865

* Raw material † Woodbridge Manufacturing Co.

Loc. 11. This is a narrow strip along a tributary of the Pequest River, east of the Lehigh and Hudson Railroad, from Tranquility to ¼ mile south of Alamuche Station. This is a dry swamp, for the most part wooded, and the borings showed only a sandy loam.

The following list of counties and localities is appended to facilitate reference:

Bergen County.

65. Few small swamps, Franklin Lake to Midland Park.
27. Small swamps. Crystal Lake to Wyckoff.
6. Group around Ramseys.
5. Allandale.
3. Westwood to Montvale, along Passaic Creek and Bear Swamp, 1½ miles west of Montvale.
4. Along Musquapsink Creek, near Westwood.
2. Along branch of Hackensack River, Randell to State Line.
8. Bordering Saddle River and Sprout Brook.
9. Hackensack to Woodridge.
52. Newark-Hackensack marshes.
53. Small part of Jersey Meadows, Dellman's Creek to Nordhoff.

Essex County.

51. Newark-Elizabeth Meadows.
35. Along Passaic River, Chatham to Columbia Bridge.
43. Columbia Bridge to Swinfield Bridge, along Passaic River.
42. Hatfield Swamp, Long Meadow and Little Piece Meadow, bordering Passaic River.
46. Great Piece Meadow, along Passaic River.

Hudson County.

53. Jersey Meadows, along Hackensack River, west of Jersey Heights.

Mercer County.

1. Bear Swamp, south of Lawrence Station.

Middlesex County.

54. Along Raritan River, Arthur Kill and Rahway River.
55. Same as 54.
50. Dismal Swamp, northeast of Metuchen.
62. Southwest part of county, south and southeast of Monmouth Junction, at Jamesburg and Spotswood. This also includes 63 and 64.

Morris County.

31. Careys to Succasunna and at Kenvil.
32. Succasunna to Chester.
28. Along Rockaway River, from D., L. and W. crossing to Berkshire Valley, also Green Pond Brook swamp.
29. Small swamps, Dover to Mt. Hope.
30. Rockaway to Dover, along Rockaway River.
33. Small swamps, Hibernia to Rockaway and at Denville and Tabor.
34. Along Whippany River, terminus of Rockaway Valley R. R. to Washington Valley.
7. Lee Meadows, north of Morristown.
39. West part of Great Swamp.
38. Center of Great Swamp.
36. East part of Great Swamp.
40. Along Passaic River, Millington to Berkeley Heights.
37. Black Meadows, east of Morristown.
41. Troy Meadows, north of Black Meadows.
35. See same number under Essex County.
42. See same number under Essex County.
47. Bog and Vly Meadows, north of Lincoln Park.
45. Along Pompton River, Wayne to Pequanac.

Passaic County.

26. North of Dunker Pond.
65. Swamp 2½ miles east of Pompton Plains.
44. Group, north of Passaic River, Mountain View to Totowa.

Somerset County.

39. West part of Great Swamp.
40. Along Dead River, south of Millington.

Sussex County.

14. Group, Stanhope to Roseville.
11a. Group on Alamuche Mt., north of Waterloo.
10. Springdale swamp and small ones east.
13. South of Sparta and group west.
16. On Germany Flats and at Sparta Junction.
18. Small swamp at Branchville Junction.
12. North of Newton.
17. Small swamps near Washingtonville.
15. Large area north of Lafayette and small ones west and northwest.

19. Monroe Corners to Franklin Junction.
25. Swamps near Beaver Run and Harmonyvale.
24. Rudeville to Hardystonville.
26. At Stockholm and west.
23. McAfee to State Line, along Pochuck Creek.
20. Along the Wallkill, Hamburg to State Line.
22. Van Syckles and Rockport.
21. Small areas at Beemerville, Plumbsock and Wykertown.

Union County.

49. Ash Swamp, Goodmans to Potters.
48. Near Union and Branch Mills.
54. Along shore, Arthur Kill, Elizabeth to Rahway River.
51. South part of Newark-Elizabeth marshes.

Warren County.

61. South end Green Pond, 1 mile northeast of Buttzville.
60. At Febletown, Mt. Herman and Swayze's Mills.
58. Group, north part of county, Southtown to Kerr's Corners.
57. Group, north of Pequest Meadows.
56. Pequest Meadows.
11. Tranquility to Alamuche Station.

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June, 1906.

PART VI.

The Mining Industry.

By HENRY B. KÜMMEL.

Notes on the Mining Industry.

HENRY B. KÜMMEL.

IRON MINES.

During the year 1905 there have been but few changes of consequence in the iron-mining industry of the State. All the mines which were large producers in 1904 have continued in active operation during 1905, and three new ventures were undertaken upon old mining properties, which had been closed for many years. One old mine, the McKinley, at Oxford, has been closed, and the Lurk mine, noted for the first time in last year's report, was not worked during 1905. So far as learned, the productive mines during the year have been the Washington and Ahles, at Oxford; the Hurd, Richard, Hoff and Baker, at Wharton; the Mount Hope mines, at Mount Hope; the Hude, at Stanhope; the Andover, DeCamp, Upper Wood and Wharton, at Hibernia; the King, at Ledgewood; the Dickerson, at Ferro Mont; and the Peters, at Ringwood. Development work was continued at the Teabo.

The total product during the year was 500,541 long tons, a slight gain over the figures of 1904.

At the Hurd or Irondale mine at Wharton, purchased in 1904 by Joseph Wharton, extensive development work has been undertaken, a new skip road is being installed, and a deposit of very rich ore 15 feet wide is reported to have been cut. The slope has now a length of about 1,100 feet, and with the discovery of this new ore-body the future of the mine is very promising.

The Hibernia mines have all been large producers. At the Andover mine No. 19 shaft is now down to the 27th level, which has been worked to the northeast about 350 feet. The drift on the 24th level, mentioned in the reports for 1903 and 1904, has been extended 1,115 feet southwest from No. 19 shaft, and seems to have reached the limit of ore in this direction. At the De-Camp mine, shaft 4 is down to the 9th level, while on the Upper Wood property shaft 6 has been sunk to the 14th level, with two working stopes on the 12th, 13th and 14th levels. At the Wharton mine, shafts 9 and 11 have each been sunk to the 15th level, with 5 working stopes tributary to No. 9 and 6 connected with No. 11. Shaft No. 12 has been sunk to the 5th level, about 860 feet, and a crosscut made to the ore, 94 feet distant, where the ore body has a width of 9 feet. The concentration of the lean ore from the Upper Wood mine has continued at the magnetic separator as in previous years.

The Richard mine has continued to be one of the largest producers in the State, its product during 1905 being in excess of that for the preceding year, although not quite equal to the high-water mark for 1902 and 1903.

In September, 1905, the Baker mine, adjoining the Richard mine at Wharton, was reopened by the Warwick Iron Ore Company, W. A. E. Woods, Superintendent. The mine was pumped out and a small amount of ore was raised previous to the close of the year, but early in January, 1906, the entire mine caved in. The following account which appeared in the Engineering and Mining Journal of January 20, 1906, gives some details of this accident:

"The Baker mine, 1½ miles north of Dover, in Morris County, New Jersey, owned by William H. Andrew and Thomas Baker, of Dover, and leased and operated by the Warwick Iron Ore Co., of New York, caved in on Monday morning, January 8, causing the operators a loss of upward of $10,000. The Baker mine had been reopened by the Warwick Co. last summer after an idleness of 29 years. The cave-in happened at a peculiarly fortunate time for the men employed. The night-shift had come up and only one pump-runner was in the mine. He heard the rumbling noises foretelling a fall of ground and hastened out, reaching safe ground only a few minutes before the shaft caved in.

"All the machinery in the mine was lost and the ore-docks, containing several hundred tons of ore, also went down. The entire roadway leading to the Richard mine, the property of the Thomas Iron Co., caved in.

"It is not likely that the operators will attempt to reopen the mine. The Baker mine was developed by the old Allentown Iron Co., which failed about 1876. The Allentown Co. took out about 150,000 tons of ore under its lease, paying a royalty of 80c. a ton. They got over the line on to the property of the Thomas Iron Co., owners of the Richard mine. A law suit resulted, and the Allentown Co. failing, the owners of the mine entered into an agreement with the Thomas Iron Co., by which the Baker mine should not be operated for a period of 21 years, the Thomas Iron Co. to have the use of the Baker mine shaft to work a large breast of ore on the Richard mine property, which the Allentown people had uncovered.

"The Thomas Iron Co. never did use the Baker shaft, however. and the mine remained idle for 29 years, until last summer, when it was leased to the Warwick Co. The cave-in of last week may be the cause of a suit for damages, brought by the owners, for it is said that it was the result of the eagerness of the operators to make a showing for the lessees, to do which they took ore wherever found, even, it is alleged, to robbing the pillars, which was contrary to the provisions of the lease.

"Less than 1,000 tons of ore had been raised, although the engineer in charge said that there were over 20,000 tons in sight.

"Less than a quarter of a mile from this cave-in is a large hole over 100 ft. in diameter and nearly as deep, where a few months ago over 400,000 tons of earth and rock dropped through a narrow fissure into an old working of the Richard mine. No damage was done, except that it was necessary to shift the tracks of the Mt. Hope Mineral Railroad."

The Hoff mine, near Wharton, which was closed in 1886, has been reopened. Pumping began in April, 1905, and mining was resumed in September. The present operations are by The Hoff Mining and Realty Improvement Co., Rockaway, C. L. Beach, President; C. H. Beach, Secretary and Treasurer. As noted in the early reports of the Survey, there were two ore bodies in this mine separated by a horse of rock about 14 feet thick, known as the "hanging-wall vein" (6 ft.), and "the foot-wall vein" (9 ft.). When the mine was closed down only the later was being worked at a depth of about 200 feet. The dip was 60° S. E., and the ore bodies pitch northeast at an angle of 35°. Bed rock was supposed to have been reached, but the new company, by sinking the shaft a few feet, has found the ore again, the so-called bed rock being only a close pinch in the ore, bringing the walls together. An analysis made in 1880 by the Survey gave the following composition for the ore then in the bottom of the mine:

Analysis of Ore from the Hoff Mine.

Metallic iron,	54.19 per cent.
Silica,	11.70 " "
Titanic acid,	0.75 " "
Phosphorus,	1.33 " "
Sulphur,	Traces.

The old Dickerson mine at Ferro Mont has been leased by the Musconetcong Iron Company, who also operate the Hude mine at Stanhope. Up to the close of the year a small amount of ore had been taken from some of the upper workings on the property.

The King mine, near Ledgewood, was reported to have been a producer during the year, but details of the operations are not at hand.

THE ZINC MINES.

The New York and New Jersey Zinc Company's mines at Franklin Furnace are the only active zinc mines in the State. The work there during 1905 was in a general way a continuation of that for several preceding years. In the Parker shaft portion most of the levels from 1,050 feet up to and including 750 feet have been blocked out from northeast to southwest, ready for mining. At the northeast end the necessary "upraises" are now being projected from the bottom to the 700-foot level, and the "upraises" No. 1 and No. 2 have been extended to the 450-foot level, so that the ore body can now be blocked out between the 750 foot and the 450-foot levels.

In the Buckwheat mine, very little ore is now left on the old tunnel level, and the hanging wall is being cut back to an angle of repose, so as to facilitate sinking to the middle level (100 feet vertical). A pair of direct-acting hoisting engines have been installed in this mine at the dike, which, when all contemplated changes are made will insure 100 per cent. additional hoisting capacity.

During the year the total product mined was 323,061.85 gross tons, a large increase over the production for 1904.

The Sterling Hill mines, at Ogdensburg, were inactive throughout the year.

THE COPPER MINES.

The general situation at the various copper mines during 1905 has been about the same as in previous years.

The Griggstown mine has been pumped out and some exploratory work undertaken by the owners. Operations have been temporarily suspended at the American Copper mine at Somerville, but the mine has been kept dry and work can be resumed at any time. At the Pahaquarry mine, in the upper Delaware Valley, there has been no mining, the efforts of the company being directed towards completing the mill, in which it is planned to treat the siliceous ore by a new process, devised and patented by N. S. Keith. Inasmuch as this method involves a somewhat radical departure from existing metallurgical processes, although extremely simple in its fundamental conceptions, the results under the stress of actual operation on a commercial scale, will be watched with much interest. There is a large amount of low-grade ore, chalcocite impregnating a hard quartzite of Silurian age, which can be blasted down cheaply and in large amounts. The unfavorable conditions which render it impossible to treat these siliceous ores by the ordinary smelting methods are, on the one hand, the great cost at the mine of suitable fuel and fluxes, such as iron oxides, iron sulphides or limestone, and on the other, the cost of transporting the ores to cheap fuel and fluxes, when the low grade of the rock is taken into account. Unless some other method of treatment, such as is proposed, can be successfully and cheaply applied, the ores are of no commercial value. In view of this fact, it is to be hoped that the proposed method will prove successful.

February 1st, 1906.

Mineral Statistics.

For the Year 1905.

IRON ORE.

The total production of the mines, as reported by the several mining companies, was 500,541 tons.

The table of statistics is reprinted, with the total amount for 1905 added.

TABLE OF STATISTICS.

Year.	*Iron Ore.*	*Authority.*
1790	10,000 tons	Morse's estimate.
1830	20,000 tons	Gordon's Gazetteer.
1855	100,000	Dr. Kitchell's estimate.
1860	164,900 tons	U. S. census.
1864	226,000 tons	Annual Report State Geologist.
1867	275,067 tons	" " "
1870	362,636 tons	U. S. census.
1871	450,000 tons	Annual Report State Geologist.
1872	600,000 tons	" " "
1873	665,000 tons	" " "
1874	525,000 tons	" " "
1875	390,000 tons	" " "
1876	285,000 tons*	" " "
1877	315,000 tons*	" " "
1878	409,674 tons	" " "
1879	488,028 tons	" " "
1880	745,000 tons	" " "
1881	737,052 tons	" " "
1882	932,762 tons	" " "
1883	521,416 tons	" " "
1884	393,710 tons	" " "
1885	330,000 tons	" " "
1886	500,501 tons	" " "
1887	547,889 tons	" " "
1888	447,738 tons	" " "

* From statistics collected later.

Year.	Iron Ore.	Authority.
1889	482,109 tons	Annual Report State Geologist.
1890	552,996 tons	" " "
1891	551,358 tons	" " "
1892	465,455 tons	" " "
1893	356,150 tons	" " "
1894	277,483 tons	" " "
1895	282,433 tons	" " "
1896	264,999 tons	" " "
1897	257,235 tons	" " "
1898	275,378 tons	" " "
1899	300,757 tons	" " "
1900	342,390 tons*	" " "
1901	401,151 tons	" " "
1902	443,728 tons	" " "
1903	484,796 tons*	" " "
1904	499,952 tons	" " "
1905	500,541 tons	" " "

* The figures, 407,596 tons, given in the report for 1900, included 75,206 tons of crude material which should have been reduced to its equivalent in concentrates. The figures for 1903, given in the report for that year, were incorrect.

ZINC ORE.

The production of the New Jersey Zinc Company's mines is reported by Mr. James B. Tonking, Superintendent, to be 323,062 gross tons of zinc and franklinite ore. It was chiefly separated at the company's mills. This report shows a large gain in production over 1904.

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

Year.	Zinc Ore.	Authority.
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	" " "

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

Year.	*Zinc Ore.*	*Authority.*
1884	40,094 tons	Annual Report State Geologist.
1885	38,526 tons	" " "
1886	43,877 tons	" " "
1887	50,220 tons	" " "
1888	46,377 tons	" " "
1889	56,154 tons	" " "
1890	49,618 tons	" " "
1891	76,032 tons	" " "
1892	77,298 tons	" " "
1893	55,852 tons	" " "
1894	59,382 tons	" " "
1895*		
1896	78,080 tons	" " "
1897	76,973 tons	" " "
1898	99,419 tons	" " "
1899	154,447 tons	" " "
1900	194,881 tons	" " "
1901	191,221 tons	" " "
1902	209,386 tons	" " "
1903	279,419 tons	" " "
1904	250,025 tons	" " "
1905	323,062 tons	" " "

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

Publications.

The demand for the publications of the Survey is continuous and active, and requests for the reports are granted in the case of all the later editions.

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

The Annual Reports of the State Geologist are printed by order of the Legislature as a part of the legislative documents. They are distributed by the State Geologist to libraries and public institutions, and, as far as possible, to any who may be interested in the subjects of which they treat.

Six volumes of the Final Report series have been issued. Volume I, published in 1888, has been very scarce for several years, but all the valuable tables were reprinted in an appendix of Volume IV, of which a few copies still remain, although the supply of this volume is so far reduced that indiscriminate requests cannot be granted.

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

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

CATALOGUE OF PUBLICATIONS.

GEOLOGY OF NEW JERSEY. Newark, 1868, 8vo., xxiv + 899 pp. Out of print.

PORTFOLIO OF MAPS accompanying the same, as follows:

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

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

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

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

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

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

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

8. Map of the zinc mines, Sussex county; colored. Scale, 8 inches to 1 mile.

A few copies can be distributed at $2.00 per set.

REPORT ON THE CLAY DEPOSITS of Woodbridge, South Amboy and other places in New Jersey, together with their uses for firebrick, pottery, etc. 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. Out of print.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. II. Part I. Mineralogy. Botany. Trenton, 1889, 8vo., x + 642 pp. (Postage, 25 cents.)

FINAL REPORT OF THE STATE GEOLOGIST. Vol. II. Part II. Zoology. Trenton. 1890, 8vo., x + 824 pp. (Postage, 30 cents.)

REPORT ON WATER-SUPPLY. Vol. III of the Final Reports of the State Geologist. Trenton, 1894, 8vo., xvi + 352 and 96 pp. (Postage, 21 cents.)

REPORT ON THE PHYSICAL GEOGRAPHY of New Jersey. Vol. IV of the Final Reports of the State Geologist. Trenton, 1898, 8vo., xvi + 170 + 200 pp. Unbound copies, postage 24 cents; cloth bound, $1.35, including photo-relief map of State. Scarce.

REPORT ON THE GLACIAL GEOLOGY of New Jersey. Vol. V of the Final Reports of the State Geologist. Trenton, 1902, 8vo., xxvii + 802 pp. (Sent by express, 35 cents if prepaid, or charges collect.)

REPORT ON CLAYS AND CLAY INDUSTRY of New Jersey. Vol. VI. of the Final Reports of the State Geologist. Trenton, 1904, 8vo., xxviii + 548 pp. (Sent by express, 30 cents if prepaid, or charges collect.)

BRACHIOPODA AND LAMELLIBANCHIATA of the Raritan Clays and Greensand Marls of New Jersey. Trenton, 1886, quarto, pp. 338, plates XXXV and Map. (Paleontology, Vol. I.) (By express.)

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

Paleozoic Paleontology. Trenton, 1903, 8 vo., xii + 462 pp., plates LIII. (Paleontology, Vol. III.) (Postage, 20 cents.)

Atlas of New Jersey. The complete work is made up of twenty sheets, each about 27 by 37 inches, including margin. Seventeen sheets are on a scale of 1 inch per mile and three on a scale of 5 miles per inch. It is the purpose of the Survey gradually to replace Sheets 1-17 by a new series of maps, upon the same scale, but somewhat differently arranged so as not to overlap. The new sheets will be numbered from 21-37, and will be subject to extensive revision before publication. These sheets will each cover the same territory as eight of the large maps, on a scale of 2,000 feet per inch. Nos. 1, 2, 4, 5, 7, 8, 11, 12, 13 and 17 have already been replaced as explained below.

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

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. 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. 18. New Jersey State Map. Scale, 5 miles to the 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. (Out of print.)

No. 21. Northern Warren and Western Sussex counties. Replaces Sheet 1. (Ready August 1, 1906.)

No. 22 Eastern Sussex and Western Passaic counties. Replaces Sheet 4.

No. 23. Northern Bergen and Eastern Passaic counties, to West Point, New York.

No. 24. Southern Warren, Northern Hunterdon and Western Morris counties. Replaces Sheet 2.

No. 26. Vicinity of Newark and Jersey City—Paterson to Perth Amboy. Replaces in part Sheet 7.

No. 27. Vicinity of Trenton—Raven Rock to Palmyra, with inset, Trenton to Princeton. Replaces Sheet 5.

No. 28. Trenton and Eastward—Trenton to Sayreville. Replaces Sheet 8.

No. 31. Vicinity of Camden, to Mount Holly, Hammonton and Elmer. Replaces Sheet 11.

No. 32. Part of Burlington and Ocean counties, from Pemberton and Whitings to Egg Harbor City and Tuckerton. Replaces Sheet 12.

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*At the date of publication of this report these sheets are out of print. New editions will be issued as soon as possible.

No. 33. Southern Ocean county, Tuckerton to Tom's River and Chadwicks. Replaces Sheet 13.

No. 37. Cape May.—Cape May City to Ocean City and Mauricetown.

Other sheets of the new series, Nos. 21-37, will be printed from time to time, as the older sheets become out of print. All the maps are sold at the uniform price of twenty-five cents per sheet, either singly or in lots. Since the Survey cannot open small accounts, and the charge is merely nominal, remittance should be made with the order. Order by ***number*** of the State Geologist, Trenton, N. J.

TOPOGRAPHIC MAPS, NEW SERIES.

These maps are the result of recent revision of the earlier surveys, and contain practically all of the features of the one-inch scale maps, with much new material. They are published on a scale of 2,000 feet to an inch, and the sheets measure 26 by 34 inches. The Hackensack, Paterson, Boonton, Dover, Jersey City, Newark, Morristown, Chester, New York Bay, Elizabeth, Plainfield, Pluckemin, Amboy, New Brunswick, Somerville, Navesink, Long Branch, Shark River, Trenton Camden, Mt. Holly, Woodbury, Taunton Sheets and Atlantic City have been published and are now on sale. The price is twenty-five cents per sheet, ***payable in advance.*** Order by ***name*** any of the sheets above indicated as ready, of The State Geologist, Trenton, New Jersey.

ANNUAL REPORTS.

REPORT OF PROFESSOR GEORGE H. COOK upon the Geological Survey of New Jersey and its progress during the year 1863. Trenton, 1864, 8vo., 13 pp. Out of print.

THE ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, to his Excellency Joel Parker, President of the Board of Managers of the Geological Survey of New Jersey, for the year 1864. Trenton, 1865, 8vo., 24 pp. Out of print.

ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, to his Excellency Joel Parker, President of the Board of Managers of the Geological Survey of New Jersey, for the year 1865. Trenton, 1866, 8vo., 12 pp. Out of print.

ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, on the Geological Survey of New Jersey, for the year 1866. Trenton, 1867, 8vo., 28 pp. Out of print.

REPORT OF THE STATE GEOLOGIST, Prof. Geo. H. Cook, for the year of 1867. Trenton, 1868, 8vo., 28 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1869. Trenton, 1870, 8vo., 57 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1870. New Brunswick, 1871, 8vo., 75 pp., with maps. Very scarce.

ANNUAL REPORT of the State Geologist of New Jersey for 1871. New Brunswick, 1872, 8vo., 46 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1872. Trenton, 1872, 8vo., 44 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1873. Trenton. 1874. 8vo., 128 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1874. Trenton, 1874, 8vo., 115 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1875. Trenton, 1875, 8vo., 41 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1876. Trenton. 1876, 8vo., 56 pp., with maps. Out of print.

ANNUAL REPORT of the State eGologist 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. Scarce.*

ANNUAL REPORT of the State Geologist of New Jersey for 1884. Trenton, 1884, 8vo., 168 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1885. Trenton, 1885, 8vo., 228 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1886. Trenton, 1887, 8vo., 254 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1887. Trenton. 1887, 8vo., 45 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1888. Camden, 1889, 8vo., 87 pp., with map.

ANNUAL REPORT of the State Geologist of New Jersey for 1889. Camden. 1889, 8vo., 112 pp.

ANNUAL REPORT of the State Geologist of New Jersey for 1890. Trenton. 1891, 8vo., 305 pp., with maps. (Postage, 10 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1891. Trenton. 1892, 8vo., xii+270 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1892. Trenton. 1893, 8vo., x+368 pp., with maps. (Postage, 10 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1893. Trenton, 1894, 8vo., x+452 pp., with maps. (Postage, 18 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1894. Trenton. 1895, 8vo., x+304 pp., with geological map. (Postage, 11 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1895. Trenton, 1896, 8vo., xl+198 pp., with geological map. (Postage, 8 cents.)

* This report can be supplied only to libraries.

ANNUAL REPORT of the State Geologist of New Jersey for 1896. Trenton, 1897, 8vo., xxviii+377 pp., with map of Hackensack meadows. (Postage, 15 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1897. Trenton, 1898, 8vo., xl+368 pp. (Postage, 12 cents.)

ANNUAL REPORT of the State Geologist for 1898. Trenton, 1899, 8vo., xxxii+244 pp., with Appendix, 102 pp. (Postage, 14 cents.)

ANNUAL REPORT of the State Geologist for 1899 and REPORT ON FORESTS. Trenton, 1900, 2 vols., 8vo., Annual Report, viii+192 pp. FORESTS, xvi+327. pp., with seven maps in a roll. (Postage, 8 and 22 cents.)

ANNUAL REPORT of the State Geologist for 1900. Trenton, 1901, 8vo., xl+231 pp. (Postage, 10 cents.)

ANNUAL REPORT of the State Geologist for 1901. Trenton, 1902, 8vo., xxviii+178 pp., with one map in pocket. (Postage, 8 cents.)

ANNUAL REPORT of the State Geologist for 1902. Trenton, 1903, 8vo., viii+155 pp. (Postage, 6 cents.)

ANNUAL REPORT of the State Geologist for 1903. Trenton, 1904, 8vo., xxxvi+132 pp., with two maps in pocket. (Postage, 8 cents.)

ANNUAL REPORT of the State Geologist for 1903. Trenton, 1904, 8vo., ix+317 pp. (Postage, 12 cents.)

ANNUAL REPORT of the State Geologist for 1904. Trenton, 1905, 8vo., x+317 pp. (Postage, 11 cents.)

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