GEOLOGICAL SURVEY OF NEW JERSEY

HENRY B. KÜMMEL, STATE GEOLOGIST

BULLETIN 12

Annual Administrative Report

OF THE

STATE GEOLOGIST

FOR THE YEAR

1913

UNION HILL, N. J.
DISPATCH PRINTING COMPANY
1914

The Geological Survey of New Jersey

BOARD OF MANAGERS.

His Excellency, James F. Fielder, Governor and *ex-officio* President of the Board, ... Trenton.

Members at Large.

Alfred A. Woodhull,	Princeton,	1914
Frank Vanderpoel,	Orange,	1914
T. Frank Appleby,	Asbury Park,	1915
David E. Titsworth,	Plainfield,	1916
William Libbey,	Princeton,	1916
Harrison Van Duyne,	Newark,	1917
John C. Smock,	Trenton,	1918

Congressional Districts.

I.	Stephen Pfeil,	Camden,	1916
II.	P. Kennedy Reeves,	Bridgeton,	1917
III.	Henry S. Washington,	Locust,	1914
IV.	Washington A. Roebling,	Trenton,	1918
V.	Frederick A. Canfield,	Dover,	1915
VI.	George W. Wheeler,	Hackensack,	1916
VII.	John H. Cannon,	Paterson,	1918
VIII.	George F. Reeve,	Newark,	1918
IX.	E. H. Dutcher,	East Orange,	1914
X.	Herbert M. Lloyd,	Montclair,	1917
XI.	Clarence G. Meeks,	North Bergen,	1915
XII.	Joseph D. Bedle,	Jersey City,	1918

State Geologist,

HENRY B. KÜMMEL.

Letter of Transmittal

TRENTON, N. J., March 6, 1914.

Hon. James F. Fielder, Governor and ex-officio President of the Board of Managers of the Geological Survey:

SIR—I have the honor to submit my administrative report summarizing the work of the Geological Survey for the year 1913. This report is made in accordance with Chapter 46 of the Laws of 1910. The manuscript of several reports setting forth the results of the scientific work of the Survey are nearly completed and their publication will be requested in the near future.

Respectfully submitted,

HENRY B. KÜMMEL,
State Geologist.

Administrative Report

HENRY B. KÜMMEL, *State Geologist.*

CONTENTS.

ADMINISTRATION.

Scope of Report.—This report is purely administrative, and does not purport to set forth except very briefly the results of the scientific work of the Geological Survey. These results are published from time to time as bulletins and final reports, and can be obtained upon application to the State Geologist.

Organization.—The Geological Survey is under the general oversight and direction of the Board of Managers who are appointed by the Governor and who serve without pay. The immediate direction of all lines of work is in the hands of the State Geologist who is appointed by the Board and holds office at their pleasure. The result of this arrangement has been to insure stability in the policies and continuity in the work of the department and the State has been protected against changes in personnel which would result in the loss of much scientific training and experience.

Members of the Survey staff are of two classes—permanent and temporary or intermittent assistants. The former are permanent in the sense that they give all their time to the Survey, receive an annual salary and hold their positions under the Civil Service law, subject, of course, to removal by the Board of Managers for inefficiency, and other proper causes. The latter are temporary or intermittent in the sense that they are not continuously engaged in State work and are on a per diem basis of payment for work actually performed. Most of these are men of high standing as geologists or engineers and their employment at low per diem rates permits the Survey to obtain the services of specialists in various lines, for specific investigations on extremely reasonable terms.

During the year the following appointments to the Board of Managers were made by the Governor:

John C. Smock, Trenton, Member at Large—Reappointed.
Washington A. Roebling, Trenton, IV District—Reappointed.
Joseph D. Bedle, Jersey City, XII District—Reappointed.
John H. Cannon, Paterson, VII District; George F. Reeve, Newark, VIII District—New Appointees.

The Survey staff comprised the following persons, those in the first group being employed continuously:

Henry B. Kümmel, State Geologist.
M. W. Twitchell, Assistant State Geologist.
R. B. Gage, Chemist.
Henry Jennings, Assistant in Charge of Soil Mapping.
Henrietta L. Kruse, Clerk and Stenographer.
John S. Clark, Assistant.
R. W. Wildblood, Stenographer and Laboratory Assistant.

C. C. Vermeule, Topographer and Consulting Engineer.
J. Volney Lewis, Professor of Geology, Rutgers College, Geologist.
D. W. Johnson, Professor of Physical Geography, Columbia University, Geographer.
C. H. Hitchcock, Retired, Honolulu, Geologist.
Max Schrabisch, Assistant, Archaeological Survey.
Leslie Spier, Assistant, Archaeological Survey.

John G. Baumann, Janitor at Laboratory.

In addition to the above persons, Messrs. C. A. Weckerly and H. L. Selden of the United States Geological Survey prepared some drawings to illustrate one of the Survey reports.

Publications.—Publications during the year were as follows:

Bulletin 8. Administrative Report of the State Geologist for 1912, by Henry B. Kümmel, State Geologist. Including a second report on Shark River Inlet by C. C. Vermeule, Consulting Engineer, and a list of new bench marks, pp. 103.

Bulletin 9. A Preliminary Report of the Archaeological Survey of the State of New Jersey, made by the Department of Anthropology in the American Museum of Natural History, Clark Wissler, Ph.D., Curator, under the direction of the State Geological Survey. Compiled by Alanson Skinner and Max Schrabisch.

Bulletin 10. The Mechanical and Chemical Composition of the Soils of the Sussex Area, New Jersey, by A. W. Blair and Henry Jennings with a chapter on the Methods of Soil Analysis, by R. B. Gage.

Bulletin 11. The Mineral Industry of New Jersey for 1912 by Dr. M. W. Twitchell.

New editions of atlas sheets.

Newark, Scale 2,000 ft.=1 mile.

Sheets Nos. 26, 31, 32 and 33, Scale 1 mile=1 inch.

Distribution.—The demand for the maps of the Survey was not quite up to the mark of previous years, as shown below:

	Sheets Sold		
	1911	1912	1913
Maps on scale of 1 inch per mile	1491	1718	1422
Maps on scale of 2½ inches per mile	2096	1658	1809
Geologic folios	65	69	60

There is more or less steady demand for the back reports of the Survey as well as for current issues. Some of the most valuable of those published in recent years are entirely exhausted in so far as copies for free distribution are concerned. A list of all reports heretofore published, with those still available accompanies this report. The total number of all reports sent out during the fiscal year was 4,221.

Library.—The library of the Survey is steadily increasing in size each year, chiefly by exchange and now demands far more space than is available, in the cramped condition of the State House. During the year an arrangement was made with the Librarian of Rutgers College at New Brunswick by which the least used portion of the Survey library could be deposited there, subject to recall at any time in whole or in part. This has resulted in freeing our shelves of much material which has never been consulted, and has made more accessible those volumes to which more or less frequent reference must be made.

Note Recording.—The combination number system for identifying and recording localities in note taking has been continued in use and found satisfactory. It has been supplemented by the adoption of loose-leaf note books, so that all notes, relating to a given area, although taken at different times by different workers can be assembled in one binder for final office reference. Since the atlas sheet affords the most convenient unit of areas, the loose sheets are grouped accordingly.

Survey Quarters Inadequate.—The crowded condition of the survey rooms and laboratory described at length a year ago is in no way improved. On the contrary it is slightly worse, owing to the natural increase in the work, particularly in the laboratory. It continues to be necessary for one assistant to work in New Brunswick at the State Experiment Station, owing to lack of room in the survey offices at Trenton. The Assistant State Geologist is compelled to have his desk in the office of the Curator of the State Museum. The loss of efficiency due to the inadequate facilities is considerable. A laboratory with the necessary offices, weighing, testing and store rooms, is the greatest need, and should be provided by the State authorities as soon as possible, particularly since the Survey occupies the present laboratory quarters only by courtesy.

Expenditures.—The expenditures of the Survey during the fiscal year ending October 31, were as follows:

FINANCIAL STATEMENT—FISCAL YEAR OCTOBER 31, 1913.

		Credit
Regular Appropriation		$18,500.00
Testing Road Materials		4,000.00
Archaeological Survey Appropriation		1,000.00
		$23,500.00
Expenditures—		
Salaries, clerical force	$ 1,825.43	
Salaries, scientific force	14,947.16	
Traveling expenses	1,861.95	
Office supplies	186.56	
Laboratory equipment	1,077.68	
Laboratory supplies	495.50	
Other scientific apparatus	25.75	
Library	105.95	
Postage	156.12	
Express and freight	88.72	
Telegraph and telephone	95.08	
Engraving and printing maps	2,331.05	
Sundries	58.63	
Museum	5.00	
Unexpended balance	239.42	$23,500.00

CASH ACCOUNT.

Balance on hand November 1, 1912 ....$	127.19	
Receipts from sales of maps and reports	854.20	
Receipts from laboratory work	10.00	
Disbursements—		
Paid State Treasurer		904.39
Balance on hand October 31, 1913		87.00
	$991.39	$991.39

TOPOGRAPHIC AND ENGINEERING WORK.

Mr. C. C. Vermeule has continued, as Consulting Engineer, to direct the topographic and engineering work of the Survey. Messrs. P. D. Staats, P. Cowdin and R. Lufburrow have been his chief assistants employed in State work.

Bench Marks.—As related in the last administrative report (Bulletin 8, p. 19) the leveling parties, organized in September, 1912, to establish new bench marks and reset old ones, continued their work into the fiscal year covered by this report. They were in the field through November, 1912, and the early part of December. After the field work was ended, Mr. Staats was engaged for several weeks in checking and tabulating results for publication. The work was limited to Bergen, Essex, Hudson, Morris, Passaic, Sussex, Union and Warren counties, and the revised list of bench marks for those counties was published in Bulletin 8, pp. 55-93.

Revision of Topographic Maps.—During the year sheet 27, on a scale of a mile to an inch, and the Newark and Hackensack sheets on a scale of 2,000 feet to an inch, were wholly or in part revised and their culture brought up to date. The last two had not been revised since their first publication, and as they both represent regions in which the growth of all municipalities has been exceedingly rapid, the changes in culture have been so great that it has been necessary to redraw entirely the sheets before photolithographing them. The Hackensack sheet was not finished at the close of the fiscal year. The revision of sheet 27 was restricted to the vicinity of the larger cities and towns, except that all relocations of improved roads were noted. This data was obtained by co-operation of the State Road Department.

Improvement of Shark River Inlet.—The Board of Managers of the Survey at its regular meeting held December 3, 1912, directed the State Geologist to advertise for bids for the construction of jetties at Shark River Inlet in accordance with the plans adopted, as soon as he was advised by the State Comptroller that $20,000 had been deposited with the State Treasurer by the County of Monmouth, the Borough of Avon and the Borough of Belmar.

On December 13, 1912, in accordance with the provisions of chapter 3923, U. S. Statutes at Large, Fifty-ninth Congress, 1906, p. 800, copies of the plans and specifications were submitted to the Secretary of War for examination and approval by the Chief of Army Engineers. On January 14, 1913, formal approval was received from the Assistant Secretary of War. On February 27, 1913, at a special meeting of the Board of Managers the following bids were received:

Messrs. Young & Hyde	$77,615.97
Mr. H. Gardner	82,237.17

Since the estimated cost on the basis of these bids exceeded the amount available under the appropriation they were rejected. The engineer was requested to revise the plans and spcifications, if possibl, so as to reduce the cost without impairing the efficiency of the plan, and the State Geologist was directed to advise those interested in the improvement that an additional appropriation of $15,000 would probably be necessary. A bill authorizing an additional appropriation of $15,000 was introduced in the Assembly by Speaker Leon R. Taylor of Monmouth County, and after passing both branches of the Legislature, was signed by the Governor on April 1, 1913. This amount was included in the Annual Appropriation bill, and, after advertising, new bids were received on May 9 from the following persons:

Herbert O. Gardner.
Bay Dredging and Contracting Co.
MacArthur Concrete Pile and Foundation Co.
Young & Hyde, Inc.
F. W. Schiers, Jr.
P. J. Monahan.

The contract was thereupon awarded to the Bay Dredging and Contracting Company of Brooklyn, N. Y., the lowest bidders, for $57,654.20 on the basis of the estimated quantities. The contract was signed on May 16, 1913, and the required bond in the sum of $29,000 executed by The Title Guaranty & Security Company of Scranton, Pa., was furnished, both documents being approved by the Attorney-General's department and filed with the Comptroller. Work was commenced within the time required by the contract, but up to the close of the fiscal year, had proceeded very slowly—so slowly, in fact, that it was evident that it could not be completed within the time limit of the contract. About 60 per cent. of the concrete piles necessary had been made, but only a few had been put in place.

The work has been in charge of a committee of the Board of Managers, consisting of Harrison Van Duyne, Chairman; Clarence G. Meeks, and T. Frank Appleby. C. C. Vermeule has been Engineer in Charge and P. D. Staats Resident Engineer.

GEOLOGIC WORK.

Geologic Map.—During the year proofs of the geologic map were received from the engravers and carefully corrected. Owing to the great detail with which the geology of New Jersey has been studied, the preparation and printing of this map has been a work of extreme difficulty. The map legend calls for fifty-eight patterns or colors to represent the many different formations which have been recognized. It has been no easy task to choose patterns and colors which will harmonize and at the same time be sufficiently distinctive to permit each formation to show as a separate area upon the map. It was found necessary to make extensive changes in the first proofs, both in the patterns chosen for some of the formations and in the color scheme, so that the completion of the map has been much delayed. It is expected, however, that it will be ready for distribution in March or early April, 1914.

Résumé of the Geology of New Jersey.—Prof. J. V. Lewis and the State Geologist have co-operated in the preparation of a short report describing each of the formations represented on the geolgic map and giving a brief outline of the successive steps in the geologic history of the State. The reports of the Survey, although a mine of information regarding the mineral wealth and geology of the State, do not in any one place contain a condensed summary of the geology of New Jersey such as this. It is believed that it will be a valuable help to mining-men, quarrymen, teachers, investors and to all others who wish this information but who have neither the time nor disposition to consult the more technical and elaborate reports of the Survey. It is expected that this report will be published during 1914.

Mineral Production.—The statistics of the mineral production of New Jersey during 1912 were collected in co-operation with the U. S. Geological Survey, Dr. Twitchell, Assistant State Geologist, having immediate charge of this work. The results of this study were published as Bulletin 11 of the Geological Survey. The results when summarized showed that the total value of the mineral production in 1912 was $40,391,548, an increase of $2,675,137 over the previous year.

The distribution of these industries presents a number of features of interest.

The only operating *zinc* mines are near Franklin Furnace, Sussex County. The *active iron* mines are in the Highlands and extend from near Ringwood, Passaic County, by way of Hibernia and Dover in Morris County, to Oxford Furnace, near Belvidere, in Warren County.

Limestone is quarried in Sussex, Warren, Morris and Hunterdon Counties. *Slate* is quarried at only two points, both in Sussex County. The *trap-rock* quarries are chiefly in the Triassic area, and are scattered along the ridges, including the Palisades, the Watchung Mountains, Rocky Hill, etc. The *granite* quarries are in the Highlands, chiefly around Pompton, Passaic County; Waterloo, Sussex County, and Boonton, German Valley and Hibernia, Morris County. The *sandstone* quarries are chiefly in the Triassic area, especially near Stockton, Byram, Princeton and Wilburtha. The only *talc* and *soapstone* quarry is near Phillipsburg.

Most of the *clay* pits and *clay-working* plants are located along the Cretaceous belt extending from Woodbridge, Middlesex County, to Salem, in Salem County, although quite a number are scattered over the rest of the State.

All of the operating *portland cement* plants are in Warren County, near Phillipsburg. The only *coke* works reporting is located at Camden. The *sand-lime brick* works are at West Palmyra, Burlington County, Penbryn and Haddonfield, Camden County, and Rockaway, Morris County. The *mineral-paint* plants are at Newark, Essex County, Lincoln, Middlesex County, and Grasselli, Union County.

The *sand* and *gravel* pits are widely distributed throughout the State, though the majority are located in the southern part. In 1912, there were pits in sixteen out of the twenty-one counties, Essex, Hudson, Hunterdon, Salem and Somerset being the only ones not reporting a production. Of the 95 producers, 21 were in Burlington, 17 in Middlesex, 10 in Cumberland, 8 in Gloucester, 7 in Camden, 6 in Morris, 5 in Sussex, 4 in Bergen, 3 each in Warren, Passaic and Cape May, 2 each in Union, Monmouth and Mercer, and 1 each in Atlantic and Ocean.

The statistics for 1913 will be collected and compiled as soon as possible after the beginning of the new calendar year and the results will be published in a separate bulletin. The work will continue under the direction of Dr. Twitchell, as last year, and will be done in co-operation with the United States Geological Survey.

Report on the Reptilian Foot-prints of the Trias.—During the year Prof. C. H. Hitchcock, formerly of Dartmouth College, prepared a brief paper for the Survey regarding the foot-prints of extinct reptiles not infrequently found upon slabs of red shale and sandstone of the Triassic formation. Great numbers of these have been found on the rocks of the Connecticut River valley, both in Connecticut and in Massachusetts. The discoveries in New Jersey while not so numerous as in those states, are of sufficient importance to warrant their collation and publication.

When these foot marks first arrested attention, every one referred them to birds, so that the name "bird tracks" was the common colloquial expression for them. Although it has long been recognized by scientists that they are the foot marks of ancient reptiles, long since extinct, they are still by most people regarded as bird tracks, which, indeed, many of them very much resemble. The finest specimens from New Jersey were excavated at a quarry near Towaco station in Morris County a numbr of years ago, and are now preserved in the Museum at Rutgers College. Within a space of 15 feet in length the foot prints of least twelve different species of reptiles are shown. Publication of Prof. Hitchcock's paper will probably be somewhat delayed in the interests of a further consideration of the questions involved, but when printed will add one more to the reports of the Survey in which the ancient life of the State is described.

Studies of the Stability of the New Jersey Coast.—The preparation of the report on the New Jersey shoreline by Prof. D. W. Johnson of Columbia University has progressed slowly during the last few months on account of the press of regular academic duties which required most of the author's time. The chapters covering the characters of waves, methods of wave erosion, currents and their work, and a review of previous writings about the New Jersey coast, are completed. The entire manuscript will be ready for the printer some time during the summer. Inasmuch as the work on the New Jersey coast was undertaken as a part of a much larger problem, involving the supposed changes of level along the entire Atlantic coast, it has not been deemed advisable to push the New Jersey studies to a conclusion before the detailed history of the rest of the coast was known. This program has delayed the publication of the New Jersey report longer than would otherwise have been necessary; but its value must be very materially increased by the close correlation with work on other parts of the coast.

When published, the report will furnish the citizens of the State with a careful review of the studies of wave action which have been carried on in different countries, in the hope that this will lead to a better understanding of the methods of wave erosion and deposition along our shores. Currents and current action will be similarly treated, and the effects of waves and currents upon cliffs and beaches will be analyzed. The effects of the recent great storm (January, 1914) on the coast at Sea Bright and vicinity are to be described briefly and a résumé of older changes in the form of the shoreline given. Then will follow a critical discussion of the supposed subsidence of the New Jersey coast, including a review of all previous writings on the subject, and a careful analysis of all the arguments in favor of the theory. It will be shown that the evidence does not really indicate a gradual sinking of the land, but that local changes in tide levels along the shores are responsible for many of the fictitious appearances of subsidence. Recent precise levelling in the vicinity of New York confirms the surveys made in southern New Jersey (referred to in the last Annual Report), by proving an absence of any tilting of the land, and shows further that mean sea level in New York Bay is the same as it was more than a quarter of a century ago when determined at Sandy Hook. The detailed results of these surveys and other evidences of coastal stability will be fully discussed in the report.

Investigation by Prof. J. Volney Lewis.—Prof J. V. Lewis of Rutgers College, reports concerning his work for the Survey as follows:

"During the greater part of the time that I have been able to devote to the work of the Geological Survey in the fiscal year ending October 31, 1913, with the exception of a few weeks in the summer, I have been engaged in the laboratory study of the wonderful variety of minerals found in many of the trap quarries, with particular reference to their modes of occurrence, associations, and the difficult question of their origin. In this work the extensive collections that I had made in former seasons in connection with other Triassic investigations for the Survey have been used and compared with collections in the Geological Museum of Rutgers College, the American Museum of Natural History, the Ward-Eric Disbrow Collection in the Newark Public Library, and the private collections of Col. W. A. Roebling and Mr. Frederick A. Canfield.

"Extensive search has been made in the literature of these occurrences and similar mineral associations elsewhere, both in this country and abroad. By this means a considerable number of widely-scattered articles concerning these New Jersey minerals and numerous comparative studies that have been made in connection with investigations of similar materials elsewhere, have been collected and summarized. Many of these publications contain valuable analyses and other information that have not been available heretofore. In order to find many of the articles to which references were obtained a considerable amount of library research was necessary. For this purpose, besides the library of Rutgers College, several days each were devoted to the libraries of New York City, the United States Geological Survey, the Smithsonian Institution, and the Library of Congress. Shorter visits to other libraries and correspondence with authors also supplemented this work.

"In connection with the field work on these minerals, their association in several localities with the peculiar rock structure known as 'pillow lava' has led to a study of this also, and a résumé of the literature on the subject has been prepared. A preliminary paper on the 'Origin of Pillow Lavas' was presented, with the consent of the State Geologist at the meeting of the Geological Society of America, at Princeton, N. J., December-January, 1913-1914.

"Considerable progress has been made on the manuscript of a report on these topics for publication by the Survey.

"Several weeks during the past summer were devoted to a field study of the Lockatong argillite of Hunterdon, Mercer and Somerset counties. The structures and field relations of this formation were carefully examined and materials were collected for chemical and microscopical investigation in the laboratory. The greatly extended use of this rock in all of the recent buildings of Princeton University was noted with much interest, and the extensive quarrying operations afforded considerable opportunity for studying the characters and structures of the formation. It is hoped that further investigation of the materials now in hand may throw light on the question of the real nature and origin of this peculiar rock."

Stratigraphical Studies.—Dr. Twitchell has continued his studies of the Eocene deposits and their faunas as noted in the last Administrative Report, but owing to the press of other duties, has been able to give but comparatively little time to this line of investigation.

Preparation of a new geologic folio in co-operation with the U. S. Geological Survey has necessitated additional field work by the State Geologist in the area covered by the Easton quadrangle. In particular, the relations of the Kittatinny limestone have been studied with a view to determining to what extent the subdivisions of this formation made in Eastern Pennsylvania are applicable to the formation in New Jersey. It is apparent that along the Delaware two members can be recognized where conditions for observation are favorable. Whether these subdivisions can be traced and mapped to the northeast remains to be determined. If so, another step will have been taken in working out the geologic history of northern New Jersey.

LABORATORY WORK.

The laboratory has continued in charge of R. B. Gage, Chemist, assisted by F. H. Bauman and R. W. Wildblood. Its location in the second story of a brick building built for a stable, the lower story of which is used as a garage, is unchanged. As set forth in previous reports, the building is entirely inadequate for the work which the Survey is called upon to do, and better accommodations are greatly needed. Inadequate as these quarters are, the Survey would not have even these, if it were not for the generous co-operation of a member of the Board of Managers who has permtted the department to use these rooms rent free ever since the laboratory was established. It is impossible to emphasize too strongly the fact that proper accommodations should be provided for this work as soon is possible, since the conditions which hinder it become more acute as the volume and variety of work increases and new apparatus is needed. Further expansion in the present quarters is impossible, but the volume of work which ought to be done is constantly increasing.

When it is necessary to make determination of materials other than those of ordinary routine work, the required space can be secured only by moving that apparatus which just then happens to be least in use. This compels a constant shifting of equipment with a corresponding loss of time which could be saved in a laboratory located in a properly constructed building. This fact has made it necessary to confine the work as much as possible to testing materials belonging to the ordinary routine.

The regular work of the laboratory was carried on along several distinct lines: (1) testing material used in State road work, (2) analysis of soil in connection with the soil survey, (3) analysis of coal delivered to State institutions to determine its heat value as a basis of payment.

Early in the year some soil work was carried on. This was mostly of an experimental nature on soils of known composition in order to determine the availability of certain ingredients. About twenty-five soils were thus tested. These determinations consumed most of Mr. Gage's time during January and February.

Twenty samples of coal were tested to determine the percentage of ash and moisture. These determinations were all made in duplicate so that the examination of each sample necessitated six separate determinations. Samples came to the laboratory unground and had to be prepared for analysis. In a properly equipped laboratory, the preparation of a sample for analysis is ordinarily quickly and easily done. This is not the case in the Survey laboratory under present conditions. It not infrequently takes more time to shift apparatus so the grinder can be used than it does to grind the sample or make the analysis. Moreover, when a sample is being ground, no other work can be done in that part of the laboratory on account of the dust and vibration.

The greater part of the time of Mr. Gage and his assistants was spent in testing road materials in co-operation with the State road department. To examine all the road materials which might properly have been tested to great advantage, would have needed the assistance of two or three more analysts and a laboratory several times the size of the present one. Of necessity their efforts were confined to those materials which under contracts in force had to be tested before use. The road specifications required that all shipments of oil, asphalt, bitumen and other binders used in road construction must be sampled and approved in the Survey laboratory before use upon the road. They also provided for taking samples of the finished pavement at frequent intervals and for its examination to determine whether the proper portion of materials were used. Since each shipment of material had to be separately tested a single contract called for a large amount of analytical work.

The immense amount of money that is now being expended in road construction has stimulated the invention of new methods of construction and of new road cements and compounds. Although it is probable that the majority of these will prove to be of little value for road building, yet some of them possess merit and it is not always possible to distinguish the good from the bad without a test, either in the laboratory or in actual practice. To test properly these new compounds is often a laborious task, but it is necessary to examine a large amount of chaff in the hope of finding a few kernels of good grain.

Since the specifications governing road material and methods of road construction are becoming each year more rigid and exacting, the work for the laboratory in this direction will unquestionably increase. Until recently, it was assumed that certain well known road compounds and methods of construction were of such standard composition or quality that detailed and frequent testing of these materials would not be necessary. Experience, however, has demonstrated that such an assumption was false and it has been found necessary to examine these materials, watch the construction of these roads, as frequently as is necessary for untried material.

New road specifications for the coming year are under consideration which will define the composition of all classes of road pavements. It is proposed to prepare a list of approved materials which contractors may use. The preparation of such a list will mean the examination of many grades of material for sale by various manufacturers. The specifications will also provide that the contractor may submit materials for examination and approval preparatory to bidding on a contract. After road construction has commenced, frequent testing of the material will be necessary to determine whether it conforms to the samples specified. It is certain that this will greatly increase the amount of work, which Mr. Gage and his assistants will be called upon to do, if much new road construction is undertaken.

Experience has demonstrated that a macadam base is not a proper one on which to construct a bituminous pavement. The use of portland cement concrete for road foundations is rapidly increasing and it will probably be the foundation eventually used on our principal highways, where there is heavy traffic. The thickness of this concrete foundation and the quantity of cement that should be used in an aggregate of a given composition are matters in which there is as yet no well settled practice, but they are questions which should engage the attention of the chemist of the Survey as soon as possible. Equipment to investigate these questions is on hand, but the present laboratory affords no place for its installation.

The importance of the work which the Survey is doing for the road department can better be appreciated, if it is born in mind that the loss on a single road contract, by the use of inferior material or improper construction, may be more than the entire cost of maintaining the laboratory for a period of five or even ten years. If the work is to continue and the Survey is to meet the demands in this direction which will probably be placed upon it in the near future, a larger laboratory must be provided as soon as possible.

SOIL SURVEY.

In the soil survey which is carried on in co-operation with the State Experiment Station at New Brunswick, and the Bureau of Soils at Washington, D. C., field work was continued in Monmouth County under the direction of Henry Jennings of the State Survey. He was assisted by Jos. Dickey of the Bureau of Soils, Washington, D. C., and for two and one-half months during mid-summer by Linwood Lee, a student at Rutgers College. In this field work the soils were examined in detail and the areal distribution of different types was carefully plotted on large scale maps. On completion of the work the map showed at a glance not only the different kinds of soil in an area but the location and boundaries of the various types. As the field work progressed, samples were collected of the different soils and will be analysed both chemically and mechanically. The chemical analysis is important in showing the total amount of plant food present in the soil and by inference the plant food requirements. By the mechanical analysis the relative proportions of gravel, coarse sand, fine sand, silt, clay, etc., are determined and the classification of a soil as a loam, silt loam, and sandy loam, fine sandy loam, sand, etc., is made. In connection with mapping the soils and collecting samples, notes are taken of the agricultural value of the different types. At the completion of this work a wealth of information regarding the soil of the region is at hand—information which is of inestimable value to the intelligent farmer and the agricultural expert and without which no adequate methods of soil improvement can be carried out.

Field work has been carried on in northern Monmouth County for two seasons and the region north of a line drawn east and west through Farmingdale and east of one drawn north and south through Tennant has been mapped in detail. At the close of the field season, the preparation of office copies of the map and a report descriptive of the soil types was begun.

Late in the year the Survey published as Bulletin 10, a Report on the Composition of the Soils of the Sussex Area. This region had been surveyed in previous seasons. The Bureau of Soils at Washington undertook the publication of the soil map prepared by co-operative effort and of a report describing particularly the physical properties of the soils. Bulletin 10, published by the State Survey, dealt more particularly with the chemical composition of the soils and discussed the presence or lack of plant foods. This work showed that the soils of the Sussex area are often very deficient in lime, although well supplied with potash, of which they contain in many instances, enormous amounts. They are also well supplied with phosphoric acid, but frequently respond to applications of commercial fertilizer which contain this constituent in an available form. The work of the soil survey has shown that the development of the soils of the Sussex area will depend upon the recognition by the farmers, that most of their soils are sour and are badly in need of lime. Neither are they so mellow as they should be, because of the insufficient amount of vegetable matter contained in them. For this reason lime and green manures must be used and the prevailing rotations modified so as to permit more frequent growing of leguminous crops.

What is true of Sussex County is also true of western Passaic County which was included in the survey of the Sussex area, and is probably true of a large part of Warren County in which the geological formations are the same as in Sussex.

Copies of the soil map of the Sussex Area and of Bulletin 10 regarding the composition of the soils of the region can be obtained upon request of the State Geologist.

Archæological Survey.—Archæological investigations authorized by the Legislature in 1912 were continued during the past field season. As in the previous year the work centered about the location of Indian village and camp sites, burial places, etc. Mr. Max Schrabisch spent about five months in Sussex County, and Mr. Leslie Spier a much shorter time in central and southern New Jersey. Mr. Schrabisch was successful in finding many village and camp sites, particularly along the upper Delaware, around Swartswood Lake, near Newton, on Germany Flats and near the borough of Sussex (Deckertown). His work has brought out the fact that the sand and gravel terraces along the upper Delaware River above Walpack bend were much frequented by the aborigines, so much so that for long distances hardly a field is without its evidence of Indian occupation. Perhaps the most interesting feature of Mr. Schrabisch's work is his discovery of twenty-one rock shelters which were occupied more or less continuously by the Indians. Some of these may have been only camping places where they paused for shelter on their hunting trips or journeys. Others favorably located and affording good shelter may have been occupied by one or more families for months at a time. All of these shelters have been excavated by Mr. Schrabisch and the relics carefully preserved. Large quantities of broken pottery, bones, stone chips and some implements, a few perfect but many of them broken, have been found. These discoveries of Mr. Schrabisch taken in connection with similar finds by him in previous years have shed new light upon the customs of the early inhabitants of New Jersey.

Mr. Spier, in the short time he was able to give to this work, located a number of sites near Plainfield, and many more along tributaries to the lower Delaware below Camden and along Maurice River.

Reports have been prepared by both workers and their publication will be requested as a separate bulletin in the near future.

CO-OPERATIVE WORK.

It is the desire of the Geological Survey to co-operate in the fullest degree with other State departments and agencies, in whatever way it can. The State Geologist is ex-officio Executive Officer of the Forest Commission, and is therefore in close touch with the work of that department and thus the activities of the Survey and of the Forest Commission so far as they approach each other at all, are in close harmony and there is no duplication of work.

With other departments and State institutions co-operation is of different types. With some it extends only to furnishing copies of the topographical atlas sheets which may be needed in their routine work. The case of the Quartermaster General's Department may be cited as an example. In this instance large scale maps of the region west of the State camp at Sea Girt were needed for use in the officers' training school. Tracings were prepared on a scale of 3 inches per mile from which a special edition for military use was printed.

At the request of the Prison Labor Commission, which was charged with the purchase of a stone quarry, where stone suitable for road metal and for lime burning could be obtained, inspections and surveys were made of various properties. Advice regarding the occurrence of ground-water supplies and possible pollution of springs from sewage was given the State Hospital for the Insane at Trenton. The State Tuberculosis Sanitarium at Glen Gardner has for several years purchased its coal under specifications providing for payment on the basis of per cent. of ash present. All deliveries are sampled and selected portions, after quartering down, are forwarded to the Survey laboratory for analysis. A deduction is made from or a bonus is added to the standard contract price, as the ash content is greater or less than the contract standard.

The pea coal furnished the sanitarium has almost uniformly been found to contain more than the standard ash content and deductions, in some cases amounting to over 30 cents per ton, have been made. The Survey so far as its laboratory facilities permit, will analyze (make ash determinations) samples of anthracite coal, without charge for any State institution. The only condition imposed is that the sampling shall be done according to approved methods so as to obtain a representative specimen, which must be delivered at the laboratory of the Survey, charges prepaid. No charge to State institutions is made by the Survey for this work.

The testing of road materials for the State Road Commissioner has already been described (see under chemical work). Its importance in road building cannot be overestimated, since it is only by work of this character that the proper standard of material can be maintained, and the Legislature has recognized its importance by making a special appropriation for it.

The co-operative agreement with the United States Geological Survey in the collection of statistics of the mineral production and in the publication of geological folios has been maintained. The work under the former head has already been discussed. No new folios were published, but the text for the Raritan folio was in part revised and just after the close of the fiscal year the proof sheets were read and corrected. The manuscript of the Greenwood Lake-Ramapo quadrangle is partially completed and will be forwarded to Washington as soon as possible. Under the terms of the agreement the U. S. Geological Survey bears the cost of engraving and printing the maps and text, and the State Survey is at liberty to purchase at cost price a special State edition. By this arrangement, a complete geologic atlas with descriptive text will be in time available at a minimum cost to the State.

Co-operation with the State Agricultural Experiment Station at New Brunswick and the Bureau of Soils at Washington in the soils survey of the State, has been set forth under the head of Soil Surveys, on a previous page.

March 4, 1914.

RECENT STORM EFFECTS

On the Northern New Jersey Shoreline, and their Supposed Relation to Coastal Subsidence

BY

DOUGLAS W. JOHNSON and WARREN S. SMITH

Introduction.

In the winter of 1913-14 the coast of New Jersey was visited by a series of severe storms during which the ocean waves attacked the land with terrible force, removing large areas of land and destroying much valuable property. The senior author of this paper visited the coast at Sea Bright, where the worst damage was done, while the second and most disastrous storm was at its height. Two days later both authors, in company with a party of Columbia University students, traversed the shore from East Long Branch to Highland Beach, a distance of six miles or more along the zone of maximum destruction. During the months of February and March the junior author made a more detailed study of the shoreline changes effected by the several storms, and collected the data upon which much of this paper is based.

PHYSIOGRAPHY OF THE REGION EXAMINED.

The region involved in the present discussion lies on the Atlantic Coast just south of Sandy Hook and north of Long Branch. (See Fig. 1.) At the latter place the waves of the sea are attacking the mainland of New Jersey and have cut a marine cliff some 20 feet in height in the seaward edge of the coastal plain. The debris eroded from these cliffs has been carried northward by long shore currents and built into a narrow bar which has extended across the mouth of Shrewsbury and Navesink rivers, and out into the Bay of New York to form the Sandy Hook spit. Formerly the sea broke against the mainland just back of Sea Bright and at Navesink Highlands; and old marine cliffs, now grass covered, may be seen at these points. But the bar now lies a short distance in front of these old cliffs, and protects them from erosion. Shrewsbury and Navesink rivers are really bays of the ocean formed by a sinking of the land or a rising of the ocean level which permitted the seawater to flood pre-existing river valleys. They are "drowned valleys," but not "rivers" in the true sense of the term.

It is important to realize, in connection with the discussion which follows, that the bar on which Sea Bright stands and its continuation in the Sandy Hook sand spit, are wholly the work of ocean waves and currents. There are, of course, many sand dunes formed by the winds which have tossed beach sands into low hillocks; and many artificial deposits of stone and other material have been

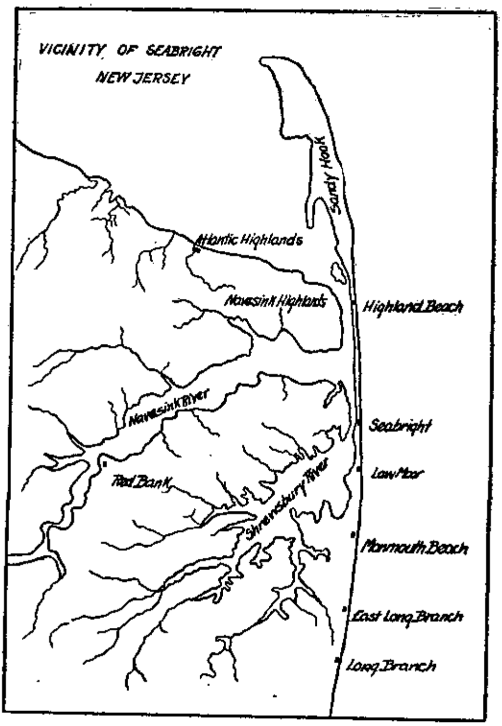

FIG. 1—Location Map.

formed by man in his attempt to save the bar from erosion. But the bar itself was built entirely by marine forces, the longshore currents bringing sand from the cliffs to the south, and waves casting it up above sea level to form the narrow ridge which rises a few feet out of the water and thus affords space for the erection of many valuable summer cottages and hotels.

There is nothing to indicate that the relative level of land and sea has changed since the bar was built. The surface of the bar, except where the winds have built sand dunes, is no higher than ordinary waves can reach; hence there is no reason to believe that an uplift of the sea bottom raised the bar any higher out of water than it was when finished by the waves. On the other hand, the bar is as high as we should expect it to be built by the waves in this vicinity, and there is nothing to indicate a sinking of the coast since it was formed. The submergence which drowned the valleys of the Shrewsbury and Navesink rivers occurred before this narrow barrier was built.

Inasmuch as the waves built the bar across the mouths of the embayed river valleys and in front of the old marine cliffs while the sea was at its present level, and since waves have the power to erode as well as to deposit material, it would seem reasonable to expect that with a change in the conditions of wave action the sea might some time remove the bar, without any change in the altitude of sea level. Indeed, we might expect the bar, or parts of it, to be repeatedly removed, whenever wave erosion exceeded wave deposition, and the missing portions to be restored whenever there was an excess of deposition. Such appears to have been the case, for there is ample evidence that portions of the bar have been removed and restored within historic times. Previous to 1778 the barrier was missing for three miles north of Sea Bright, Sandy Hook connected directly with the Highlands of Navesink, and Navesink River emptied directly into the sea by a widely open mouth. Shrewsbury River has repeatedly connected directly with the ocean through breaches in the portion of the bar across its mouth, and Sandy Hook has been temporarily left as an island by the removal of that part of the bar connecting with its southern end.

OBJECTS OF THIS PAPER.

In the present paper we propose to indicate briefly the nature of the storms which brought so much damage to the coast of New Jersey, especially in the Sea Bright district; to review some of the conditions which affect the destructive power of waves and note their operation during the recent disaster; to show the extent to which waves eroded the coast between Sea Bright and Long Branch; and to examine the processes by which the waves accomplished the damage to land, sea defences and buildings. The danger to which the coast is subjected through lack of a central control of the problem of marine protection is pointed out.

There is a widely held opinion that the Atlantic Coast of the United States, and the coast of New Jersey in particular, is gradually subsiding at a rate of from one to two feet per century. Vigorous wave erosion has often been cited as a proof of this supposed sinking of the land, and not a few have regarded the disastrous erosion of the New Jersey shores during the recent storms as a clear indication of the downward movement. Without entering into any general discussion of the theory of recent subsidence, we shall endeavor to show in the present paper that such wave erosion as the New Jersey coast has recently experienced affords no support for that theory.

THE STORMS.

Three unusually severe storms with violent onshore winds visited the coast of New Jersey during the winter of 1913-14. The first of these, known as "the Christmas storm," attained its maximum strength early on the morning of December 26th, and was accompanied by winds which attained a velocity of 123 miles an hour.

The second or "New Year's storm" was even more disastrous than the first, partly because the coast had been left in an unprotected condition by the preceding attack. On January 4th the fury of the second storm reached its maximum. Driven by a terrific gale whose extreme velocity reached 120 miles per hour, the waves broke upon the beach with a thunderous roar. Bulkheads which had been destroyed or weakened during the earlier storm afforded no protection for the unconsolidated sand of the beach, and every wave seemed to sweep a little of it out to sea. As the senior author walked through the streets of Sea Bright on this eventful day he witnessed an impressive illustration of the impotence of man in the face of an angry ocean. Groups of dejected men, soaked to the skin by driving rain and salt spray, stood helplessly by the shore and watched the waves remove the land from under their houses, the houses tip over into the sea, and the waves pound them to kindling wood in the space of a few moments. Others labored to place wooden rollers under some of the smaller cottages and drag them farther back upon the beach before the waves demolished them; while still others hurriedly removed their furniture in wagons, abandoning the buildings to their fate. A few men stood under the corner of a partially undermined summer residence and struggled in vain to erect a plank bulwark which would stop the advancing sea, while the surging waters nearly swept them from their feet. Crowds of spectators waded knee-deep through the foam blown up from the surf zone by the winds, and watched the water of the sea leap high above three-story dwellings where waves were breaking against some resisting bulkhead. Many observed with anxiety the attack of the sea upon the beach under the large Octagon Hotel, and shortly before noon saw the great building collapse and become, in a short time, a tangled mass of splintered wood rising and falling with the waves. Occasional waves sent water across the narrow bar, the streets of Sea Bright were inundated, and the unusually high tide which accompanied the storm kept many houses on the lower, back part of the beach surrounded by water for hours. Fortunately, the waters were quiet in the protected bay, and the damage here was slight compared with that on the exposed outer shore, where for a couple of hours a large building collapsed on an average every fifteen minutes. North of Sea Bright the waves broke through the breakwater which protects the railroad, swept part of the tracks out to sea, and buried other portions under masses of heavy stones.

On February 14th and 15th occurred the third and least destructive storm of the series, when the wind reached an extreme velocity of 116 miles per hour. At this time the waves completed the destruction of the Sea Bright Beach Club-house and certain other structures badly damaged by the earlier storms. In the unprotected state of the shore some further damage has been subsequently accomplished by normal wave erosion during comparatively calm weather, at least one valuable summer residence being demolished in this manner.

SOME CONDITIONS AFFECTING THE DESTRUCTIVE POWER OF WAVES.

The destructive power of a wave depends in part upon its size, and this in turn partly upon the water depth. Waves usually break and dissipate their energy when they come into water of a depth equal to the wave height. Hence, the deeper the water immediately at the shore the larger the waves which can attack it, and the greater the damage they will effect at that point. It follows from this that the rise of the tide must increase the destructive power of storm waves on the coast, not only because it brings the zone of wave activity further in upon the shore, but also because the deepening of the water as the tide rises against the steeper upper part of the shore profile permits larger and more powerful waves to break against the shore cliffs. In all the recent storms the chief damage to the New Jersey coast occurred at the high tide periods, and the citizens worked feverishly during low water to prepare for the violent wave attack which they knew would ensue at the next high tide.

On-shore winds increase the destructive power of the waves in a variety of ways. First of all, they raise the water level by blowing the surface of the sea upon the coast faster than the water escapes seaward along the bottom as undertow. In the second place, on-shore winds, by driving the surface of the sea landward, insure a vigorous undertow seaward; this undertow carries the beach material out to deep water, thereby aiding beach destruction. Vigorous on-shore winds drive in large waves, whereas off-shore winds, no matter how violent, cannot form large waves in the immediate vicinity of the shore. During the recent storms on-shore winds raised the high-tide level on the New Jersey coast from one to several feet above its normal elevation, much beach sand was sucked out to sea by the resulting undertow, and large waves were driven upon the shore with terrific violence.

Other things being equal, the greatest damage will occur where the land exposed to wave erosion is lowest. Waves may expend their energy in two ways: in eroding the land or sea-bottom, or in transporting debris. If the land is high, the waves break at the base of a high cliff which sheds much debris into the water as its base is undermined. This debris must be removed by the waves if effective erosion is to continue, as otherwise the cliff would soon be protected by the accumulated waste. Removal of the debris requires much of the waves' energy, and leaves them less competent to wear back the cliff. If the land is low, the low cliff sheds but a small amount of waste upon the shore, the waves quickly dispose of it, and energetically continue their landward advance. It is true that the effect of cliff height may be more than offset by other factors, among which the form of the sea bottom off-shore is important. Of still greater importance for such a region as the one in question is the effect of artificial sea defences, such as breakwaters, bulkheads, and similar devices. At Sea Bright and adjacent towns the greatest damage was suffered where the bar was lowest, or where the defences were weakest. One of the lowest places on the bar was occupied by the Octagon Hotel, which was completely destroyed. For a long distance along this low region the shore was cut back from 100 to 150 feet, and the damage to buildings was greater than elsewhere. Both north and south of Low Moor station are unusually high portions of the bar, and here the advance of the sea was not so great, even where the defences were battered down and the houses partially undermined. On the other hand, there are plenty of instances where unusually weak defences failed to prevent fairly extensive erosion of comparatively high areas, and where strong defences saved low areas from attack.

Variations in the character of the material composing a coast necessarily influence the rate of wave erosion. In the Sea Bright district there is not enough of such variation in the material of the bar to be of any importance. The bar first formed some distance seaward of its present position, and has been pushed landward by the waves. A salt marsh formed back of the bar, and the sands of the latter have been driven in over the surface of the marsh deposits. Hence the wave-cut cliff on the seaward edge of the bar shows at the base a layer of somewhat indurated black sand, mud and peat, projecting as a little terrace where recently exposed. Above this the yellow-brown beach sands constitute the rest of a cliff which stands nearly or quite vertical where recently cut into. As these conditions appear to be essentially uniform along the length of the bar under discussion, there is little difference in the rate of erosion at different points which could be attributed to variations in resistance of materials.

INROADS OF THE SEA.

For the region under discussion, good maps are available showing property and street lines, and the tracks of the New Jersey Central Railroad provide an additional reference line from which measurements may be made. Along the shore, remains of bulkheads often mark the former position of the seaward edge of the low cliff upon which the buildings were situated; for whenever property owners found that the waves were cutting into the beach they placed bulkheads just in front of the low cliff made by the cutting, to check its further retreat. It is true that in places these protective devices were located a short distance in front of the cliff, and the intervening area filled artificially; hence measurements from the bulkhead line to the present position of the storm cut cliff include an uncertain, but probably not large, amount of erosion of artificial material. Care has been taken to calculate cliff retreat from the actual front of the property formerly sufficiently elevated for building purposes, and not from the protective lines of piling frequently placed in front of the bulkheads either on the low shore or in the edge of the water.

On certain parts of the bar it is much more difficult, if not impossible, to determine the exact amount of shoreline retreat, because the position of that line just before the first storm is not readily determined with accuracy. The position of the storm cliff after the New Year's storm has been carefully plotted upon property

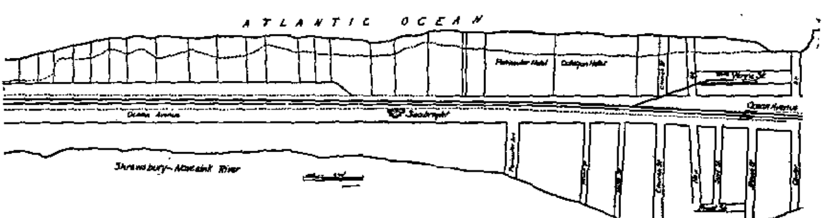

FIG. 2.—Inroads of the sea at Sea Bright. shown by broken line back of former shore line. By W. S. Smith.

maps of that portion of the bar between East Long Branch and Highland Beach; and the difference between the shoreline of the map and the location of the low storm cliff might be assumed to represent roughly the amount of erosion accomplished by the first two storms. On this basis the encroachment of the sea varied from 50 to 135 feet along three-fourths of a mile of the shore at Sea Bright (Fig. 2); from nothing (where the bulkheads resisted the attack) to as much as 50 to 70 feet at various points along three-fourths of a mile of the shore near Low Moor (Fig. 3); and from 150 to 275 feet at most points for three-fourths of a mile near Monmouth Beach (Fig. 4). Difficulty arises from the fact that, in the latter region, especially, the real shoreline may have been appreciably within the line shown on the maps, before the storms

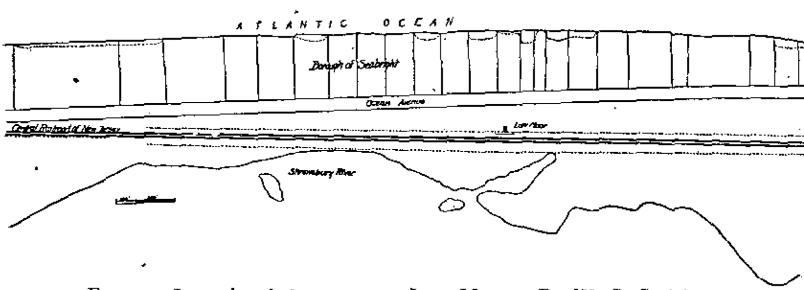

FIG 3.—Inroads of the sea near Low Moor. By W. S. Smith.

began their destructive work. Lines of piling still mark the position of the shoreline of the map in places, but the waves could pass between the pilings and erode the beach with comparative vigor. Much of this region was not built over and therefore was not as

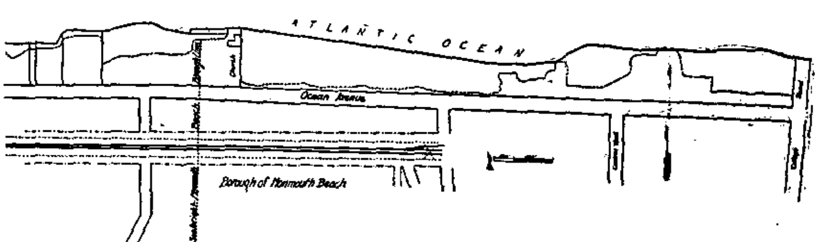

FIG. 4.—Inroads of the sea at Monmouth Beach. By W. S. Smith.

efficiently protected by bulkheads as the more valuable properties farther north; hence greater inroads during the recent storms were to be expected here. But the lack of adequate protection may also have permitted appreciable shoreline retreat before the attack of these storms, in which case the estimates for the Monmouth Beach district, and possibly for some other points, are too great.

Where good bulkheads protected the face of the low cliff from erosion previous to the Christmas storm, and the low tide line was close to the bottom of the bulkheads, the map must represent the actual amount of recent shoreline retreat with a fair degree of accuracy. For several such places the following amounts of backward cutting have been measured, all figures referring to the work of the first two storms only, unless otherwise specified. In many localities the third storm made comparatively little change in the shoreline:

One-third of a mile north of Sea Bright station, near Hall properties	135′
Twelve hundred feet north of Sea Bright station	105′
North of Church St., Sea Bright	102′
(After third storm)	144′
Opposite Low Moor station	60′
North of Central Road, Monmouth Beach, near house shown in Plate II, Fig 1	90′
Just south of above	160′

METHODS OF WAVE DESTRUCTION.

An examination of the Sea Bright shore indicates that the greatest damage to bulkheads resulted from the direct impact of the waves, whereas the buildings suffered most from the undermining of the ground upon which they stood. When it is remembered that ocean waves strike a vertical face with a force of from a few hundred pounds to more than 6,000 pounds per square foot, their enormous destructive power may readily be appreciated. Solid blocks of granite have been shattered by wave impact upon the coast of Holland, and it is therefore not surprising that the wooden bulkheads of the Jersey Coast should yield to the attack of the sea, wherever they were not reinforced by parallel rows of piling with heavy stone filling, or otherwise rendered especially strong. Plate I. shows one of the weaker bulkheads in the early stages of destruction. Most of the bulkheads were surmounted by a broad boardwalk which served to shed falling wave crests back into the sea, and thus protect the cliff from erosion. But the force generated by masses of water falling from the great height to which they are projected when a storm wave strikes a vertical wall, may be sufficient to crush very heavy timbers. During a severe gale at Buffalo, New York, many large timbers, 12 x 12 inches in thickness, 12 feet long, and 10 feet between supports, were broken like match sticks by the impact of falling water which had been hurled from 75 to 125 feet into the air by breaking waves. We observed several localities in the Sea Bright district where the demolishing of the bulkheads had been hastened in this manner.

Many of the bulkheads are protected by rows of piling set some distance out in the sea to break the force of the on-coming waves.

Plate I, Fig. 1.—House at Monmouth Beach protected by bulkhead and outlying rows of piling. See Plate II, Fig. 2, and Plate III, Fig. 1 and 2.

Plate I, Fig. 2.—Same house as in Plate II, Fig. 1, showing breaching of protecting bulkhead. Undermining of one corner of house just beginning.

Even where the sea attack was powerless to break these pilings or to tear them from their positions, the waves passed between the pilings and still retained sufficient force to destroy the bulkheads which presented a more continuous surface to their impact. Plate I, Fig. 1 shows such a series of protecting piling which remained largely intact while the bulkhead immediately in front of the house was battered down and the house itself destroyed. (Plate I, Fig. 2, and II, Fig. 1 and 2.) Plate III, Fig. 1, shows a series of pilings surmounted by undamaged bathhouses, back of which the shore has been so badly eroded that the superjacent houses have collapsed.

In the last case mentioned, and indeed as a rule, the houses were not damaged as much by direct wave impact as by the undermining of the beach upon which they stood. It is of course true that a building from under which most of the support was already removed by the sapping action of the waves, often received its "death blow" from some extra large wave; and a building which was once tipped over into the edge of the sea as a result of being undermined was soon pounded to pieces by the waves. But the real damage was largely accomplished independently of direct impact upon the structures themselves. Where a house simply rested upon the beach, and the latter was cut away by wave sapping, the house toppled over bodily. Even where the beach was low and flat, as in the town of Sea Bright, the foundations were sapped from under dwellings (Plate IV, Fig. 2), allowing them to tip over toward the sea, instead of their being crushed in the first instance by the impact of the waves. In some cases the houses collapsed piecemeal as the sea advanced under them, or were crushed by the fall when they tipped over into the sea. Where houses were built on pilings driven into the beach sand the removal of the sand left the buildings precariously supported on the pilings alone until shaken down by the moderate waves of some later storm. (Plate II).

One reason for the destructiveness of the undermining action as compared with the direct wave attack is to be found in the fact that lines of piling and bulkheads were together able to break the force of the waves to a large extent, but could not prevent the water of each wave from washing against the foot of the cliff, removing part of the sand, and carrying it back to sea. In many places the lines of piling, and even the bulkheads, are still in a state of partial preservation, while the cliff back of them is badly eroded and the superjacent houses completely destroyed. The fact that the houses were at a higher level than the cliffed beach was, of course, another factor which rendered direct wave impact less destructive than undermining.

SUPPOSED RELATION OF WAVE CUTTING TO COASTAL SUBSIDENCE.

It is evident that a gradual subsidence of the land would enable the sea to advance inland more rapidly than would otherwise be possible; for such a subsidence would not only progressively submerge more and more of the continent, but the continual deepening of the off-shore zone would constantly permit large waves to reach to the shore line, there to accomplish their erosive action unimpeded by the shallow submarine platform which results when waves, effective only to a limited depth, cut into a still-standing land mass. With this well-established principle in mind, many have leaped to the erroneous conclusion that vigorous wave erosion proves a subsidence of the land.

The fallacy of this reasoning may be demonstrated either by a careful analysis of the process of marine erosion, or by showing the existence of rapidly retreating marine cliffs on shores which are demonstrably not subsiding. A complete treatment of the problem from either of these two standpoints would require more space than the present paper affords. A full analysis of the marine erosion cycle will appear in a future report of the New Jersey Geological Survey, dealing with shore-line changes along this coast; but a brief outline of the principles especially applicable to the erosion of a bar like that at Sea Bright is given below. As regards the actual evidence furnished by retreating cliffs on stable shores, it may be stated (1) that while such cliffs are being cut back in one place, the eroded material is being used by the waves to build forward the closely adjacent parts of the coast; (2) that the erosion should not be regarded as proof of a coastal subsidence unless the deposition is considered proof of coastal elevation, an impossible view when we remember the rapid alternation of zones of cutting and filling along some coasts; and (3) that the forward-built coasts often consist of series of successive beach ridges or bars whose crests rise to the same average level above the sea, proving the stability of the coast during the time the whole series was forming,

PLATE II, FIG. 1.—Same house as in Plate II, almost completely undermined by the waves. Wave-cut cliff seen at left.

PLATE II, FIG. 2.—Same house as in Plate II, completely destroyed by the waves. Remnants of bulkhead and outlying lines of pilings seen at right.

and hence during the time the adjacent cliff was being cut back to supply the debris of which the ridges are made. The chalk cliffs of southeastern England have been cut far back of their former positions during the same time that the Dungeness and other capes or forelands have been built out into the sea to form horizontal beach plains of great breadth; and large areas of land on the islands enclosing Boston Harbor have been cut away by the waves while the eroded debris was built into successive beach ridges, the comparative altitude of whose crests proves essential coastal stability during their formation. Vigorous wave erosion is known to occur on lake shores where the mean water level remains constant.

In order to appreciate the real significance of the shore changes at Sea Bright, we must consider for a moment the conditions under which a narrow bar, like that on which the town stands, is maintained. Marine erosion is chiefly accomplished by wave action, while transportation of the eroded debris is performed by the short, pulsating currents of wave motion, tidal currents, wind-formed currents or "wind drift," and a large number of other currents which need not here be specified. Neither is it necessary for us to take up the disputed question as to which particular type of current action causes the long-shore transportation toward the north in the special region under investigation. It is enough for us to know that some kind of current or currents moves sand prevailingly northward along the seaward side of the bar, and that the oscillatory or back-and-forth movement of the water particles during wave action produces pulsating currents alternately landward and seaward.

A study of wave action shows that sometimes the landward component of the pulsating currents prevails, and material is swept toward the coast to build the shore forward into the sea; at other times, or in other places, the seaward component prevails, the beach is eroded, and the material dragged out into deep water. The changing action is due to changes in the conditions of the marine forces, such as size of waves, direction of wave advance on the shore, strength and direction of winds, depth of water, rapidity of supply of sand by longshore currents, etc. Under each set of circumstances the marine forces endeavor to produce a beach and offshore slope so nicely adjusted to their action that the effect of the landward component of wave action will exactly balance the effect of the seaward component. A profile of the beach and sea bottom when thus nicely adjusted to the marine forces is called "the profile of equilibrium," because it is the profile which exists when onshore and off-shore forces are just balanced, or in equilibrium. When the profile is not in equilibrium with the marine forces, these forces automatically operate to change it until it is. If rapid deposition by longshore currents makes the offshore bottom too shallow, thereby making the profile too gentle, wave currents will carry some of the bottom sand to the shore, thus deepening the bottom and building forward the shore until a profile of the proper steepness is established. From that time on the effort of the waves to bring more material to the shore is just balanced by their tendency to sweep that material, with the aid of the undertow, back down the steepened slope to deep water. The profile of equilibrium is perfected. But a change in the size of the waves disturbs the balance. Under the new conditions the profile may be too near the water surface or too steeply inclined. Waves then cut into the beach and deposit the material farther out until a new profile of equilibrium, adapted to the new conditions, is established.

The constant shifting of debris back and forth in the shallow shore zone as a result of the changing conditions of equilibrium, grinds that debris finer and finer, with the result that some of it is carried in suspension by currents to far distant localities where it is deposited in the quiet waters of the deep ocean. This constant loss of material from the shore means that more material must be secured to keep up the conditions of equilibrium; and the additional supply may be secured either by the waves cutting farther inland at the point in question, or by longshore currents bringing it from some other point where the waves are eroding.

Applying the foregoing principles to the Sea Bright bar, it is evident that the seaward side of the bar, exposed to wave and current action, must have a profile which keeps as nearly as possible in equilibrium with the marine forces. Since those forces are constantly changing, the profile must change also, and the beach must be built forward at one time and cut back at another, independently of any movement of elevation or subsidence. Owing to the constant loss of finer material from the shore zone, the cutting back must prevail over the forward building, unless the northward moving current brings enough material from the Long Branch district to fully compensate the loss. Even a general tendency for back-

PLATE III, FIG 1.—Storm cliff cut in seaward edge of bar at Sea Bright, showing houses demolished by undermining, and unharmed bath-houses on pilings.

PLATE III, FIG. 2.—Scene on the shore at Sea Bright after the New Year's Storm, showing undermined houses, and piles of wreckage on beach.

ward cutting to prevail is therefore no indication of coastal subsidence. The longshore supply of material has been sufficient to preserve the bar from complete destruction, although it has not been sufficient to build forward the shore, or even to prevent a gradual retreat of the bar toward the land. Such retreat is proved by the fact that the marsh deposits, formed back of the bar, are now exposed on its seaward side under the beach sands; and by the testimony of the inhabitants who have lost buildings formerly located on land seaward of the present shoreline.

The loss of land during the recent storms represents exceptionally rapid erosion of a purely temporary character, due to an unusual disturbance of the profile of equilibrium by exceptional storms. Longshore currents carried some of the eroded material to Sandy Hook, but no extensive additions to its area have so far resulted from this action. Most of the material removed from the bar was carried seaward to perfect the proper profile of equilibrium demanded by the storms. Part of it, at least, should be carried back to the beach as new conditions demand a new profile. In fact, this process is already in operation, and the shore has been built so far forward in places as to obscure much of the erosive effect accomplished a few weeks ago. Nothing in the nature of the erosion or the deposition indicate any change in the relative level of land and sea.

If the land were sinking at the rate of one or two feet per century, the problem of maintaining sea defenses against the ravages of the ocean in the Sea Bright district would be more serious than it is. The tendency of storm waves to cut into the land would be more marked than at present, and the tendency of marine forces to repair the damage by deposition during calm weather would be less evident. Even as it is the problem is sufficiently serious. That there is a prevailing tendency for the bar to retreat toward the land as a result of wave cutting on the seaward side, has already been shown. Along with the alternate erosion and accretion in the shore zone, due to the varying effect of the marine forces, there is a slow loss of land which can only be arrested by superior methods of artificial protection.

That the damage of which the sea is capable justifies the expenditure of large sums of money in improved sea defences is abundantly proved by the recent storms. The actual value of property completely destroyed in the single town of Sea Bright was enormous, and the suffering of its citizens cannot be estimated in money. Many who were unable to bear any loss saw the savings of a lifetime swept out to sea by the merciless waves. It would be difficult to estimate the depreciation in the value of property along this part of the coast alone, a depreciation shared by lands not actually eroded because of the apparent magnitude of the dangers to which they are subjected.

So long as the defence of the land is in a large number of hands and every landowner is practically free to do as little or as much as he pleases toward preventing the sea from gaining access to his property, many must suffer from the failure of a few to take proper precautions against marine erosion. As soon as the sea finds a point of weakness in the defences, it rapidly widens the breach and attacks adjoining property on either side. In some places where the bulkheads in front of one man's property resisted the direct attack, the property was badly damaged by erosion from one or both sides after the sea had entered neighboring lots. Some method of government supervision of marine defences would seem to be the only satisfactory solution of this serious problem.

May 1, 1914.

Publications

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. On March 16, 1914, books will be mailable at parcel post rates. The postage rate as given in the following lists applies to all points in the first and second zones from Trenton, which includes all parts of New Jersey. Applications from more distant points should be accompanied by the proper amount of postage, based upon distance from Trenton. If not so accompanied, reports will be sent *express collect. When the stock on hand of any report is reduced to 200 copies, the remaining volumes are withdrawn from free distribution and are sold at cost price.*

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, 8 vo., 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. Unbound copies, postage, 8 cents. Bound copies, $1.50.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. II. Part II. Zoology. Trenton, 1890, 8vo., x+824 pp. (Postage, 8 cents.)

REPORT ON WATER-SUPPLY. Vol. III. of the Final Reports of the State Geologist. Trenton, 1894, 8vo., xvi+352 and 96 pp. (Postage, 7 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, $1.00; cloth bound, $1.35, with photo-relief map of State, $2.85. Map separate, $1.50.

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, 9 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. (Price, $1.60.)

REPORT ON IRON MINES AND MINING in New Jersey. Vol. VII. of the Final Report of the State Geologist. Trenton, 1910, 8vo., xv+512 pp., with two maps in a separate envelope. (Postage, 8 cents.)

BRACHIOPODA AND LAMELLIBRANCHIATA of the Raritan Clays and Greensand Marls of New Jersey. Trenton, 1886, quarto, pp. 338, plates, XXXV. and map. (Paleontology, Vol. I.) (To residents of New Jersey, postage, 10 cents; to non-residents, $1.50, charges prepaid.)

GASTEROPODA AND CEPHALOPODA of the Raritan Clays and Greensand Marls of New Jersey. Trenton, 1892, quarto, pp. 402, Plates L. (Paleontology, Vol. II.) (To residents of New Jersey, postage, 10 cents; to non-residents, $1.40, charges prepaid.)

PALEOZOIC PALEONTOLOGY. Trenton, 1903, 8vo., xii+462 pp., Plates LIII. (Paleontology, Vol. III.) (Price, $1.00.)

CRETACEOUS PALEONTOLOGY. Trenton, 1907, 8vo., ix+1106 pp., Plates CXI. (Paleontology, Vol. IV.) (Price, $2.70.)

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 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. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1871. New Brunswick, 1872, 8vo., 46 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1872. Trenton, 1872, 8vo., 44 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1873. Trenton, 1874, 8vo., 128 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1874. Trenton, 1874, 8vo., 115 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1875. Trenton, 1875, 8vo., 41 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1876. Trenton, 1876, 8vo., 56 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1877. Trenton, 1877, 8vo., 55 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1878. Trenton, 1878, 8vo., 131 pp., with map. Out of print.

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. (Price, 50 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1884. Trenton, 1884, 8vo., 168 pp., with maps. (Postage, 5 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1885. Trenton, 1885, 8vo., 228 pp., with maps. (Postage, 6 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1886. Trenton, 1887, 8vo., 254 pp., with maps. (Postage, 6 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1887. Trenton, 1887, 8vo., 45 pp., with maps. (Postage, 5 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1888. Camden, 1889, 8vo., 87 pp., with map. (Postage, 5 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1889. Camden, 1889, 8vo., 112 pp. (Postage, 6 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1890. Trenton, 1891, 8vo., 305 pp., with maps. (Postage, 6 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. (Price, $1.55.)

ANNUAL REPORT of the State Geologist of New Jersey for 1893. Trenton, 1894, 8vo., x+452 pp., with maps. (Postage, 7 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1894. Trenton, 1895, 8vo., x+304 pp., with geological map. (Postage, 6 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1895. Trenton, 1896, 8vo., xl+198 pp., with geological map. (Postage, 5 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1896. Trenton, 1897, 8vo., xxviii+377 pp., with map of Hackensack meadows. (Postage, 6 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1897. Trenton, 1898, 8vo., xl+368 pp. (Postage, 6 cents.)

ANNUAL REPORT of the State Geologist for 1898. Trenton, 1899, 8vo., xxxii+244 pp., with Appendix, 102 pp. (Postage, 6 cents.)

ANNUAL REPORT of the State Geologist for 1899 and REPORT ON FORESTS. Trenton, 1900, 2 vols.. 8vo., Annual eport, xliii+192 pp. FORESTS, xvi+327 pp., with seven maps in a roll. (Postage, 5 and 7 cents.)

ANNUAL REPORT of the State Geologist for 1900. Trenton 1901, 8vo., xl+231 pp. (Postage, 6 cents.)

ANNUAL REPORT of the State Geologist for 1901. Trenton, 1902, 8vo., xxviii+178 pp., with one map in pocket. (Postage, 6 cents.)

ANNUAL REPORT of the State Geologist for 1902. Trenton, 1903, 8vo., viii+155 pp. (Postage, 5 cents.)

ANNUAL REPORT of the State Geologist for 1903. Trenton, 1904, 8vo., xxxvi+132 pp., with two maps in pocket. (Price, 40 cents.)

ANNUAL REPORT of the State Geologist for 1904. Trenton, 1905, 8vo., x+317 pp. (Postage, 6 cents.)

ANNUAL REPORT of the State Geologist for 1905. Trenton, 1906, 8vo., x+338 pp., with three maps in a pocket. (Price, 55 cents.)

ANNUAL REPORT of the State Geologist for 1906. Trenton, 1907, 8vo., vii+192 pp. (Postage, 6 cents.)

No. 28. Trenton and Eastward—Trenton to Sayreville. Replaces Sheet 8.

ANNUAL REPORT of the State Geologist for 1907. Trenton, 1908, 8vo., ix+192 pp. (Postage, 6 cents.)
ANNUAL REPORT of the State Geologist for 1908. Trenton, 1909, 8 vo., xi+159 pp. (Postage, 5 cents.)
ANNUAL REPORT of the State Geologist for 1909. Trenton, 1910, 8vo., vii+123 pp. (Postage, 5 cents.)

BULLETINS.

In 1910 the series of Annual Reports was replaced by a series of Bulletins, each being a separate report upon some subject. Up to date eleven Bulletins have been issued.

BULLETIN 1.—Administrative Report of the State Geologist of New Jersey for 1910. Trenton, 1911, 43 pp. (Out of print.)

BULLETIN 2.—A report on the Approximate Cost of a Canal between Bay Head and the Shrewsbury River, by H. B. Kümmel. Trenton, 1911, 20 pp., 1 map.

BULLETIN 3.—The Flora of the Raritan Formation, by Edward W. Berry. Trenton, 1911, v+233 pp. and xxix plates.

BULLETIN 4.—A Description of Fossil Fish Remains of the Cretaceous, Eocene and Miocene Formations of New Jersey, by Henry W. Fowler. Trenton, 1911, 192 pp.

BULLETIN 5.—The Mineral Industry of New Jersey for 1910, by H. B. Kümmel and S. Percy Jones. Trenton, 1911, 24 pp. (Out of print.)

BULLETIN 6.—Administrative Report of the State Geologist for 1911, including a report on Shark River Inlet by C. C. Vermeule. Trenton, 1912, 82 pp. and iv plates.

BULLETIN 7.—The Mineral Industry of New Jersey for 1911, by Henry B. Kümmel. Trenton, 1912, 37 pp.

BULLETIN 8.—Administrative Report of the State Geologist for 1912, including a second report on Shark River Inlet by C. C. Vermeule, Consulting Engineer, and a List of New Bench Marks. Trenton, 1913, 8vo., 102 pp.

BULLETIN 9.—A Preliminary Report of the Archæological Survey of the State of New Jersey, made by the Department of Anthropology in the American Museum of Natural History. Clark Wissler, Ph.D., Curator, under the direction of the State Geological Survey. Compiled by Alanson Skinner and Max Schrabisch. Trenton, 1913, 8vo., 94 pp. one map.

BULLETIN 10.—(In co-operation with the New Jersey State Agricultural Experiment Station). The Mechanical and Chemical Composition of the Soils of the Sussex Area, New Jersey, by A. W. Blair and Henry Jennings. The Analysis of Soils—Methods Used, by R. B. Gage. Trenton, 1913, 8vo., 110 pp., two plates.

BULLETIN 11.—The Mineral Industry of New Jersey for 1912, by M. W. Twitchell. Trenton, 1913, 8vo., 43 pp., one map.

TOPOGRAPHIC MAPS.

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. Sheets numbered 21 to 37 replace old sheets numbered 1-17, which cannot longer be furnished. These sheets each cover the same territory as eight of the large maps, on a scale of 2,000 feet per inch.

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.
No. 22. Eastern Sussex and Western Passaic counties. Replaces Sheet 4.
No. 23. Northern Bergen and Eastern Passaic counties, to West Point, New York. Replaces northern part of Sheet 7.
No. 24. Southern Warren, Northern Hunterdon and Western Morris counties. Replaces Sheet 2.
No. 25. Morris and Somerset counties, from Lake Hopatcong to Somerville and New Brunswick. Replaces Sheet 6.
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.