GEOLOGICAL SURVEY OF NEW JERSEY

ANNUAL REPORT

OF THE

STATE GEOLOGIST

For the Year 1907

TRENTON, N. J.:
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1908.

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PLATES.

The Geological Survey of New Jersey.

BOARD OF MANAGERS.

HIS EXCELLENCY EDWARD C. STOKES, Governor and *ex-officio* President of the Board ....Trenton.

Members at Large.

JOHN C. SMOCK	Trenton	1908
THOMAS W. SYNNOTT	Wenonah	1909
ALFRED A. WOODHULL	Princeton	1909
EMMOR ROBERTS	Moorestown	1910*
DAVID E. TITSWORTH	Plainfield	1911
GEORGE G. TENNANT	Jersey City	1911
HARRISON VAN DUYNE	Newark	1912

Congressional Districts.

I.	FREDERICK R. BRACE	Blackwood	1911
II.	P. KENNEDY REEVES	Bridgeton	1912
III.	M. D. VALENTINE	Woodbridge	1909
IV.	WASHINGTON A. ROEBLING	Trenton	1908
V.	FREDERICK A. CANFIELD	Dover	1910
VI.	GEORGE W. WHEELER	Hackensack	1911
VII.	HERBERT M. LLOYD	Montclair	1912
VIII.	JOSEPH L. MUNN	East Orange	1909
IX.	JOSEPH D. BEDLE	Jersey City	1908
X.	AARON S. BALDWIN	Hoboken	1910

State Geologist,

HENRY B. KÜMMEL.

* Died April 7th, 1908.

Charles L. Pack, Lakewood, was appointed in March, 1908, as Member at Large.

ADMINISTRATIVE REPORT.

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Administrative Report.

HENRY B. KÜMMEL, STATE GEOLOGIST.

The work of the Geological Survey for the year ending October 31, 1907, is briefly summarized in the following pages of the Administrative Report. Several special reports setting forth the work in fuller detail will follow.

ADMINISTRATION.

Organization.—The following reappointments to the Board of Managers were made by the Governor for terms expiring April 1, 1912:

P. Kennedy Reeves, Second Congressional District.
Herbert M. Lloyd, Seventh Congressional District.
Harrison Van Duyne, Member-at-Large.

During the year the Board lost by death two of its oldest members in point of service. Mr. Wendell P. Garrison died February 27, after an illness of several months, and Mr. S. Bayard Dod, on April 19. At the meeting of the Board on May 8, the following resolutions were adopted and ordered printed in the Annual Report:

"*Resolved,* That by the decease of Mr. Wendell P. Garrison the Board of Managers of the Geological Survey of New Jersey has not only lost one of its oldest members in point of service, but one whose constant presence at its meetings and whose attention to its duties have materially preserved its consistent character for seventeen years.

"*Resolved,* That Mr. Garrison's amiability, fidelity and sagacity have held without wavering the regard and respect of his associates on the Board, who are deeply grieved at this sad termination of their intercourse and at the public loss it occasions.

"*Resolved,* That both the public service and the private character of Mr. Garrison have been so conspicuous in furthering the public work and in preserving the harmonious action of the Board of Managers that the Board formally enters these resolutions upon its minutes, requests the State Geologist to incorporate them in his next Annual Report, and directs that a copy be sent, with the sympathy and condolence of its members, to Mr. Garrison's son and daughter."

"WHEREAS, By the decease of Mr. S. Bayard Dod, on April 19, the Board of Managers of the Geological Survey has lost its oldest member in point of service, and one who had always taken a deep interest in its work; therefore, be it

"*Resolved,* That the Board enters this memorandum regarding his services upon its minutes, requests the State Geologist to incorporate them in his next Annual Report, and directs that a copy be sent, with the sympathy and condolence of its members, to Mr. Dod's family.

"S. Bayard Dod became a member of the Board of Managers of the Geological Survey in December, 1885, thus being associated with Dr. George H. Cook, for twenty-five years State Geologist. Upon the death of Dr. Cook, in 1889, he was made chairman of the committee to which was referred the question of the continuation of the Survey. He was also chairman of the committee later charged with the duty of selecting a successor to Dr. Cook, and in 1900, upon the resignation of Dr. Smock, he again served on the committee to select a new State Geologist.

"The subject of forestry was of great interest to him, and as chairman of the Committee on Forest Reservations he did much to forward the forest studies of the Survey—investigations which led eventually to the adoption by the State of a definite forest policy under a commission closely allied to the Geological Survey."

During the year the following persons were employed on the Survey for varying periods, all but the first four on a per diem or temporary basis:

Henry B. Kümmel, State Geologist.

R. B. Gage, Chemist.

Laura Lee, Clerk.

Howard M. Poland, General Assistant.

Rollin D. Salisbury, Geologist.
George N. Knapp, Geologist.
Stuart Weller, Paleontologist.
W. S. Bayley, Geologist.
J. Volney Lewis, Geologist.
E. W. Berry, Paleobotanist.
W. E. McCourt, Assistant Geologist.
Gilbert Van Ingen, Geologist.

C. C. Vermeule, Topographer and Consulting Engineer.
Lewis M. Haupt, Engineer.
P. D. Staats, Assistant Topographer.
C. V. Coriell, Assistant Topographer.
J. B. McBride, Assistant Topographer.
D. C. Stagg, Draughtsman.
R. C. Rice, Assistant.
J. Clifford Wilkes, Assistant.
Wilson Faussett, Assistant.
E. B. Sterling, Jr., Assistant.
J. F. Stout, Assistant.

E. E. Locke, Janitor at Laboratory.
M. W. Caldwell, Clerk.
Anabelle Lesser, Stenographer.

Publications.—There were published during the year two reports—the Annual Report of the State Geologist for 1906 (VIII. + 192 pp., plates XXXII., figures 9) and Paleontology, Vol. IV., Cretaceous Faunas, in two parts, Text and Plates (1108 pp., plates CXI.).

The Annual Report contained the following papers:

Administrative Report.
The Fire-Resisting Qualities of Some New Jersey Building Stones—W. E. McCourt.
The Glass-Sand Industry of New Jersey—Henry B. Kümmel and R. B. Gage.
The Origin and Relations of the Newark Rocks—J. Volney Lewis.
The Newark (Triassic) Copper Ores of New Jersey—J. Volney Lewis.
Properties of Trap Rocks for Road Construction—J. Volney Lewis.
Notes on the Mining Industry—Henry B. Kümmel.

The publication of Dr. Weller's report upon the Cretaceous Paleontology of New Jersey marks the completion of studies commenced in 1903 and continued, with some interruption, until late in 1906. Other reports prepared by the State Survey and dealing with fossils found in New Jersey are as follows:

Mollusca and Crustacea of the Miocene of New Jersey—R. P. Whitfield. Published as Monograph XXIV. by the U. S. Geological Survey.
Brachiopoda and Lamellibranchiata of the Raritan Clays and Greensand Marls of New Jersey, Paleontology, Vol. I.—R. P. Whitfield.
Gasteropoda and Cephalopoda of the Raritan Clays and Greensand Marls of New Jersey, Paleontology, Vol. II.—R. P. Whitfield.
The Paleozoic Faunas, Paleontology, Vol. III.—Stuart Weller.
A Brief General Account of Fossil Fishes, and the Triassic Fishes of New Jersey—C. R. Eastman, Part I. of the Annual Report of State Geologist for 1904.
A Brief Sketch of Fossil Plants, and the Flora of the Cliffwood Clays—Edw. W. Berry, Part II. of the Annual Report of the State Geologist for 1905.

Copies of all of these reports can be obtained, upon payment of postage or express charges, by those particularly interested in these subjects.

During the year a new State Map, on a scale of five miles per inch, showing all political subdivisions, was issued. It was prepared in response to a frequent demand for a map which should show distinctly township and county lines, and to this end it was printed in four colors. It forms an exceedingly valuable means of ready reference to townships, boroughs and other political divisions. A cloth-mounted edition was prepared for the State Board of Education for distribution to the public schools of the State, the cost being defrayed by a special appropriation by the Legislature.

A new edition of the New York bay sheet, on the scale of 2,000 feet per inch, was also published.

Distribution.—The sale of the Survey maps during the past three years is shown in the table below:

	Sheets sold.		
	1905.	*1906.*	*1907.*
Maps on scale of 1 inch per mile	1,245	1,974	1,127
Maps on scale of 2½ inches per mile	1,942	2,607	2,160
	3,187	4,581	3,287

It will be seen that there has been a considerable decrease in the number of sheets sold in 1907 as compared with 1906, although there is a slight gain over the sales of 1905. The decrease is most marked in the case of the older series of one-inch per mile maps, and is only partially accounted for by the fact that several sheets of this series have been out of print for the entire year, so that some orders have been refused.

Since on the average 90 copies of each sheet of the large-scale maps have been sold as against 68 of the smaller scale, it is evident that the former are more popular with those who use the maps. At the same time, the comparatively small demand for such of the large-scale maps as do not lie in what may be called the metropolitan districts of the State, indicates that it will not be wise to extend the publication of these maps much beyond the present limits.

The Annual Report for 1906 was distributed late in the year to all persons on the mailing list, and a few copies of Paleontology, Vol. IV., were also sent out. Owing to the size of this report and the consequent expense of distribution, recipients will be requested to pay the express charges. During the year there was also a considerable demand for earlier reports of the Survey, in response to which 1,581 separate volumes were shipped. The demand for the various reports during 1907, as compared with 1906, is shown in the following table:

Survey Reports Distributed in 1906 and 1907.

	1906.		*1907.*	
Annual Report for 1906			2,926	copies.
" " " 1905	3,237	copies.	404	"
" " " 1904	147	"	66	"
" " " 1903	72	"	44	"
" " " 1902	43	"	38	"
" " " 1901	42	"	32	"
" Reports between 1883–1900	637	"	438	"
Final Reports, Vol II	99	"	56	"
" " Vol. III	81	"	58	"
" " Vol. IV	85	"	42	"
" " Vol. V	89	"	67	"
" " Vol. VI	177	"	119	"
Other Reports	107	"	138	"
Total Reports	4,816	"	4,428	"
Map sheets—				
Scale 1 inch per mile—19 sheets	1,974		1,127	
Scale 2,000 feet per inch—24 sheets	2,607		2,160	
Total map sheets	4,581		3,287	

Library.—The accessions to the Survey Library during the year were 33 bound volumes, 130 unbound volumes, 85 pamphlets and 37 maps. The bulk of these were obtained by exchange.

Collections.—A few specimens to fill gaps in the stratigraphic series were obtained, but apart from these there have been no notable additions to the Survey collections. The work of indexing and cataloguing the material on hand has been continued by Mr. Poland, under my direction.

Two sets of the school collections were sold at the regular price of $25 per set, and there are now remaining only two sets, which can be obtained by any school in the State upon payment of the above amount to cover the cost of preparation, labelling and packing.

Editorial Work.—A considerable portion of my time continues to be occupied in the reading and revision of manuscripts, reading of proof and other editorial work. During the past year the manuscript and proof sheets for both the Annual Report and Paleontology, IV., aggregating about 1,100 printed pages, were so read and revised. In making up the indices for these two volumes I had the efficient assistance of R. B. Gage and Laura Lee.

Correspondence.—The Survey continues to be a bureau of information regarding the natural resources of the State, and so far as possible all such inquiries are answered fully, either by reference to published reports or by correspondence. In some instances the answering of a single inquiry of this sort necessitates several hours' investigation and study, but it is doubtful whether the work of the Survey can be made more effective in any other way than by carefully answering letters of this sort. In this connection, attention is invited to the paragraphs in this report under the heading, "Mining and Quarrying Industry."

Forestry Work.—By law, the State Geologist is *ex-officio* executive officer of the State Board of Forest Park Reservation Commissioners. Since the establishment of the Forest Commission, in 1905, the Geological Survey has undertaken no new work in forestry, but, of necessity, the State Geologist has been obliged to give a portion of his time to forestry work. In addition to office work, some time has been spent in the field inspecting forest tracts offered for purchase to the Forest Commission. A more detailed account of this branch of the work will be found in the report submitted by the Forestry commissioners.

Potable Water Commission.—The Legislature in 1906 appointed a special commission, of which the State Geologist was a member, to investigate and report upon the potable waters of the State. Owing to the detailed study which the Survey had given this subject, and the vast amount of data upon it in our possession, the preparation of the report naturally fell to the State Geologist, and considerable time during the early part of the past fiscal year was spent in this work. After the submission of the report to the Legislature, further time and study were given, at the request of the Governor, to preparing bills embodying the recommendations of the commission and to advocating their passage by the Legislature.

TOPOGRAPHIC WORK.

Mr. C. C. Vermeule has continued in charge of all topographic work done by the Survey.

Field Work.—A large-scale map of the region about the Hibernia mines was surveyed in the early part of the year. A reduced copy of the map will be used in the Passaic geologic folio, now being published in co-operation with the United States Geological Survey, and it will also be available for illustration of the report on iron ores, in preparation by W. S. Bayley.

Later, Atlas Sheets Nos. 35 and 36 were revised in the field and extensive alterations were made previous to publishing editions of these new maps, which will replace Sheets Nos. 15 and 16.

Office Work.—In the office a small amount of work was done in completing the preparation of Sheet No. 25, which was sent the engraver in November, 1906. The Hibernia mine map was drawn and the revised copy for Sheets Nos. 35 and 36 was prepared and sent to the engraver the latter part of June. The proof sheets of the State map showing borough and township lines, and also of Sheet No. 25, which was entirely re-engraved on copper, were examined and corrected.

HYDROGRAPHIC WORK.

In accordance with the requirements of the last Legislature, as set forth in two acts, the Survey has, during the past summer, given considerable attention to the question of the improvement of

Manasquan Inlet and to the cost of excavating an inland waterway from Bay Head to Cape May of sufficient width and depth to accommodate yachts, motor boats and other small ocean-going craft. This work was entirely unsolicited by the Survey, and the bills were introduced in response to local interest in these improvements, and their final passage by the Legislature and approval by the Governor were due to the awakening of the people to the importance of improving our waterways. Special appropriations were made to cover the expenses of these surveys, and although the amounts named were in each case meager, considering the work to be done, yet, by strict economy and by the co-operation of local parties, it was possible to complete the work within the limits of the sum available.

Owing to the limited time between the approval of the acts in June and the end of the fiscal year, it seemed best to divide the work. Accordingly, a contract was entered into with Mr. Lewis M. Haupt to survey that portion from Cape May to Great Bay, while the portion from Great Bay to Bay Head was done directly by the Survey staff, under the immediate supervision of Mr. C. C. Vermeule. The report of the State Geologist on this work, together with the detailed reports of the engineers, will be published as Part I. of the Annual Report of the State Geologist for 1907, and, as required by the act, will be accompanied by the necessary maps and profiles.

The survey of Manasquan Inlet and the preparation of a plan and estimate of its cost were made by Mr. Haupt, who for so many years has been the earnest advocate of the curved "reaction jetty" for harbor improvement. Inasmuch as the act specifically required a plan and estimate for works of this character, it was eminently fitting that Mr. Haupt should prepare them. His report, together with my recommendations in the matter, will form Part II. of the Annual Report.

GEOLOGIC WORK.

Trap Rock and Building Stone Investigations by J. Volney Lewis.—Professor Lewis has continued his studies on the trap rocks which occur in the Triassic or Newark red shales, and is preparing a paper dealing particularly with their petrographical features. This paper, which is expected to make Part III. of the Annual Report, supplements the papers published in the last report, which were, in part at least, written during the early portion of this year, and which therefore must be considered as a portion of this year's work. In carrying out these investigations many thin rock sections have been examined by Mr. Lewis with the microscope and a number of trap rock analyses have been made for him in the laboratory of the Survey.

Professor Lewis has more recently taken up studies on the building stones of the State to supplement the investigations made by Mr. McCourt regarding their fire-resisting qualities. During the summer most of the quarrying localities, whether now active or not, were visited for the purpose of studying the working conditions, qualities of the material, accessibility to markets, &c. A considerable suite of specimens was collected, from which many thin-rock slides were made for microscopic study. This investigation has not been completed, but will be continued during the coming year.

Iron-Ore Investigations by W. S. Bayley.—Dr. Bayley has continued his compilation of data regarding the iron ores and iron mines, giving to that work during the year the equivalent of about two months' continuous service. He had previously visited the mines in connection with his field work for the United States Geological Survey on the crystalline rocks and collected some new data. He expects to submit his completed report for publication during the coming year.

Paleontologic Work by Dr. Stuart Weller.—Dr. Weller's paleontologic work upon the Cretaceous fossils was practically completed in 1906, but he has given considerable time during the past year to office work incidental to the completion and publication of his report. The material in his hands is now being labeled and packed for shipment to Trenton, where the best specimens will be placed on exhibition in the Museum and the balance will be available for reference and study.

Paleobotanic Work by E. W. Berry.—A small allotment was made to Edward W. Berry to permit him to continue his studies of the fossil plants in the Cretaceous sands and clays. He spent several days in the field, chiefly near Matawan, where continual excavations in the brick yards and the wave action at Cliffwood

Point are constantly exposing new sections and offering new opportunities for the collector.

Work of the State Geologist.—The field work of the State Geologist has been chiefly in the nature of conferences with workers on the State Survey and with geologists of the United States Geological Survey regarding investigations undertaken in common. In January, plans for co-operative work between the several State Surveys of the Atlantic coast and the United States Geological Survey for work in the coastal plain were made at a conference held in Washington, D. C. Inasmuch as the work on these formations was further advanced in New Jersey than in any other State, it was arranged that Mr. M. L. Fuller, who was put in charge of these investigations, should spend some time in New Jersey in order to familiarize himself with the coastal plain formations as here developed. In order that he might do this to the best advantage, the State Geologist planned the route and accompanied him. Conferences in the field were also had with Drs. W. B. Clark, B. L. Miller and F. Bascom.

In the office the papers on the Glass Sand Industry and Mineral Industry for 1906 were prepared. Manuscript maps of the Cretaceous and Miocene formations for the Philadelphia and Trenton folios were drawn and sent to Washington. Portions, also, of the text for these folios were written.

CHEMICAL WORK.

Mr. R. B. Gage has continued in charge of the chemical laboratory which the Survey is able to maintain through the interest of Colonel W. A. Roebling, of the Board of Managers. During the year the following analyses were made:

Glass sands.	
Complete chemical analyses	24
Partial chemical analyses	15
Physical analyses	16
Trap rock.	
Complete chemical analyses in duplicate	6
Water.	
Complete chemical analyses in duplicate	3

Owing to pressure of other duties, Mr. Gage gave only a part of his time to this work.

CO-OPERATION WITH THE UNITED STATES GEOLOGICAL SURVEY.

In accordance with the plan for co-operation in the publication of geologic folios relating to New Jersey, Professor R. D. Salisbury prepared the maps and manuscript relating to the Pleistocene deposits of the Trenton and Raritan folios. The State Geologist prepared the maps and portions of the text relating to the Cretaceous and Miocene formations of the Philadelphia and Miocene folios. The Passaic, Philadelphia, Trenton and Franklin Furnace folios have been completed and are now in the hands of the engravers and editors at Washington. The first two will, in all probability, be published during the present year, and perhaps also the others. Special editions for the State Survey have been ordered and when received will be placed on sale at a nominal price.

THE JAMESTOWN EXPOSITION.

Near the end of February the New Jersey Commissioners of the Jamestown Exposition requested the State Geologist to prepare an exhibit illustrating the mineral resources of the State. Owing to the lateness of the date and consequent lack of time for extensive preparation, no attempt was made to collect new material, but an exhibit was prepared from the material in the Geological Museum. Mr. R. B. Gage had immediate charge of the selection and arrangement of this material, and was assisted by Mr. Poland. Eighteen cases of specimens of ores, rocks and minerals were prepared and displayed. In the zinc and iron ores special effort was made to illustrate processes of treatment, and a series of specimens showed the various steps in the separation and concentration of these ores. In the exhibit of clays, samples of both raw and burned clays were shown, with analytical data regarding shrinkage, temperature of burning, chemical composition, &c. The manufacture of Portland cement was illustrated by the raw materials, samples showing the product at various stages of manufacture, the finished product, test pieces, &c. In addition to the ordinary printed label for each specimen, larger descriptive labels were prepared, which, with small maps of the State, gave concise information regarding the mode of occurrence, location, composition, &c., of the various materials.

The exhibit was installed by Mr. Gage as a part of the New Jersey exhibit in the State's exhibit building. It received the highest award—a gold medal.

THE MINING AND QUARRYING INDUSTRY.

It is a function of the State Geologist to obtain current and reliable information regarding the geology and the development of the mineral resources of the State, and by all proper means to make public such information in order that the legitimate development of our resources may be encouraged and ill-advised or fraudulent schemes may be prevented. Any person, upon application to the State Geologist, can obtain copies of the reports of this department, and in them find accurate and impartial information regarding the resources of the State. While the members of the Survey are not at liberty to make special examinations and reports of properties for private parties, yet all requests by letter for information of the *known facts* regarding any mineral property will always be carefully answered, and except in the rare cases where the data are of a confidential nature, they will be given. The State Geologist cannot undertake to advise investors, but they may frequently obtain from this office statements of fact which will assist them in reaching a decision.

In the last report it was thought necessary to direct specific attention to a mining company whose extravagant and reckless claims of mineral wealth of a property at Franklin Furnace were not borne out by any records in the possession of the Survey, and which were indeed contrary to known and generally accepted geologic facts. That these claims were intended to appeal to the credulity of small investors, and that they did so appeal, is abundantly shown by letters received by the Survey during the year. So fraudulent in character were these circulars that the attention of the post-office department was early attracted to them and an exhaustive investigation made. In October, the assistant attorney-general for the post-office department directed the company to show cause why a fraud order should not be issued, and the State Geologist was requested by the post-office inspector to be present at the hearing in order to present evidence regarding cerns is large. Apart from the cost of the land, a 2,000-barrel-per-day plant would cost not less than $500,000* at the lowest estimate, and some reliable authorities set the figure at $700,000 or more. But the amount of capital required to start properly a cement proposition is much more than the cost of the land and plant. A large reserve working capital is necessary for several reasons. No new cement plant can be expected to produce normal cement at normal cost until after a profitless and expensive period of experimentation. Even after a plant is working normally, ready sales of its product cannot be expected, owing to the well-founded prejudice in favor of old-established brands whose worth has been proved by long experience. Against this prejudice headway can be made but slowly, and then only by superior quality or lower prices until the reliability of the new product is well established.† Moreover, many of the running expenses of the plant must be paid in cash, while cement is sold on comparatively long time. Including the cost of land, the capital needed to start successfully a 2,000-barrel plant will probably be not far from $1,000,000.

It is commonly believed that the profits in the Portland cement industry are very large, and this belief is energetically fostered by many so-called "cement engineers" and "cement experts," as well as by irresponsible promoters. For instance, the circular in question promises a "clean profit of 60 cents on each barrel manufactured," and asserts that "this big margin of profit should be just as sure in this company as a 4 per cent. in a bank or trust company or a 7 per cent. Pennsylvania railroad stock." The actual facts seem to be, on the contrary, that there is not now, and has not been for a number of years, a large margin of profit for most of the plants now engaged in Portland cement manufacture.

According to some authorities,‡ the cost of manufacture in the Lehigh district (which embraces also Warren county, N. J.), in a 2,000-barrel-per-day plant, ranges from 77¾ cents to 68 cents

* Eckel, Cements, Limes and Plasters, p. 556.

† The specifications used by the engineer corps of the U. S. army under date of 1902, provide that "no cement will be allowed to be used except established brands of high-grade Portland cement which have been made by the same mill and in successful use under similar climatic conditions to those of the proposed work for at least three years." (Eckel loc. cit., p. 617.)

‡ Boilleau & Lyon, Municipal Engineering, Vol. 26, p. 394, June, 1904; Eckel, Cement, Limes and Plasters, p. 561.

per barrel, exclusive of the package, according to the size and number of kilns, while in the smaller plants the cost is somewhat higher. These published figures are somewhat lower than similar data obtained directly from cement manufacturers of New Jersey and Pennsylvania, and on file in this office. These show costs between 80 and 90 cents per barrel when all fixed charges, such as interest on the plant, depreciation, &c., have been allowed for, but they do not include the cost of the package in which the cement is shipped.

During the past three or four years, the selling price of cement has varied considerably. A careful distinction must be made between the price in bulk and the price including the package. The average cost of the package is 35 cents for a barrel, 40 cents (per barrel) for cloth bags, and 15 cents (per barrel) for paper bags. This cost is charged to the purchaser with a rebate of about 75 per cent. for the return of the barrel or cloth bags in good condition. Since the cost of these packages is not included in the cost of manufacture as given above, it must therefore be deducted from the selling price in order to arrive at a true determination of the margin of profit.

The following table shows the production, total value, and the selling value per barrel of Portland cement in bulk, at the factory, in Pennsylvania and New Jersey, during 1904, 1905 and 1906, as reported by the United States Geological Survey:*

	PENNSYLVANIA.			NEW JERSEY.		
	1904.	1905.	1906.	1904.	1905.	1906.
Amount in barrels	11,496,099	13,813,487	18,645,015	2,799,419	3,654,777	4,423,648
Total value	$8,969,206	$11,195,940	$18,598,439	$2,099,564	$2,775,768	$4,445,364
Value per barrel	78 cents	81 cents	99 cents	75 cents	76 cents	$1 00½

The present selling price† (November, 1907) at the mill is from 85 to 95 cents, although some sales have been made at lower figures. A comparison of these figures with the average cost per barrel is evidence at once that the margin of profit is close. Whenever the net selling price of cement (exclusive of the pack-

* Mineral Resources of the United States—The Cement Industry in the United States in 1906, p. 17. The value per barrel was not given in the U. S. G. S. tables, but was computed by dividing the total value by the total product.

† In December the price had further declined to 75 to 85 cents per barrel net.

age, freight, &c.) reaches 80 cents per barrel at the mill, some of the mills of the Lehigh district sell at an actual loss, and the average dividends paid by one of the most successful plants since its establishment are reported not to have exceeded 6 per cent. on the capital stock. During 1904 and 1905 the margin of profit of one large mill was only a few cents per barrel, with nothing allowed for depreciation of the plant. It can be accepted as certain, therefore, that all claims of net profits of "60 cents per barrel" for Portland cement are grossly exaggerated, if not willfully fraudulent.

There have been several editions of the prospectus in question. In the earlier ones, 10,000 shares of stock are offered the public at $5 per share ($6 time payments), and the statement is made that "this is the original ground floor offering." However, it appears in a later edition that the stock is offered at $7.50 per share, and prospective purchasers are again assured that this *later advanced price* "is the original ground floor offering."

If further comment were necessary, ground for it might be found in the statement: "The property has a frontage of six hundred and fifty feet on the Delaware river, *so that the product can be shipped to Philadelphia and to the seaboard by water.*" *

To one familiar with the Delaware river between Trenton and Carpentersville, and the dams at Scudder's Falls and Lambertville, to say nothing of rock reefs and rapids at other points, the misleading effect of such a statement is apparent, and it casts suspicion at once upon the motives of those who make it. To the prospective investor in some distant State ignorant of these facts it appeals with force as evidence of a cheap water route which will give the company a marked advantage over its competitors.

It is extremely desirable that all the available cement land of the State should be developed and utilized by the establishment of successful plants. Misleading statements regarding the fundamental facts can only hamper this development.

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* Italics not in the original.

PART I.

Report on an Inland Waterway from Cape May to Bay Head

By Henry B. Kümmel,

WITH

Accompanying Reports and Maps.

By C. C. Vermeule and L. M. Haupt.

Report on an Inland Waterway from Cape May to Bay Head.

By Henry B. Kümmel.

This report is submitted in compliance with the following act passed by the one hundred and thirty-first Legislature:

CHAPTER 236, LAWS OF 1907.

An Act providing for a survey or surveys to show the amount of dredging necessary to deepen the channels of the inland waterways extending from Cape May to Bay Head along the Atlantic coast, and for estimates of the cost of deepening the same and appropriating five thousand dollars to defray the expenses of such surveys and estimates.

Be it enacted *by the Senate and General Assembly of the State of New Jersey:*

1. The State Geologist of the State of New Jersey is hereby authorized and directed to make an estimate of the amount of expenditures ncessary to deepen such portions of the inland waterway extending from Cape May to Bay Head along the Atlantic coast as may be required to be deepened to secure a channel between said points of the minimum depth of eight and ten feet, respectively, at low water, and of the width of fifty feet, and to make a report of the estimate so made by him to the one hundred and thirty-second session of the Legislature of the State of New Jersey at the opening thereof.

2. Said report to be made by the said State Geologist shall include a detailed statement of the manner in which said estimate is by him made, and shall show the estimated cost of the width named in the preceding paragraph at the two depths respectively named, and shall be accompanied by suitable maps and data to elucidate the same.

3. In making such surveys as may be essential to procure the necessary data from which the estimates referred to in the preceding sections may be made the State Geologist is authorized to employ such assistance as in his judgment may be necessary, and the total cost of making said survey and estimates shall not exceed the sum of five thousand dollars; and there is hereby appropriated from the treasury of the State of New Jersey the sum of five thousand dollars from which all expenses connected with said survey and estimates which shall be approved by the said State Geologist shall be paid.

4. This act shall take effect immediately.

Approved June 10, 1907.

Immediately upon the approval of this act, the matter was referred to Mr. C. C. Vermeule, consulting engineer of the State Survey, who was directed to plan and report upon a method by which the survey could be made and the necessary data obtained within the limits of the appropriation. Inasmuch as the distance from Cape May to Bay Head, by the most feasible route, is nearly 117 miles, it will be noted that the amount appropriated, being less than $43 per mile, demanded strict economy in administration and the adoption of methods which would insure the completion of the entire work within the amount appropriated. After giving the matter proper consideration, it was found that Professor Lewis M. Haupt was familiar with the work which had been done between Cape May and Great Bay by the United States Engineer Corps, in 1887, and that he had in his possession complete copies of those surveys, which were made in considerable detail, on a scale of 200 feet to an inch. In view of this fact and Professor Haupt's familiarity with the questions involved, together with the short time at his disposal in which to complete the work, Mr. Vermeule recommended that the surveys for this lower half of the route should be placed in charge of Professor Haupt. The work to be done consisted of the revision of the surveys of 1887 and their verification to determine any changes in depth which might have occurred, together with some important changes of the route which both Professor Haupt and Mr. Vermeule considered to be desirable. An arrangement was accordingly made with Professor Haupt, by which he was to supervise the necessary surveys and furnish the estimates of the amount of dredging necessary.

For the northern half of the route no such data were available. An original survey had to be made throughout from the southern shore of Great Bay to Bay Head. Mr. Vermeule took personal charge of this portion of the work and he also has co-ordinated the surveys and prepared maps and profiles to illustrate this report throughout. The organization of the work was completed about July 20 and the field surveys were finished September 6. A detailed statement of the manner in which the surveys and estimates have been made will be found in the reports of the engineers herewith submitted. Owing to the fact that the route from Cape May to Great Bay follows, in the main, the narrow thoroughfares through the marsh, and the further fact that this portion of the route had previously been surveyed by the United States Engineer

Corps, as already mentioned, while the northern half of the route runs mainly through wide bays and open waters, the methods pursued in the two parts of the work were essentially different.

This report is illustrated by a series of maps and profiles covering the entire distance, which show in detail the route adopted for the proposed channel and the amount of dredging which will be necessary and where such dredging is located. In addition to these printed maps, there are on file in the archives of the Survey the field books, the profiles in detail, and copies of the surveys made by the United States Engineer Corps between Cape May and Great Bay, in 1887. The present depth of water along the proposed route is indicated by the following summary:

	Miles.	*Per cent.*
Cape May to Great Bay	65.8	100
Less than 6 ft. deep	15.54	23.6
Less than 8 ft. deep	21.82	33.2
Less than 10 ft. deep	26.65	40.5
Great Bay to Bay Head	50.8	100
Less than 6 ft. deep	5.15	10.1
Less than 8 ft. deep	20.45	40.0
Less than 10 ft. deep	27.11	53.4
Cape May to Bay Head	116.6	100
Less than 6 ft. deep	20.69	17.8
Less than 8 ft. deep	42.27	36.3
Less than 10 ft. deep	53.76	46.1

The deepest portions of the route, or those requiring the least dredging, are the section between Hereford and Townsend's inlets, the section between Great Egg and Absecon inlets, much of which has already been dredged by private enterprise to secure filling for land, and the section from Great Bay to Cedar Bonnets through the main channel of Little Egg Harbor and Tuckerton Bay.

SUMMARY OF ESTIMATES.

The following is a brief summary of the estimates of the engineers of the cost of an 8-foot channel and a 10-foot channel, respectively. The details will be found in the reports of the engineers:

CAPE MAY TO GREAT BAY.

	8-ft. channel.	10-ft. channel.
Cold Spring to Hereford Inlet	$16,876 40	$30,878 60
Hereford to Townsend's Inlet	8,103 00	16,655 50
Townsend's to Great Egg Inlet	57,524 94	88,467 30
Great Egg to Absecon Inlet	3,248 04	8,622 72
Absecon Inlet to Great Bay	40,912 60	53,814 78
Contingencies, 10 per cent	12,666 49	19,843 80
Engineering, supervision, inspection	10,000 00	12,000 00
Auxiliary works, jetties and revetments	15,000 00	20,000 00
Total from Cape May to Great Bay	$164,331 47	$250,282 70

GREAT BAY TO BAY HEAD.

	8-ft. channel.	10-ft. channel.
Great Bay to Cedar Bonnets	$9,012 96	$20,224 80
Cedar Bonnets to Barnegat Pier	41,676 30	99,490 40
Barnegat Pier to Bay Head	53,933 04	101,783 50
Contingencies, 10 per cent	10,462 23	22,149 87
Engineering, inspection, &c	10,000 00	20,000 00
Total from Great Bay to Bay Head	$125,084 53	$263,648 57

It will be noted that for the 8-foot channel the greater cost is in the southern section, while for the 10-foot channel the greater part of the cost is in the northern section. According to the above estimates, the total cost of an 8-foot channel from Cape May to Bay Head will be $289,416, and the total cost of a 10-foot channel from Cape May to Bay Head will be $513,931.

Possible Variations.—The engineers point out the possible wide variation in the cost of dredging, due to many conditions which cannot readily be foreseen, so that these estimates of cost, while they are deemed to be reasonable, may prove to be either somewhat too small or too great owing to conditions, such as the cost of labor, the existence of a plant free to be used upon the work, &c., prevailing at the time when the work may be done.

A summary of the estimates and the number of cubic yards to be dredged is furnished by Mr. Vermeule at the end of his report.

Draw Bridges.—The foregoing estimates do not include any allowance for improving and reconstructing draw bridges. Between Cape May and Great Bay there are 6 highway, 6 railroad and 3 trolley bridges which cross the proposed waterway, and some of these are deficient and should be reconstructed in order to provide more ample openings and structures which can be more readily opened for traffic. Between Great Bay and Bay Head there are 2 railroad bridges and 1 highway bridge, the draws of which are very well built and afford ample openings. It has not been considered that the present act contemplates the reconstruction of these bridges, and certain of them are so clearly an obstruction to navigation and so inadequate for the purpose that it seems probable that the railroad companies will be willing to reconstruct them when it shall prove necessary.

In reporting to the Legislature these estimates of cost, with suitable maps and other data to make clear their meaning, the State Geologist has discharged the duty laid upon him by the act quoted. It seems advisable, however, in this connection to call attention to certain facts which should be kept in mind in any consideration of this improvement.

Relative to Other Works.—It would seem as if this improvement should be considered together with the proposed improvement of Manasquan Inlet, upon which subject a separate report is made by Prof. Haupt, and the proposed tide waterway from Manasquan Inlet to Bay Head, the surveys and estimates for which were made by direction of an act of the Legislature and printed in the report for 1903. It might be held that the improvement of Manasquan Inlet was properly a work to be done by the United States Government, but in view of the utter failure of the improvements made there under its direction in 1881-1883, and the enormous total of harbor improvements which have already received the approval of the Engineers of the War Department, it is questionable whether any assistance can reasonably be expected from the National Government. It seems more than likely that if Manasquan Inlet is to be improved, it will have to be done under State control, as the present policy of the National Government is to improve only those harbors which have a well-established commerce. The estimated cost of the channel from Manasquan Inlet to Bay Head, as given in the report already referred to, is $154,560. This would make the entire cost of an 8-foot channel from Manasquan Inlet to Cape May $443,976, to which $30,000 to $40,000 should be added to secure an 8-foot channel across the bar at Manasquan Inlet.

The opening of such a waterway from Manasquan Inlet to Cape May, provided with a good entrance and harbor at Manasquan Inlet, would furnish a serviceable and useful waterway. In order to pass down the coast from New York harbor to Cape May it would then be necessary to run outside in the open ocean, a distance of only 27 miles, between Sandy Hook and Manasquan Inlet. As this distance could be covered in about three hours, it would present no serious obstacle to comparatively small craft, and the remaining 120 miles to Cape May would be through sheltered inland waters.

Value of the Improvement.—Undoubtedly this improvement will prove valuable in adding to the attractiveness and the accessibility of all of our seashore resorts and other towns along the coast. Such a waterway would unquestionably have a considerable value for commerce as well as for the use of motor boats, steam yachts and other pleasure craft. The investment in seashore property in the counties of Monmouth, Ocean, Atlantic and Cape May constitutes a very important fraction of the entire ratables upon which taxes are assessed in those counties. Furthermore, this investment is not so exclusively a local interest as it may at first sight appear to be. The owners of houses, hotels and other real estate, and of yachts and motor boats along the coast will be found to have their residences in all parts of the State. Only a minority are residents of the counties mentioned. While the seashore interests are the most important to be served by the proposed waterway, it will unquestionably be valuable also to the fishermen and oystermen along the coast and to the farmers and gardeners of that part of the State, who find an important and desirable market in the seashore resorts.

The importance of the seashore developments between Sandy Hook and Cape May is indicated by the fact that Atlantic City alone, with a population in 1905 of 38,000, had an assessed valuation for taxation purpose of $49,069,922. It has been estimated that the gross income from the year's business in that city amounts to $110,000,000. Inasmuch as the total population of the seashore towns, cities and boroughs amounted in 1905 to 112,000, or about three times that of Atlantic City, the amount of the total investment and the total volume of yearly business becomes evident. From the best figures obtainable, the total assessed valuation on the 1905 basis was not far from $125,000,000, and the gross receipts of the business $250,000,000 per annum.

Since at the present time the relative value of waterways and railroads, and the manner in which each may properly supplement the other, is being much discussed, the following quotation from the annual report of the Geological Survey for 1855 is of interest. Discussing the Camden and Amboy railroad, this report says (see page 34): "It is much more important as a route of travel than commerce, since the Delaware and Raritan canal, which has the same general direction and connections, is a better medium for heavy transportation." This quotation expresses quite accurately the view of the present-day advocates of waterways, namely, that they do not necessarily compete with, but supplement, the railroads, and are peculiarly adapted for the handling of heavy and bulky goods, such as coal, building material, &c. There is little doubt that by enabling the shore towns to obtain such bulky material at low rates of freight the proposed waterway would conduce materially to their growth and prosperity, and by this increased growth and development the railroad would undoubtedly be benefited to a much greater extent than they would be injured by the diversion of this class of traffic, since they would enjoy an increase in passenger receipts and receipts from the higher classes of freight, which would be shipped preferably by rail.

Although the proposed waterway would be of material value for commerce, its chief use would unquestionably be for pleasure travel and intercommunication between the many resorts upon the sea and bay shores. There is at present a regular passenger service by water maintained between Toms River and Sea Side Park, and also between Tuckerton, Beach Haven and Atlantic City. The proposed improvement would undoubtedly lead to the establishment of several useful routes of travel by steamers or power boats.

Dimensions of the Channel.—The width and depth of the channels covered by the estimates were fixed by the act directing this survey, but it seems proper to point out the fact that while the total estimated cost of the 8-foot channel, as already given, amounts to $289,416, and that of the 10-foot channel to $513,931, Mr. Vermeule states in his report that the 8-foot channel can be made 100 feet wide, instead of 50 feet wide, at a cost not exceeding that of a 10-foot channel 50 feet wide. When the depth and width of the channel shall be finally fixed upon, this fact should be borne in mind. It would appear that an 8-foot channel 100 feet wide would be more useful and better adapted to the traffic than a 10-foot channel 50 feet wide. Boats which would require 10 feet of depth would find it difficult to pass each other in a channel 50 feet wide. Furthermore, it would be more difficult to follow so narrow a channel through the open bays.

Means of Accomplishment.—The report made to the general government by the chief of engineers, as given by Mr. Haupt, seems to indicate that this improvement is not likely to be made by the United States, and it appears to follow that the construction of this waterway must be left either to the State or to private capital. The only important inland waterways constructed in the State thus far are the Morris canal, commenced in 1825, which cost upwards of $2,000,000, its total length being about 102 miles, and the Delaware and Raritan canal, having a total length, with its feeder, of 65 miles, which was built about 1834, the cost of which was reported, in 1854, as $3,707,916, and in 1866 as $4,-381,251. Both of these canals were built by private enterprise.

The route of this proposed waterway lies through open bays and navigable thoroughfares, which are natural highways, and which cannot be dedicated to private corporations, consequently its construction by private enterprise cannot be seriously considered. It would seem, therefore, that if the work is to be done at all it must be undertaken by the State.

Whether or not such a procedure is a wise policy, is for the Legislature to determine; its discussion here is not called for by the act under which this investigation was made.

Acknowledgments.—During the progress of this work offers of assistance were received from a number of yacht clubs along the coast. The Cape May Yacht Club, the Wildwood Yacht Club and the Ocean City Yacht Club offered power boats for use in sounding near those places. The Atlantic County Oyster Commission and the State Fish and Game Commission likewise offered the use of their launches for this work. That these offers were not accepted was not due to any failure to appreciate the interest thus manifested in the survey, but to the nature of the work, which was pushed so rapidly, particularly in the southern portion, that it was deemed advisable not to change boats. The Bay Head Yacht Club and the Sea Side Park Yacht Club kindly permitted the use of their piers for the tide gauges, and the Corinthian Yacht and Gun Club, of Beach Haven, offered co-operation in any line. To all these my thanks are due not only for what they did to assist in the work, but for what they stood ready to do.

INLAND WATERWAY SURVEY.

Section from Bay Head to Great Bay.

Summary, Bay Head to Cape May.

Report and Estimates

BY

C. C. VERMEULE.

INLAND WATERWAY FROM CAPE MAY TO BAY HEAD — SHEET I.

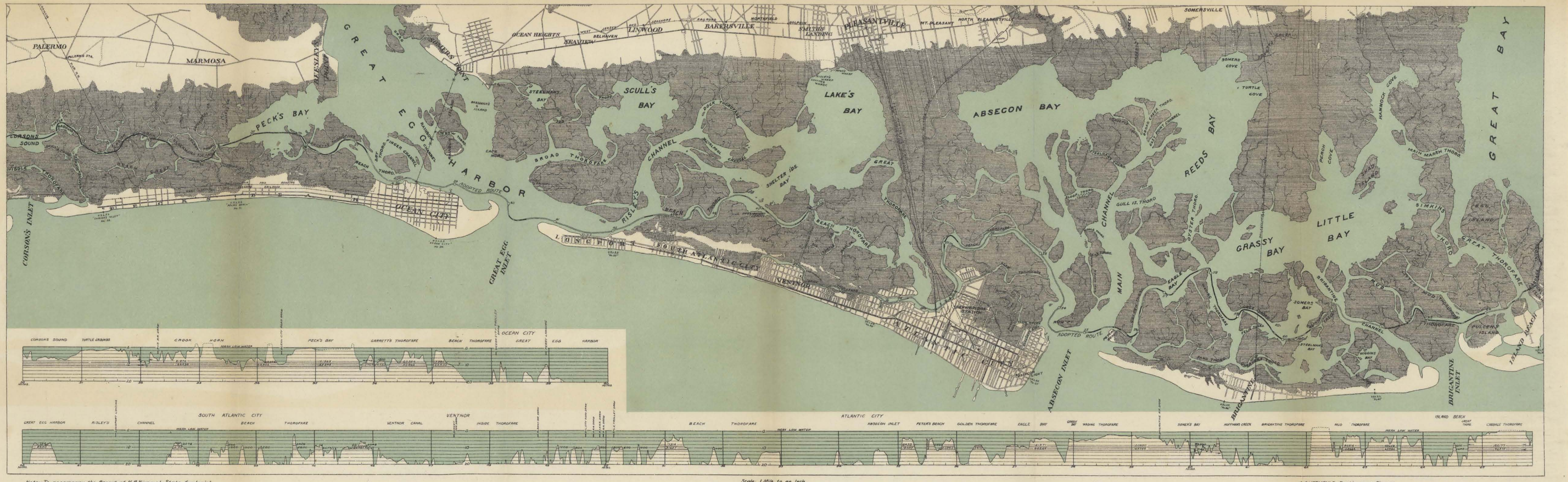
Note—To accompany the Report of H.B.Kümmel, State Geologist, made by direction of an act of the Legislature.

Scale: 1 Mile to an Inch.

—— Section of route to be dredged for 8 ft. channel, as shown above.

C.C.VERMEULE, Engineer in Charge.
Note: Surveys and estimates for Section from Cape May to Great Bay made by L.M.Haupt, C.E.

INLAND WATERWAY FROM CAPE MAY TO BAY HEAD — SHEET II.



Note:—To accompany the Report of H.B.Kummel, State Geologist, made by direction of an act of the Legislature.

Scale: 1 Mile to an Inch.

Section of route to be dredged for 8ft channel, as shown above.

C.C.VERMEULE, Engineer in Charge.
Note—Surveys and estimates for Section from Cape May to Great Bay made by L.M.Haupt, C.E.


INLAND WATERWAY FROM CAPE MAY TO BAY HEAD — SHEET III
TUCKERTON
PARKERTOWN
WEST CREEK
SPRAGUETOWN
COXS
STAFFORDVILLE
MANAHAWKEN
CEDAR RUN
BARNEGAT
WARETOWN
GREAT BAY
LITTLE EGG HARBOR
PARKER'S COVE
MUD COVE
MANAHAWKEN BAY
TURTLE COVE
BARNEGAT BAY
THOROFARE
GREAT
ISLAND BEACH
SHOOTING THORO
NEW INLET
TUCKERS BEACH
SEA HAVEN
HOLGATE
BEACH HAVEN
PEAHALA
SURF CITY
HARVEY CEDARS
BARNEGAT CITY
BARNEGAT INLET
L O N G B E A C H
ADOPTED ROUTE
MUD THORO
ISLAND BEACH
CABBAGE THOROFARE
GREAT BAY
ANCHORING ISLAND
TUCKER'S ISLAND
HOLGATE
BEACH HAVEN
LONG POINT
DINNER POINT
MUD COVE
REED'S ISLAND
SURF CITY BULKHEADS
HARVEY CEDARS
SANDY ISLAND
LOVELADY
WARETOWN
MEAN LOW WATER
Note:- To accompany the Report of H.B.Kummel, State Geologist, made by direction of an act of the Legislature.
Scale - 1 Mile to an Inch.
Section of route to be dredged for 6 ft. channel, as shown above.
C.C.VERMEULE, Engineer in Charge.

INLAND WATERWAY FROM CAPE MAY TO BAY HEAD — SHEET IV.

Note—To accompany the Report of H. B. Kümmel, State Geologist, made by direction of an act of the Legislature.

Scale—1 Mile to an Inch.

Section of route to be dredged for 8 ft. channel, as shown above.

C. C. VERMEULE, Engineer in Charge.

Section from South Shore of Great Bay to Bay Head.

CONTENTS.

The portion of the proposed inland waterway extending from the southerly shore of Great Bay at the mouth of Cabbage Thoro, north through Great Bay, Tuckerton Bay and Barnegat Bay to Bay Head, being a distance of about 50 miles, lies mainly through broad, open bays. The survey for this portion of the channel was made by the following method:

The party was furnished with a power boat and a row boat, and consisted of four men in the boats and two men reading tide gauges. A point approximately in the best natural channel having been reached, it was located by means of what is known as the trilinear or three-point method, angles being measured between three fixed objects on the shore of the bay, the position of which was known. This point was then marked by means of a long pole and flag, and a similar point was set off 300 feet to the right and another 300 feet to the left, and similarly marked. The party then proceeded ahead a distance varying from 600 feet to 1,800 feet and averaging about 1,300 feet. Here another point was established approximately in the middle of the channel, and as before other points were laid off 300 feet to the right and 300 feet to the left, all three points being marked with a pole and flag. The power boat was then run over the center line of the channel and the two side lines at a moderate uniform speed. Soundings were made at regular intervals of time, the time being taken also at the beginning and end of the course. These soundings were plotted at distances indicated by the elapsed time between soundings. Similar soundings were made across the channel at the beginning and end of each course. Where the water did not exceed about 12 feet in depth, the soundings were made with a rod of wood marked off in feet and tenths of a foot. Where the depth was greater, a line and lead was used, and also buoys were substituted for the poles and flags to mark the stations. In order to correct the soundings to mean low tide, tide gauges were set up and read while the work was in progress, the readings being taken at each end of the section of the course under survey. The points at which the tides were read are as follows:

Bay Head Yacht Club Pier,
Seaside Park Yacht Club Pier,
Barnegat City Pier,
Surf City 12th Street Pier,
Little Egg Light. Bay shore west of Light House.

Readings of the tide were taken each hour during daylight, and all soundings were corrected to mean low water.

The stations along the proposed route were plotted on the original maps of the Geological Survey on a scale of 3 inches to 1 mile, and the length of each course was determined by scaling the distance on the map. Having plotted the soundings on the center lines and the side lines, they were examined in order to determine whether the center line was in the deepest and best channel, and if not, the route was shifted so as to secure the greatest depth of water. In some instances the selected route has also been straightened somewhat, where the straightening could be done without undue cost. The final center line for the proposed route having been thus determined, the profile was plotted showing the depth of water along the entire route. From this profile the depth of cutting or dredging necessary was read off for each station and the number of cubic yards to be dredged was computed. In making this computation, the bottom width of the channel was taken at 50 feet, as provided by the Legislature, and the side slopes were assumed at 3-feet base for 1-foot rise. In other words, with a channel 8 feet deep, there would be a depth of 4 feet over a width of 74 feet. This side slope is believed to be sufficiently flat to be maintained without slipping into the channel. It is customary to allow one foot extra depth for undercutting and irregularities in the dredging, consequently for a channel 8 feet deep, the dredging was actually estimated to a depth of 9 feet, and for a channel 10 feet deep, the dredging was estimated for an actual depth of 11 feet. This is necessary because the Act provides for a channel of a minimum depth of 8 feet, or of 10 feet, and such minimum depth cannot be secured throughout without in some cases exceeding the given depth.

RESULT OF TIDE MEASUREMENTS.

The following exhibits some of the results of the tide-gauging at the points above described:

Mean Difference in Time of High Water—

Bay Head and Sea Side Park, July 19 to July 31	2 hrs. 52 min.
Sea Side Park and Barnegat City, August 1 to 13	2 hrs. 47 min.
Barnegat City and Surf City, August 15 to August 20	3 hrs. 57 min.
Surf City and Little Egg Station, August 22 to September 6	3 hrs. 12 min.

Mean Difference in Time of Low Water—

Bay Head and Sea Side Park, July 19 to 31	2 hrs. 51 min.
Sea Side Park and Barnegat City, August 1 to 13	2 hrs. 41 min.
Barnegat City and Surf City, August 15 to 20	4 hrs. 12 min.
Surf City and Little Egg Station, August 22 to September 6	3 hrs. 37 min.

Range of Tide in Feet—	*Mean tidal range.*	*Lowest tide below mean low.*	*Highest tide above mean low.*
Bay Head, July 19 to July 31	.45	.45	.95
Sea Side Park, July 18 to August 14	.57	.35	1.08
Barnegat City, August 1 to August 20	1.36	.34	1.67
Surf City, August 15 to September 6	.94	.45	1.67
Little Egg Station, August 21 to September 6	3.08	.37	3.59

It will be observed that the tide in the bay throughout is very much less than in the ocean, the mean tidal range in the ocean being about 4.7 feet. The difference in the time of high water at Bay Head and at Barnegat City is 5 hours and 39 minutes. Observations, made in 1903 during the progress of the survey for the proposed tide waterway between Bay Head and Manasquan Inlet, determined that the difference in time between high water at Manasquan Inlet and at Bay Head was about 6 hours. At the same time the mean tidal range at Bay Head was ascertained to be 0.35 feet and at Mantoloking 0.54 feet. These observations in 1903 extended over a longer period than those taken this year. The storm tides also occasionally depart more widely from the mean than is indicated by the figures given above. Reference to the report of 1903, already referred to, will show that extreme high tides at Bay Head rise 2.85 feet above mean low tide at that point. The figures given to show how much the lowest tide runs below mean low tide at the several stations, are of especial interest in connection with the proposed waterway as showing how much the navigable depth of channel will be affected by extreme low tides. The surveys of 1903 do not indicate that the lowest tides at Bay Head run lower than 0.45 feet below mean low tide, but at Mantoloking they were observed in September, 1903, to run 0.6 feet below mean low tide.

The rate of movement of the tidal wave appears to be as follows:

	Average speed in miles per hour.	*Average depth of channel, feet.*
Bay Head to Sea Side Park	4.02	6.45
Sea Side Park to Barnegat City	4.50	10.56
Barnegat City to Surf City	3.38	10.67
Surf City to Little Egg Station	4.25	16.20

In making up the above, the distances are measured along the main channel. Some uncertainty exists as to the course of the tide between Barnegat City and Surf City, but in this computation it is assumed to follow Oyster creek channel from the inlet to the main channel along the westerly side of the bay, thence down the main channel to Surf City.

The velocity of the current differs materially from the velocity of the tidal wave. Owing to rather high winds and frequent eddies, it was difficult to obtain good current measurements, but the following are some of the values obtained for velocity at the surface, all measurements being taken along the main channel:

	Velocity in miles per hour.
Goose Creek, opposite Ortley	0.37
Good Luck Point, mouth of Toms River	0.50
Off Forked River	0.40
South of Manahawken Bridge	1.25
Off West Creek	1.24
One mile south of Long Point	1.44
Off Holgate or Bonds	1.52

SELECTION OF ROUTE.

Two principal considerations influenced the selection of the route, namely, the first cost of dredging and the cost and practicability of maintenance of the channel. In order to secure a minimum first cost, it is, of course, desirable to follow mainly the natural channels, where the depth of water is greatest. Fortunately a route following these natural channels will also be the most easily maintained, because the same natural influences which have directed the current along these natural routes, thereby scouring and lowering the bed of the bay, will continue to operate, after the channel is dredged, to prevent its silting up. In order to determine accurately where the deepest water is, a large number of soundings were taken. The limits of these soundings are shown on the accompanying maps. The total length of the lines sounded amounts to 183.7 miles and 222 principal stations were located instrumentally along the route. In order to do this work, the motor boat was run over a total distance of 397 miles, while on the work, and if to this we add 369 miles, traversed in going to and returning from the work, we find the total distance traveled 766 miles. The total number of soundings is 10,120, all of which were recorded, entered up on the detailed sheets and utilized in selecting the route and determining the amount of material to be dredged. All of these soundings were corrected to mean low water. The maps show the distances measured continuously beginning at Cape May and ending at Bay Head. The south shore of Great Bay, at the mouth of Cabbage Thoro, is 65¾ miles from Cape May, and the description of the route which follows refers to these distances. After careful consideration and consultation with Professor Haupt, it was decided that the route should follow Cabbage Thoro, rather than Great Thoro. Although the depth through Great Thoro is ample, Great Bay is shoal near the mouth of that Thoro, so that the aggregate amount of dredging to be done on the route through Cabbage Thoro is less than by Great Thoro, while the route is shorter by 2¾ miles. From the mouth of Cabbage Thoro the route runs northwesterly to clear the shoals which lie inside of the northerly point of Island Beach. The route thence turns northeasterly in the Shooting Thoro, which is followed easterly to the main channel of Little Egg Harbor. It then turns northeasterly through this channel to a point off the northerly end of Tucker's Island. From this point there are two possible routes northerly to a point off Holgate or Bonds. There is more than 10 feet of water over either of these routes. The westerly channel is the wider and in certain winds is better for sailing vessels, but the easterly route is wider and deeper than the channel called for in the act, and being more direct, it has been adopted as the course of the proposed channel. From Holgate to Beach Haven we follow the inner line of the beach quite closely, but off Beach Haven the channel turns and crosses the bay to just off Long Point; thence following the westerly shore of the bay to Mud Cove, it turns easterly to a point just north of Reed's Island, where a straight cut is made across the bar into the channel at the Cedar Bonnets. Over this part of the route the dredging is comparatively light except over the first mile from the mouth of Cabbage Thoro, where a 10-foot channel requires about 53,000 cubic yards of dredging, and another point just north of Reed's Island, in the eighty-second mile, where the 10-foot channel would require the removal of about 27,000 yards. Excepting these two cuts, the total amount of dredging for a 10-foot channel amounts to only 32,000 yards in 16 miles.

The next section of the route extends from the eighty-second mile to Barnegat Pier, a distance of 22 miles. It continues through the channel on the Cedar Bonnets and the drawbridge of the Long Beach railroad, northerly across the shoals off Surf City, known as the Bulkheads, following the beach rather closely to Lovelady Island, from which point it turns northwesterly, crossing to a point about three-fourths of a mile off Waretown Landing. Thence it follows the westerly side of the bay gradually approaching the west shore, being about one-half mile off shore at Cedar Point and not more than one-eighth of a mile from the west shore at Barnegat Pier. The yardage to be dredged in this section is more than five and one-half times the amount in the first section. The total is 621,815 cubic yards for the channel 10 feet deep, of which 216,000 lies between the end of the eighty-second and the end of the eighty-sixth mile, being through the Cedar Bonnets channel and across the "Bulk Heads." There is another considerable cut across the shoal from the ninety-one mile mark to the ninety-five mile mark, being principally in the ninety-second and ninety-third mile. Over the remainder of the section the work is light, amounting to only about 35,000 cubic yards in all for the 10-foot channel.

The third section extends from the Pennsylvania railroad drawbridge at Barnegat Pier to the railway bridge at Bay Head. From Barnegat Pier to Mantoloking it follows the western shore of the bay at a distance of from one-fourth to one-half of a mile. From Mantoloking bridge to Bay Head the route follows the channel between Herring Island and the beach, which is much more direct than the deeper channel to the west of Herring Island. The saving in length compensates for some increase in depth of dredging, so that the amount of work to be done is no greater than by the indirect westerly route. At Bay Head the route terminates near the railroad bridge, where it connects with the proposed waterway from Manasquan Inlet to Bay Head, for which surveys and estimates were made by direction of an act of the Legislature in 1903.[1]

Over this section the dredging is heavy and almost continuous, as will be seen from the profile and the estimate of quantities.

[1] Annual Report of the State Geologist, 1903.

AMOUNT OF DREDGING.

For Channel 8 Feet Deep.

Bottom width 50 feet, side slopes 1 on 3.

Locality.	*Miles from Cape May.*	*Length of cut—feet.*	*Average depth of cut—feet.*	*No. of cubic yards.*
Great Bay	65.8 to 66.6	4,500	3.0	29,205
Long Point	75.9	150	.8	553
" "	76.8	480	.7	690
Dinner Point	78.6	600	.8	934
Mud Cove	80.4	600	2.0	3,756
Reed's Island	80.9 to 81.2	1,025	1.3	2,644
" "	81.4 to 81.6	780	5.8	11,146
" "	81.7	280	.5	276
" "	81.9 to 82.1	760	.6	868
Great Bay to Cedar Bonnets,	65.8 to 82.1	9,195		50,072
Cedar Bonnets	82.2 to 82.6	2,130	4.2	20,378
" "	82.6 to 83.2	3,000	2.2	13,705
" "	83.3 to 83.8	2,260	3.2	16,673
" "	83.9	700	.5	434
Bulk Heads	84.3 to 85.9	8,550	4.9	98,810
" "	86.0 to 86.2	780	1.5	2,409
Harvey Cedars	86.5 to 86.6	650	.9	1,116
" "	87.0	300		66
Lovelady Island	88.9	650	.5	589
" "	90.7	360	.6	431
" "	90.8	450	1.6	1,459
" "	91.2	450	.6	580
" "	91.6 to 92.7	6,150	2.3	29,284
" "	92.7 to 93.6	4,800	0.2	3,162
" "	93.6 to 94.8	5,400	1.1	12,286
Cedar Creek to Barnegat Pier	99.9 to 104.0	21,900	1.7	76,460
Cedar Bonnets to Barnegat Pier	82.1 to 104.1	58,230		277,842
Sea Side Park	104.2 to 106	9,600	3.0	62,379
Toms River	106.1 to 107.3	6,750	2.4	33,948
" "	107.6 to 109.6	10,890	2.4	56,608
Mosquito Cove	109.8	180	1.1	622
Kettle Creek to Mantoloking,	110 to 115.1	26,500	2.7	152,336
" " " "	115.1	600	0.9	1,100
Bay Head	115.2 to 116.6	7,200	4.6	78,243
Barnegat Pier to Bay Head,	104.1 to 116.6	61,720		385,236
Great Bay to Bay Head	65.8 to 116.6	129,145		713,150

For Channel 10 Feet Deep.

Bottom Width 50 feet, side slopes 1 on 3.

Locality.	Miles from Cape May.	Length of cut—feet.	Average depth of cut—feet.	No. of cubic yards.
Great Bay	65.8 to 66.6	4,800	5.0	53,731
" "	68.7	100	0.3	560
" "	70.9	300	1.2	714
Long Point	75.9	375	1.2	895
" "	76.8 to 77.0	1,100	1.8	3,985
Dinner Point	78.4	650	.6	761
" "	78.7	1,400	1.7	5,010
" "	80.3 to 80.5	1,200	3.5	9,353
" "	80.5 to 80.7	750	.9	1,244
Reed's Island	80.9 to 81.6	3,750	3.2	26,941
" "	81.7	200	1.0	486
" "	81.8	450	2.2	2,147
Cedar Bonnets	81.8 to 82.1	1,660	2.1	7,033
Great Bay to Cedar Bonnets,	65.8 to 82.1	16,730		112,360
Cedar Bonnets	82.2 to 83.2	5,850	4.5	63,722
" "	83.2 to 83.8	2,700	4.8	31,036
" "	83.8 to 84.0	825	2.2	3,762
Bulk Heads	84.2 to 86.2	10,600	6.1	162,494
" "	86.4 to 86.7	1,350	2.0	5,605
" "	86.8 to 87.2	1,700	1.2	4,380
Lovelady Island	88.9	600	2.1	2,498
" "	89.9 to 90.5	2,700	1.1	6,138
" "	90.6 to 90.9	1,800	2.4	9,260
" "	91.0 to 91.2	975	2.1	4,124
" "	91.2 to 92.7	7,800	4.7	87,720
" "	92.7 to 93.6	4,800	1.3	11,948
" "	93.6 to 95.3	8,700	2.0	36,124
Forked River	96.4	900	.6	1,038
" "	97.4	475	.4	339
" "	97.8 to 98.1	1,410	.4	1,025
" "	99.4	150	.2	56
Cedar Creek to Barnegat Pier	99.5 to 104.1	24,000	3.6	190,546
Cedar Bonnets to Barnegat Pier	82.2 to 104.1	77,345		621,815
Barnegat Pier	104.1	150	.4	114
Toms River	104.2 to 107.3	16,800	4.7	186,816
" "	107.6 to 109.9	12,100	4.1	115,204
Mosquito Cove	109.9 to 115.1	27,500	4.6	296,891
" "	115.1 to 116.6	8,050	6.2	128,000
Barnegat Pier to Bay Head,	104.1 to 116.6	64,600		727,025
Great Bay to Bay Head	65.8 to 116.6	158,675		1,461,200

The foregoing table shows the length of each cut, the total length of cut in each section, the total number of cubic yards in each cut and the total number of yards in each section.

The depth is indicated by the following tables:

Great Bay to Cedar Bonnets	16.3 miles.
Less than 6 ft. deep	0.53 "
Less than 8 ft. deep	1.10 "
Less than 10 ft. deep	2.36 "

The shoals in Great Bay have only a depth at mean low tide of 3.5 feet. These shoals extend about one mile from the mouth of Cabbage Thoro, and after they are passed the depth is nowhere less than 9 feet until shoals are reached near Long Point at about the seventy-sixth mile, where the depth is 8 feet. This is the least depth encountered until at about 80.5 miles a shoal is passed with only 6 feet of water at mean low tide. In the eighty-second mile, just north of Reed's Island, there is a shoal having only 2.8 feet of water, but this extends about 200 yards, dropping off suddenly on either side to 8 or 10 feet. There is at this point a sharp turn in the natural channel, and the actual navigable depth following the natural channel is 4.6 feet.

Cedar Bonnets to Barnegat Pier	22.0 miles.
Less than 6 ft. deep	2.70 "
Less than 8 ft. deep	8.10 "
Less than 10 ft. deep	12.65 "

The least depth in this section is at the Cedar Bonnets, near the drawbridge of the Long Beach railroad and at the Bulkheads off Surf City. Through this section, from the eighty-second to the eighty-sixth mile, there are three points where the depth does not exceed 18 inches at mean low tide along the adopted route, although by following a tortuous channel, a navigable depth of about 2½ feet may be had. This is the place where the tides from Barnegat Inlet and from Little Egg Inlet meet, and is the shoalest part of the entire route from Great Bay nearly to Bay Head. After passing the Bulkheads, there is a navigable depth of 8 feet nearly to the one hundredth mile, near Cedar Creek, and the depth is nowhere less than 5 feet to Barnegat Pier.

Barnegat Pier to Bay Head	12.5 miles.
Less than 6 ft. deep	1.92 "
Less than 8 ft. deep	11.25 "
Less than 10 ft. deep	12.10 "

In this section the navigable depth is 4.5 feet from Barnegat Pier to Mantoloking, and between Mantoloking and Bay Head it shoals up to less than 3 feet.

NATURE OF MATERIAL.

The material to be dredged consists mainly of mud or silt, but there is some sand. The sand for the most part, however, appears to consist of a rather thin layer overlying the mud. The material is such as may be readily removed by the use of a suction dredge. There may be a few crusts of the cemented sand rock or conglomerate which prevails through southern New Jersey, but so far as could be ascertained, the amount of this is trifling and not sufficient to have any appreciable effect upon the cost of the work.

UNIT PRICES FOR DREDGING.

The fixing of the unit prices for the estimate of the cost of dredging, while it may be based upon experience in other places, is in a large measure a matter of judgment. There are important factors, which will affect the cost of the work at the time when it is executed, which cannot at the present be foreseen. An important one is the availability of a plant adapted for the work. This seems so uncertain and the work, for reasons given later, is of such a nature that I have thought best to include the cost of a suitable plant in the estimate. Another important element will be the cost of labor, which has varied through rather wide limits during the past five years. The disposal of the material dredged must be given due consideration, because over most of the distance from Great Bay to Bay Head the channel runs through open bays too far removed from the shore to permit the material to be pumped directly upon the meadow. It does not seem permissible to turn the material dredged back into the bay alongside the channel, because it would usually prove an obstruction to navigation by light draft boats which would not confine themselves entirely to the channel, and for the further reason that it might prove very detrimental to the oyster beds in the vicinity. In some cases it would be washed back into the dredged channel. For these reasons it may be found necessary to employ a type of dredge with bins for holding the dredgings, which may be pumped out of the bins onto the meadow at some convenient landing place. The necessity for this will materially increase the cost of the works. A dredge of the type proposed, which could be filled while steaming along the channel, would be but little embarrassed by the fact that the depth of dredging is not great. Having these various considerations in mind, I have estimated that the cost of dredging will range between 14 cents and 18 cents per cubic yard in the different sections.

DRAWBRIDGES.

There are but three drawbridges between Great Bay and Bay Head. The draw of the Long Beach railroad at the Cedar Bonnets is a single track swing bridge, with a total length of 100 feet and a clear channel opening on either side of about 40 feet. The depth of the water at mean low tide is 9.3 feet, consequently no injury can be done to the foundations by the proposed dredging, even for a 10-foot channel.

The Barnegat Pier drawbridge is a single track, through-truss, swing bridge, with a total length of 170 feet and two clear openings of 67 feet and 68 feet, respectively. The depth of water is 12.7 feet.

At Mantoloking there is a highway bridge which has a through-truss, swing draw, with a total length of 125.6 feet and two clear openings of 49 feet each. The depth of water is 6.2 feet. No difficulty will be found in securing a channel 8 feet deep and only slight protection will be needed even for 10 feet of depth.

It is not believed that it is necessary to add anything to the estimate of cost for changes of these drawbridges.

ESTIMATED COST OF IMPROVEMENT.

I estimate the cost of the proposed improvement between Great Bay and Bay Head, as follows:

Estimate for 8-foot Channel.

Section.	*Cu. Yds.*	*Price.*	*Cost.*
Great Bay to Cedar Bonnets...............	50,072	@ 18c.	$9,012 96
Cedar Bonnets to Barnegat Pier...........	277,842	@ 16c.	41,676 30
Barnegat Pier to Bay Head...............	385,236	@ 14c.	53,933 04
Contingencies, 10 per cent.			10,462 23
Engineering, inspection, &c............			10,000 00
Total, Great Bay to Bay Head..........			$125,084 53

Estimates for 10-foot Channel.

Section.	*Cu. Yds.*	*Price.*	*Cost.*
Great Bay to Cedar Bonnets...............	112,360	@ 18c.	$20,224 80
Cedar Bonnets to Barnegat Pier............	621,815	@ 16c.	99,490 40
Barnegat Pier to Bay Head...............	727,025	@ 14c.	101,783 50
Contingencies, 10 per cent.			22,149 87
Engineering, inspection, &c.			20,000 00
Total, Great Bay to Bay Head..........			$263,648 57

SUMMARY OF ESTIMATES FROM CAPE MAY TO BAY HEAD.

For convenient reference I herewith summarize the results of the surveys and estimates from Cape May to Bay Head, making use of Professor Haupt's estimates in his report upon the section between Cape May and Great Bay.

I. CAPE MAY TO BAY HEAD.

Bottom width of channels 50 feet—Side slopes 1 on 3—Under-cut one foot.

For 8-foot Channel.

Section.	*Length miles.*	*Cubic yards.*	*Price per cu. yd.*	*Cost.*
Cape May-Cold Spring...........	1.3	A		A
Cold Spring-Hereford Inlet.......	10.6	168,764	10c.	$16,876 40
Hereford-Townsend's Inlet........	10.0	81,030	10c.	8,103 00
Townsend's-Great Egg Inlet.......	18.0	639,166	9c.	57,524 94
Great Egg-Absecon Inlet..........	14.6	27,067	12c.	3,248 04
Absecon Inlet-Great Bay.........	11.3	409,126	10c.	40,912 60
Great Bay-Cedar Bonnets.........	16.3	50,072	18c.	9,012 96
Cedar Bonnets-Barnegat Pier......	22.0	277,842	16c.	41,676 30
Barnegat Pier-Bay Head.........	12.5	385,236	14c.	53,933 04
	116.6	2,038,303		$231,287 28
Auxiliary works				15,000 00
Contingencies				23,128 72
Engineering, supervision, &c.				20,000 00
Total for 8-foot channel............				$289,416 00

For 10-foot Channel.

Section.	Length miles.	Cubic yards.	Price per cu. yd.	Cost.
Cape May-Cold Spring	1.3	A		A
Cold Spring-Hereford Inlet	10.6	308,786	10c.	$30,878 60
Hereford-Townsend's Inlet	10.0	166,550	10c.	16,655 50
Townsend's-Great Egg Inlet	18.0	982,970	9c.	88,467 30
Great Egg-Absecon Inlet	14.6	71,856	12c.	8,622 72
Absecon-Great Bay	11.3	597,942	10c.	53,814 78
Great Bay-Cedar Bonnets	16.3	112,360	18c.	20,224 80
Cedar Bonnets-Barnegat Pier	22.0	621,815	16c.	99,490 40
Barnegat Pier-Bay Head	12.5	727,025	14c.	101,783 50
	116.6	3,589,304		$419,937 60
Auxiliary works				20,000 00
Contingencies				41,993 67
Engineering, supervision, &c.				32,000 00
Total for 10-foot channel				$513,931.27

A This section is provided for by the improvement of Cold Spring Harbor, now in progress.

II. LENGTH OF DREDGING.

Eight-foot Channel, with one foot under-cutting allowed.

	Feet.	Miles.
Cape May to Great Bay	118,830	22.50
Great Bay to Bay Head	129,145	24.46
Total	247,975	46.96

Ten-foot Channel, with one foot under-cutting allowed.

	Feet.	Miles.
Cape May to Great Bay	148,965	28.02
Great Bay to Bay Head	158,675	30.05
Total	307,640	58.07

III. PRESENT DEPTH OF WATER AT MEAN LOW TIDE ALONG PROPOSED ROUTE.

Section.	Total length. Miles.	Less than 6 ft. deep. Miles.	Less than 8 ft. deep. Miles.	Less than 10 ft. deep. Miles.
Cape May to Hereford Inlet	11.9	2.61	4.63	5.70
Hereford to Townsend Inlet	10.0	1.55	1.92	2.72
Townsend to Great Egg Inlet	18.0	6.20	9.05	10.65
Great Egg to Absecon Inlet	14.6	0.35	0.77	1.08
Absecon Inlet to Great Bay	11.3	4.83	5.45	6.50
Cape May to Great Bay	65.8	15.54	21.82	26.65
Great Bay to Cedar Bonnets	16.3	.53	1.10	2.36
Cedar Bonnets to Barnegat Pier	22.0	2.70	8.10	12.65
Barnegat Pier to Bay Head	12.5	1.92	11.25	12.10
Great Bay to Bay Head	50.8	5.15	20.45	27.11
Cape May to Bay Head	116.6	20.69	42.27	53.76

	Percentage of total distance.		
	Less than 6 ft. deep.	*Less than 8 ft. deep.*	*Less than 10 ft. deep.*
Cape May to Great Bay	23.6	33.2	40.5
Great Bay to Bay Head	10.1	40.0	53.4
Cape May to Bay Head	17.8	36.3	46.1

The first table shows that the total cost of the proposed inland waterway is, for a channel 8 feet deep, $289,416, and for a channel 10 feet deep, $513,931.27. The total number of cubic yards to be dredged is, for a channel 8 feet deep, 2,038,303 cubic yards, and for a channel 10 feet deep, 3,589,304. For the 8-foot channel the dredging extends over 46.96 miles out of a total distance of 116.6 miles, while for a channel 10 feet deep, the dredging will extend over 58.07 miles. Because of the undercutting of one foot, which has been allowed in order to secure the prescribed depth and allow for some irregularity in dredging, as well as for some slight silting up of the channel, the total length of dredging is greater than the total distance in which the natural channels are less than 8 feet deep or less than 10 feet deep.

Reference to the third table of the series shows that these natural channels are less than 6 feet deep for 20.69 miles, or 17.8 per cent. of the entire distance, and less than 8 feet deep a distance of 42.27 miles, being 36.3 per cent. of the entire distance, while they are less than 10 feet deep 53.76 miles, or 46.1 per cent. of the entire distance. In places the depth at present, at mean low tide, does not exceed 18 inches.

The depth of water over the bar at the principal inlets at mean low tide is, according to the latest United States Coast Survey charts, as follows:

Cold Spring Inlet	Under improvement.
Hereford Inlet	8 feet.
Great Egg Inlet	10 feet.
Absecon Inlet	8 feet.
Little Egg Inlet	9 feet.
Barnegat Inlet	7 feet.

These depths are subject to constant change. The tide rises more than 4 feet over the bar, in each case giving a depth at high tide of from 11 to 14 feet.

When the depth of channel shall finally be determined upon, these depths over the inlet bars, connecting the proposed channel with the ocean, should be considered. Another point which is worthy of serious consideration is the fact that while the act provides for a bottom width of both channels of 50 feet, and detailed estimates have been made for that width only, an approximate estimate shows that the cost of a channel 8 feet deep and 100 feet wide at the bottom will be nearly the same as the cost of a channel 10 feet deep and 50 feet wide at the bottom. I am of the opinion that a channel 8 feet deep with a bottom width of 100 feet will be found much more useful than a channel 10 feet deep and 50 feet wide. The deeper and narrower channel will be more difficult to maintain, and it will also be difficult to navigate where it passes through the broad, open bays, such as Barnegat, Tuckerton and Great Bay. It would be very difficult for two vessels of sufficient draft to require a depth of 10 feet to pass each other in a channel only 50 feet wide, especially so in the open bays, when the seas are running high during a storm. The wider channel would also be much more useful to sailing craft.

Respectfully submitted,

C. C. VERMEULE,
Consulting Engineer.

October 31, 1907.

INLAND WATERWAY SURVEY.

Section from Great Bay to Cape May.

Report and Estimates

BY

LEWIS M. HAUPT, C. E.

From Cape May to Great Bay.

CONTENTS.

From Cape May to Great Bay the proposed channel would follow the winding thoroughfares which connect the shallow bays and inlets along this part of the coast.

PREVIOUS SURVEYS.

In 1887 an extensive survey of these channels was made by the War Department, and the results plotted on a scale of 200 feet per inch. Blue-prints of these maps were available for comparison and study in connection with the recent survey and facilitated greatly our field work, which consisted, in large part, of the revision of the survey of 1887, and its verification to determine any changes in depth which might have occurred.

The earlier survey showed that a 6-foot channel, 50 feet wide at the bottom, would require the dredging of about 20 miles, involving the removal of 1,310,000 cubic yards, scow measurement. Of this amount about 430,000 cubic yards are north of Atlantic City. These calculations are all estimated on a 7-foot depth, or an undercut of 1 foot, and side slopes of 1 foot vertical to 3 horizontal, and the quantity is reduced to scow measurement by adding 20 per cent. to place measurement.

The estimated cost was supposed, by Lieutenant-Colonel Henry M. Robert, the engineer in charge, to be 15.3 cents per yard by contract, and about 10 cents per yard by the government, including the plant, although the report of the assistant engineer placed the cost of "all material which can be banked by the dredge with a single handling at 15 cents per cubic yard, and for all material which requires to be dredged and removed by scows at 20 cents" (page 733). He adds: "Upon this basis the cost of the several plans would be as follows:

Four-foot channel, 50 feet wide	$120,000
" " 75 " "	195,000
" " 100 " "	270,000
Six-foot channel, 50 feet wide	217,000
" " 75 " "	350,000
" " 100 " "	500,000

"If Atlantic City be made the northern terminus, the cost would be reduced about one-third, as the northern 4 miles of the route passing through Grassy and Little bays is continuously shoal water less than 1 foot deep."*

As a result of these surveys, the engineers of the War Department reported that in their opinion the channels were not worthy of improvement by the United States government.

METHODS OF OUR WORK.

The estimates of cost depend for their accuracy upon—*first,* the number and accuracy of the soundings from which the amount of material to be moved can be computed; and *second,* upon the unit prices adopted.

Quantity Determinations.—To secure the best results a motor boat was used and was propelled at the lowest, practicable speed, whether with or against the tide; frequent locations as to position were noted, and identified both by time intervals and landmarks; the stage of the tide was taken upon gauges at the inlets and divides and checked by water-marks on the borders of the channels, for it was noted that the simultaneous tidal observations made

* The quantities for each mile are tabulated on page 733 (1888).

upon gauges placed less than 1,000 feet apart showed differences of altitude varying from about 0.4 feet at high water to over 1.0 foot† at low.

The accuracy of the results was further assured by taking continuous depths along the axis of the channels, which were readily identified by the landmarks or stakes placed on either side, and in the shoal water using a graduated rod, instead of the lead-line. Thus the data collected in the field were checked by careful observations of the local stages of the water surface on objects in the immediate vicinity.

The frequency of the soundings varied with the depths from intervals of one minute in very deep water to a few seconds in the shoalest reaches, thus giving a much larger number of soundings than were recorded. The total number of soundings taken on the section from Cape May to Great Bay probably exceeded 5,000, and these were supplemented by those of the government survey of 1887.

Office Work.—These data, having been corrected for the various sources of errors and reduced to the datum of mean low water, were entered upon the general office charts of the Geological Survey, scale 3 miles to 1 inch, and a profile was also made on a vertical scale of 8 feet to 1 inch, and horizontal scale of 800 feet to 1 inch, or 6,400 square feet to each square inch. To provide for a clear channelway of 8 and 10 feet depths, an allowance or undercutting was made of 1 additional foot in each case, making the estimate depths 9 and 11 feet.

From these profiles the longitudinal area of each "cut" was determined by planimeter measurements, and the mean depths thus computed were taken as the basis for the contents of the sectional areas, in cubic yards per lineal foot, which, being multiplied by the length, gave the cubic contents per cut, or per mile, as stated in the accompanying tables and shown on the profiles.

In view of the increased depths of these estimates, as compared with that of 1887, it might seem at first sight as if the volume of material to be excavated is too small, but in this case the quantities are "place-measurement," whereas in the former they were "scow-measurement," which is 20 per cent. greater. Moreover, in the

† Survey of the Thoroughfare running back of the ocean from Cape May to the Great Bay north of Atlantic City, N. J.—Report of L. Y. Schermerhorn, Assist. Eng., from report of Chief of Engineers, U. S. A., 1888, Part 1, p. 733.

reach behind Brigantine Beach, which contained about one-third of the total excavation of 1887, a great saving and more permanent channel has been secured by a change of alignment, made necessary by the movements in Great Bay and "New Inlet." Thus the shoals of Grassy and Little bays are avoided and the cutting relatively reduced.

The standard cross section used was one having a base of 50 feet, with side slopes of 3 feet base to 1 of height, giving the following cubic contents for each foot of depth or fraction thereof:

Table for Volumes of Typical Cross Sections of Known Mean Depths.

Depth in feet.	Area in sq. ft.	Total area sq. ft.	Cubic yards per lin. ft.	Increments per unit.
1	53	53	1.96	2.19
2	59	112	4.15	2.41
3	65	177	6.56	2.63
4	71	248	9.19	2.85
5	77	325	12.04	3.07
6	83	408	15.11	3.30
7	89	497	18.41	3.52
8	95	592	21.93	3.74
9	101	693	25.67	3.96
10	107	800	29.63	

By the use of this table, after the mean depths were ascertained with the planimeter, the contents were readily computed and entered in the following statement:

In the quantitative estimate the cuts were numbered consecutively for identification, those of the 8-foot project being designated by an "m" and entered in the first column.

The average depth was determined by dividing the planimeter area of the cut by its proper base, and entered in the second column. The volume per foot of length corresponding to the mean depth was then computed from the above table and placed in column No. 3, followed by the length, and the product of these last two gave the total prism of excavation entered in two columns, one showing the total cut, the other the amount per mile. The section below Cold Spring Inlet is omitted from the estimates for the reason stated in the tables.

TABULAR STATEMENT OF EXCAVATION FOR EIGHT-FOOT CHANNEL.

Section No. 1.—(Poverty Beach), South of Cold Spring Inlet, Cape May.

Cut No.	Av. depth in feet.	Vol. per ft., cub. yds.	Length of cut in ft.	Vol. in cut, cub. yds.	Vol. per mile, cub. yds.	Miles.	Remarks.
1m	3.71	8.44	380	3,207	5,044	1	This section having been almost completed by private capital, to be supplemented by the Government work for a harbor, is not included in the totals of this estimate.
2m	1.60	3.28	560	1,837			
3m	1.66	3.41	500	1,705	4,401	2	
4m	1.76	3.62	800	2,696			
5m	5.56	13.76	4,040	54,580	54,580	3	
			6,280	64.025	64,025		

Section No. 2.—Cold Spring to Hereford Inlets (Two and Five-Mile Beaches).

Cut No.	Av. depth in feet.	Vol. per ft., cub. yds.	Length of cut in ft.	Vol. in cut, cub. yds.	Vol. per mile, cub. yds.	Miles.	Remarks.
6m	2.84	6.16	1,060	6,529	6,529	4	Lower Thoroughfare.
7m	2.00	4.15	240	1,000	34,264	5	Jarvis' Sound.
8m	3.69	8.40	3,960	33,264			
9m	2.90	6.32	3,730	23,573	23,573	6	Swan's Channel.
10m	5.16	12.55	3,050	38,277	38,277	7	Turtle Gut (cut off).
11m	3.19	7.10	2,800	19,880	19,880	8	Grassy Sound Channel.
12m	4.61	10.93	3,800	40,934	40,934	9	" " to Dead Thoro.
13m	2.54	5.45	830	4,523	4,523	10	" "
14m	1.00	1.96	400	784	784	11	
			19,870	168,764	168,764		To Hereford Inlet.

Section No. 3.—Hereford to Townsend's Inlets (Seven-Mile Beach).

Cut No.	Av. depth in feet.	Vol. per ft., in cub. yds.	Length in feet.	Vol. of cut, cub. yds.	Vol. per mile, cub. yds.	Miles.	Location.
15m	3.65	8.26	4,800	39,648	39,648	13, 14	Abreast Hereford Inlet.
16m	....	....	420	800	800	15	Great Channel.
17m	....	....	240	500	2,300	16	" "
18m	2.00	4.15	430	1,800			
19m	....	....	280	1,200	1,200	17	Great Sound or Leaming's Bay.
20m	3.31	7.40	2,860	21,464	21,464	18	" " " "
21m	3.02	6.60	2,230	14,718	14,718	19	" " " "
22m	....	....	250	900	900	21	Ingraham's Thoro.
			11,510	81,030	81,030		

EIGHT-FOOT ESTIMATE.

Section No. 4.—Townsend to Great Egg Inlets (Ludlam's and Peck's Beaches).

Cut No.	Av. depth in feet.	Vol. per ft. in cub. yds.	Length in feet.	Vol. of cut, cub. yds.	Vol. per mile, cub. yds.	Miles.	Location.
23m	2.65	5.72	700	4,004	4,004	23	Ludlam's Thorofare.
24m	2.56	5.50	600	3,300	3,300	24	" "
25m	6.60	17.09	2,530	43,237	43,237	25	" " Sea Isle City.
26m	4.65	11.04	660	7,286	7,286	26	Ludlam's Bay (cut off).
27m	5.46	13.47	3,900	130,929	52,533		" "
"	6.75	17.59	4,400		77,396	27	" "
28m	....	....	340	800	800	28	Main Channel.
29m	....	....	200	500	500	29	Ben Hand's Thoro.
30m	2.38	5.08	350	152,785	1,778		
"	2.55	5.48	5,280		28,934	30	Corson's Sound.
"	2.96	6.46	5,280		34,108	31	" "
"	6 47	16.66	5,280		87,965	32	"Turtle Grounds."
31m	4.80	11.47	4,520	91,870	51,644	33	"Crook Horn" Thoro.
"	5.51	13.59	2,960		40,226	34	Beasley's Point and Ocean City bridge.
32m	2.03	4.27	1,040	24,042	4,441		
"	4.82	11.53	1,700		19,601	35	Peck's Bay.
33m	7.46	20.03	2,660	141,365	53,280		
"	8.10	22.30	3,950		88,085	36	Garrett's Thoro.
34m	3.41	7.62	600	4,572	4,572		
35m	....	....	700	1,500	22,084	37	" "
36m	3.03	6.64	3,100	20,584			
37m	4.69	11.16	1,200	18,392	13,392	38	Beach Thoro, Ocean City.
			51,950	639,166	639,166		

Section No. 5.—Great Egg to Absecon Inlets.

Cut No.	Av. depth in feet.	Vol. per ft. in cub. yds.	Length in feet.	Vol. in cut, cub. yds.	Vol. per mile, cub. yds.	Miles.	Location.
38m	.76	1.46	1,180	1,722	1,722	41	Ocean City to Middle Ground Inlet.
39m	1.46	2.97	700	2,079	2,079	43	Risley's Channel.
40m	....	....	140	500	500	44	Beach Thoro.
41m	4.09	9.47	360	3,409	3,409	45	" "
42m	1 14	2.27	900	2,043	2,043	46	" "
43m	3.50	7.87	2,200	17,314	17,314	52	" "
			5,480	27,067	27,067		

EIGHT-FOOT ESTIMATE.

Section No. 6.—Absecon Inlet to Great Bay (Brigantine Beach). Line A.[1]

Cut No.	Av. depth in feet.	Vol. per ft., cub. yds.	Length in feet.	Vol. per cut, cub. yds.	Subline	Vol. per mile, cub. yds.	Miles.	Location.
44m	3.27	7.27	1,160	8,433		19,953	56	Golden Thoro.
45m	3.24	7.20	1,600	8,220				
				3,300				
46m	3.76	8.56	2,520	21,571	Subline "A" 148,321	21,571	58	Eagle Bay.
47m	5.23	12.75	5,800	120,950		73,950	59	Wading Thoro.
"	4.28	10.00	4,700			47,000	60	Somers' Bay.
48m	....	....	520	2,500		2,500	61	" " and Hoffman's Cr.
49m	8.11	22.31	3,600	80,316	Subline "A" 244,152	80,316	63	Mud Thoro (cut off).
50m	4.03	9.28	4,640	43,059		43,059	64	" "
51m	....	....	200	600		600	65	Cabbage Thor.
52m	5.45	13.42	1,280	120,177		17,177		
"	9.02	25.75	4,000			103,000	65¾	To Great Bay.
			30,020	409,126		409,126	....	

[1] This is the line shown on the maps as printed.

Section 6, Line B.[2]

Cut No.	Av. depth in feet.	Vol. per ft., cub. yds.	Length in feet.	Vol. in cut, cub. yds.	Vol. per mile, cub. yds.	Miles.	Location.
1d	3.84	8.77	2,880	25,258	25,258	57b	Peters' Beach Thoro.
2d	3.57	8.06	1,040		8,382		
"	5.67	14.10	5,280		74,448	58b	Sand Thoro.
"	6.35	16.26	5,280	226,294	85,853	59b	Quarter's Thoro.
"	4.26	9.93	5,280		52,450	60b	Steelman's Bay.
"	3.39	7.59	680		5,161		
3d	1.46	2.97	740	2,198	2,198	61b	Weakfish Thoro.
4d	1.44	2.94	640	1,881	1,881		
			21,820	255,631	255,631		

[2] Line shown on original maps, not on published sheets.

Section 6, Line C,[3] via Brigantine Inlet, and Crossing Line "A" to Great Thoro and Bay.

Cut No.	Av. depth in feet.	Vol. per ft., cub. yds.	Length in feet.	Vol. in cut, cub. yds.	Vol. per mile, cub. yds.	Miles.	Location.
1f	1.12	2.22	800	1,776	2,757	64c	Brig'e Inlet and Little Simkins' Thoro.
2f	2.31	2.71	360	975			
3f	....	....	350	600	600	65c	Little Crooked Thoro.
4f	....	....	300	400	3,575	66c	" " "
5f	2.63	5.67	560	3,175			
6f	1.90	3.93	2,780	27,360	10,925	67c	Great Thoro.
"	2.92	6.37	2,580		16,435	68c	" " to Great Bay.
	Tot'ls	....	7,730	34,286	34,286		

[3] Line shown on original maps, not on published sheets.

TABULAR STATEMENT OF EXCAVATION FOR TEN-FOOT CHANNEL.

Section No. 1—(Poverty Beach).

Cut No.	Av. depth in feet.	Vol. per ft., cub. yds.	Length in feet.	Vol. in cut, cub. yds.	Vol. per mile, cub. yds.	Miles.	Remarks.
1	5.50	13.50	400	5,400	9,950	1	Cuts Nos. 1 and 2 are outside of dredged basin. This section is being enlarged and deepened by private capital, supplemented by Government appropriations, and is therefore omitted from the total in this estimate.
2	3.16	7.00	650	4,550			
3	4.75	11.30	600	6,780	13,120	2	
4	2.91	6.34	1,000	6,340			
5	7.00	17.25	4,200	77,280	77,280	3	In U. S. Harbor work at entrance.
			6,800	100,350	100,350		

Cold Spring to Hereford Inlets—Section No. 2—(Two and Five-Mile Beaches).

Cut No.	Av. depth in feet.	Vol. per ft., cub. yds.	Length in feet.	Vol. in cut, cub. yds.	Vol. per mile, cub. yds.	Miles.	Location.
6	3.80	8.67	1,300	11,270	15,040	4	Lower Thorofare.
6a	1.60	3.30	500	1,650			
7	2.50	5.30	400	2,120			
8	5.53	13.60	4,200	57,120	57,120	5	Jarvis' Sound.
9	4.30	10.00	4,800	48,000	48,000	6	Swan's Channel.
10	7.14	19.00	3,200	60,800	60,800	7	Turtle Gut (cut off).
11	4.96	12.00	3,600	43,200	43,200	8	Grassy Sound Channel.
12	5.30	12.90	5,540	71,466	71,466	9	" " to Dead Thoro.
13	4.10	9.40	1,400	13,160	13,160	10, 11	" "
			24,940	308,786	308,786		

Hereford to Townsend's Inlets (Seven-Mile Beach)—Section No. 3.

Cut No.	Av. depth in feet.	Vol. per ft., cub. yds.	Length in feet.	Vol. in cut, cub. yds.	Vol. per mile, cub. yds.	Miles.	Location.
14	5.50	13.50	5,300	71,550	71,550	13	Hereford Inlet.
15	2.66	5.60	760	4,256	4,256	15	Great Channel.
15a	....	....	700	3,000	14,200	16	" "
16	3.01	6.60	1,700	11,200			
17	4.27	9.90	4,500	44,550	44,550	18	Great Sound or Leaming's Bay.
18	4.80	11.44	2,600	29,744	29,744	19	" " " "
19	3.40	7.50	300	2,250	2,250	21	Ingraham's Thoro to Leaming.
			15,860	166,550	166,550		

TEN-FOOT CHANNEL.

Townsend's to Great Egg Inlets (Ludlam's and Peck's Beaches)—Section No. 4.

Cut No.	Av. depth in feet.	Vol. per ft., cub. yds.	Length in feet.	Vol. in cut, cub. yds.	Vol. per mile, cub. yds.	Miles.	Location.
20	2.43	5.30	1,840	9,752	9,752	23	Ludlam's Thoro.
21	....	....	2,030	10,300	10,300	24	" "
22	7.30	19.50	3,100	60,450	60,450	25	" " Sea Isle City.
23	6.77	17.60	4,960	87,296	87,296	26	Ludlam's Bay (cut off).
23	9.10	26.07	4,400	114,708	114,708	27	" "
24	2.35	5.00	600	3,000	3,000	28	Main Channel.
25	....	....	420	1,800	1,800	29	Ben Hand's Thoro.
26	2.87	6.25	1,400	....	8,750		" " "
26	4.58	10.90	5,080	244,384	55,372	30	Corson's Sound.
26	4.79	11.47	5,280		60,562	31	Corson's Sound, abreast of Inlet.
26	8.21	22.67	5,280	....	119,700	32	"Turtle Grounds."
27	6.20	15.77	5,200	144,434	82,000	33	"Crook Horn" Thoro.
27	6.40	16.43	3,800		62,434	34	
28	3.31	7.38	1,200	42,302	8,856		
28	7.11	18.79	1,780		33,446	35	Beasley's Pt. and Ocean City Bridge.
29	7.03	18.50	3,725	185,948	68,912		Peck's Bay.
29	10.00	29.63	3,950		117,036	36	
30	3.84	8.77	1,200	10,724	10,724		Garrett's Thoro.
31	2.50	4.35	1,030	4,480	45,472	37	" "
32	5.05	12.20	3,360	40,992			
33	6.26	16.00	1,400	22,400	22,400	38	Beach " Ocean City.
			61,005	982,970	982,970		

Great Egg to Absecon Inlets—Section No 5.

Cut No.	Av. depth in feet.	Vol. per ft., cub. yds.	Length in feet.	Vol. in cut, cub. yds.	Vol. per mile, cub. yds.	Miles.	Remarks—Location.
34	2.10	4.20	220	924	924	39	Ocean City.
35	2.01	4.17	2,000	8,340	8,340	41	Middle Ground in Inlet.
36	2.40	5.11	1,200	6,132	6,132	43	Risley's Channel.
37	2.18	4.63	350	1,620	2,620	44	Beach Thoro.
38	....	....	240	1,000			
39	....	....	400	500	6,150	45	" "
40	4.74	11.30	500	5,650			
41	1.37	2.77	750	2,077	10,933	46	" "
42	3.31	7.38	1,200	8,856			
43	....	....	240	1,000	2,800	50	Inside Thoro.
44	....	....	200	300			
45	....	....	400	1,500			
46	....	....	200	300	1,900	51	Beach Thoro.
47	....	....	300	600			
48	....	....	200	1,000			
49	4.80	11.47	2,760	31,657	32,057	52	" "
50	....	....	260	400			
			11,420	71,856	71,856		

TEN-FOOT CHANNEL.

Section No. 6.—Absecon Inlet to Great Bay (Brigantine Beach). Line A (Shown on Map).

Cut No.	Av. depth in feet.	Vol. per ft., cub. yds.	Length in feet.	Vol. in cut, cub. yds.		Vol. per mile, cub. yds.	Miles.	Remarks—Location.
51	5.10	12.85	1,300	16,055				
52	4.38	10.27	2,000	14,890		36.595	56	Golden Thoro.
				5,650				
53	1.66	3.41	1,000	3,410		3,410	57	" "
54	4.05	9.33	4,740	44,224	Subline "A" 244,190 c. y.	44,224	58	Eagle Bay.
55	7.49	20.13	5,620	183,766		110,638	59	Wading Thoro.
55	5.58	13.85	5,280	....		73,128	60	Somers' Bay.
56	2.26	4.76	1,500	7,140		7,140	61	" " and Hoffman's Cr.
57	9.67	28.32	3,880	109,882		109,882	63	Mud Thoro (cut off).
58	5.43	13.36	4,860	64,930	Subline "A" 822,807	64,930	64	" "
58a	2.56	5.40	300	1,620		1,620	65	Cabbage Thoro.
59	7.77	21.12	1,300	146,375		27,456		" "
59	10.10	30.03	3,960			118,919	65¾	To Great Bay.
			35,740	597,942		597,942		

Line B[1] from Golden Thoro to Brigantine Thoro.

Cut No.	Av. depth in feet.	Vol. per ft., cub. yds.	Length in feet.	Vol. in cut, cub. yds.	Vol. per mile, cub. yds.	Miles.	Location.
1b	5.64	14.00	3,200	44,800	44,800	57b	Peter's Beach Thoro.
2b	4.91	11.78	1,120		13,194		
"	7.56	20.38	5,280		107,606	58b	Sand Thoro.
"	8.31	23.09	5,280	334,866	121,915	59b	Quarter's Thoro.
"	6.26	15.97	5,280		84,321	60b	Steelman's Bay.
"	4.44	10.44	750		7,830		
3b	2.94	6.42	1,000	6,420	6,420	61b	Weakfish Thoro.
4b	3.20	7.06	720	5,098	5,098		Connects with Line "A" in Brig. Thoro.
			22,630	391,184	391,184		

[1] Line shown on original sheets, not on published maps.

Line C[2] via Brigantine Inlet, and Crossing Line "A" to Great Thoro and Bay.

Cut No.	Av. depth in feet.	Vol. per ft., cub. yds.	Length in feet.	Vol. in cut, cub. yds.	Vol. per mile, cub. yds.	Miles.	Location.
1c	2.60	5.60	1,050	5,880	5,880	64c	Brig'e Inlet and Little Simkins' Thoro.
2c	1.33	2.68	1,760	4,717	4,717		
3c	1.54	3.14	500	1,570	1,570	65c	Little Crooked Thoro.
4c	2.37	5.04	540	2,722	2,722		
5c	....	....	450	2,300	2,300	66c	" " "
6c	2.48	5.23	2,780		14,539		
"	2.63	5.67	5,280	76,171	29,938	67c	Great Thoro.
"	5.05	12.19	2,600		31,694	68c	" " to Great Bay, two miles W. of Cabbage Thoro.
			14,960	93,360	93,360		

[2] Line shown on original maps, not on those published.

Summary of Quantities.

Number.	EIGHT-FOOT CHANNEL. Length, feet.	EIGHT-FOOT CHANNEL. Volume, cub. yds.	Location.	TEN-FOOT CHANNEL. Length, feet.	TEN-FOOT CHANNEL. Volume, cub. yds.	TEN-FOOT CHANNEL. Miles.
1	6,280	64,025	Poverty Beach	6,800	100,350	2.5
(Omitted as being under U. S. and private jurisdiction.)						
2	19,870	168,764	Two and Five-Mile Beaches. Hereford Inlet.	24,940	308,786	9.5
3	11,510	81,030	Seven-Mile Beach. Townsend's Inlet.	15,860	166,550	10.0
4	51,950	639,166	Ludlam's and Peck's Beaches. Great Egg Inlet.	61,005	982,970	18.5
5	5,480	27,067	Absecon Beach. Absecon Inlet.	11,420	71,856	14.0
6*	30,020	409,126	Brigantine and Island B'ch's.	35,740	597,942	11.25
Totals	118,830 22.5 mls.	1,325,153	To Great Bay	148,965 28.02 mls	2,128,104	65.75
6* "B"		516,436	via "A" and "B" lines.		744,936	
6* "C"		306,570	via "A," "B," "C" routes.		368,495	
Total via "B"		1,432,463	via Cabbage Thoro } to Great Bay.		2,275,098	
" " "C"		1,222,597	" Great " } to Great Bay.		1,898,657	

COMPARATIVE SECTIONS.

As the above reaches between the inlets are of variable lengths and differ largely in the amounts of excavation, a better basis of comparison may be obtained by reducing them to the volume per mile, as in the following table:

	Cu. yds. per mile for 8-ft. channel.		*Cu. yds. per mile for 10-ft. channel.*
Section 2....	17,440	Two and Five-Mile Beaches...	32,500
" 3....	8,100	Seven-Mile Beach	16,650
" 4....	34,500	Ludlam's and Peck's Beaches..	53,079
" 5....	2,000	Absecon Beach	5,132
" 6....	36,370	Brigantine and Island Beaches,	53,300

From this it appears that section 5 lying back of Absecon Beach has the least amount of dredging because of the extensive improvements made by riparian owners, while sections 4 and 6 have the greatest amount per mile, being almost wholly unimproved and more remote from the sea.

SELECTION OF ROUTE.

To avoid the shoal waters of Little and Grassy bays, section No. 6, where it would be difficult to maintain the channel, several routes were examined as designated on the maps and profiles.[1] In general, those which are nearest the beach are of greatest utility, but not always of the greatest depth, since the action of the flood tide, after passing within the inlet, is to deposit its burden of beach sand upon the expanded inner middle grounds, between which and the outer spit the ebb usually maintains a deep exit channel. This normal condition, however, no longer exists at Absecon Inlet, where the westerly end of Brigantine Beach has receded about three-fourths of a mile, and the deep channel formerly existing at Peters' Island has shoaled and changed materially, a portion of it having entirely closed.

Line "A," through Golden Thoro, Eagle Bay, Wading Thoro and Somers Bay to Brigantine Thoro, has 409,126 yards of exca-

[1] On the published maps only route A, which seems most advisable, is designated.—H. B. K.

vation, while Line "B," skirting the beach, has 516,436 yards, but the latter is about a half mile shorter, hence more direct. Line "C" has the least amount of dredging up to the shore of Great Bay, but its entrance is nearly two miles west of the other routes, and the waters of the bay are so shallow as to make it less desirable as a part of a through route. To avoid the constant changes taking place at Brigantine Inlet (portion of Line "C"), it is recommended that a "cut-off" be made from mile 62, through Mud Thoro, to Little Simkins Thoro, as included in the estimates on Line "A," thus securing a well-protected interior channel, which will be relatively permanent after its regimen becomes established. The cut should be slightly curved, not straight.

To save distance and avoid sharp bends, the alignment has been modified in a few cases by cutting through the meadows.

BRIDGES.

Aside from the shoals found in the waters adjacent to the coast, there are other obstructions to navigation due to highway, railroad and trolley bridges and causeways. Most of these are of comparatively recent origin, as the first railroad crossing the marshes was not opened prior to 1853, when Atlantic City was incorporated, and all the structures subsequently erected have been provided with drawbridges. The clearance under most of these is only from 2 to 5 feet at ordinary high water, and it may happen to be nothing with storm tides. The spans vary from 28 to 30 feet, and the causeways on piling constitute serious obstructions to the tidal movements, which increase as the piles decay and new ones are driven to maintain the tracks, thus increasing the rapidity of the shoaling. Therefore, if this water route is to be made available and to become an instrument in the development of the resources and revenues of this State, the co-operation of the transportation companies will be necessary in improving several of these bridges, which are of extremely antique design. The abandoned trolley line crossing from Oceanville to Brigantine contains many submerged piles and snags which are a menace to navigation, and which should be removed.

The following is a list of the various bridges crossing the marshes and channels connecting Cape May with Great Bay:

Character.	*Service.*
Highway	Rio Grande to Holly Beach and Wildwood.
Railway, W. J. & S.	Crossing Grassy Channel to Anglesea.
Highway	Ocean View to Sea Isle City (Ludlam's Thoro).
Railroad, P. & R.	Ocean View to Sea Isle City (Ludlam's Thoro).
P. & R. R. R. (1889)	Seaville to Corson's Inlet (Ben Hands Thoro).
" " (1896)	Ocean City branch (Crook's Horn Thoro).
Highway	Beasley's Point to Ocean City (Crook's Horn Thoro).
Trolley	Somer's Point to Ocean City (Great Egg Harbor).
Highway	Dorset Ave., Ventnor (Inside Thoro).
"	Albany Ave. at Chelsea (Inside Thoro).
"	Phila. to Atlantic City (Beach Thoro).
P. & R. R. R. (1890)	Phila. to Atlantic City (Beach Thoro), plate girder.
C. & A. (P. R. R.)	Phila. to Atlantic City (Beach Thoro).
Trolley "	Phila. to Atlantic City (Beach Thoro).
"	Oceanville to Brigantine—dilapidated and abandoned.

From the above it appears that there are 6 highway, 6 railroad and 3 trolley bridges, or 15 in all, and 4 of them are at Atlantic City, where drawbridges must always be a hindrance to navigation, owing to the heavy railroad traffic. But alterations in these bridges, however desirable in some instances for the improvement of the channel, were not mentioned in the act, and are not included in the estimates.

PERMANENCY OF CHANNEL.

While the act authorizing the survey and report makes no reference to the maintenance of the channel, it is desirable that some provision be made in the estimate for this purpose. To this end, the side slopes have been taken at 1 foot vertical to 3 horizontal, as being reasonably stable in the protected waterways through which the route passes. In the large sounds or bays where the currents are mainly due to winds from variable quarters, a small amount of annual dredging will suffice to keep the channels open to the full depth, if the dredgings are banked on the concave flank of the cut which should be curved and so located, where practicable, as to furnish cover from the northeast or the northwest winds.

At a few of the inlets, such as Turtle Gut, Hereford or Brigantine, whilst a sufficient depth may generally be found, the channel is prone to shift, and in rough weather the crossings may become dangerous with a heavy, beam sea. In these localities protection and permanence may be secured by a stockade jetty, so placed as to guide a portion of the ebb discharge from the main channel across the confluent spit to the secondary channel, and at the same time defend this cut from drift and wave action at moderate cost.

At Turtle Gut a jetty about 1,200 feet in length should suffice, while at Hereford Inlet it would require one of about 3,000 feet. If made of wooden piles these two works could be built at a cost of $29,400, and should stand for about seven years. If desired, this latter inlet may be avoided by an interior route, through Great Flat Thorofare, which would be half a mile shorter and be well protected.

ESTIMATES OF COST.

Unit Prices.—The unit price adopted is the most important factor in the preparation of the estimate, since slight variations in its amount greatly affect the sum total. It is affected by many variable conditions, physical, social and financial, but the best criterion is the price paid for similar work in the same locality. Fortunately this is readily ascertained from the extensive works of back filling by pumping along the coast, and it may confidently be taken at from 10 to 12 cents per cubic yard in place. Yet even this variation of 2 cents in a factor which is purely a matter of judgment represents a difference of 20 per cent. in the total cost, and is believed to be much greater than any possible error of quantity as determined from the surveys. In large quantities, work of this class has been done for less than 7 cents per yard.

From the foregoing facts and figures giving quantities and the above unit prices, there results the following estimate of costs:

FOR AN 8-FOOT CHANNEL 50 FEET WIDE AT BOTTOM WITH SIDE SLOPES OF 1 ON 3.

	Dredging.			*Cost.*
Section 2.	168,764 cu. yds.	@ 10 cents	=	$16,876 40
" 3.	81,030 " "	@ 10 "	=	8,103 00
" 4.	639,166 " "	@ 9 "	=	57,524 94
" 5.	27,067 " "	@ 12 "	=	3,248 04
" 6.	409,126 " "	@ 10 "	=	40,912 60
	1,325,153 " "			$126,664 98
Contingencies, 10 per cent.				12,666 49
Engineering, supervision, inspections				10,000 00
Auxiliary works, jetties and revetments				15,000 00
				$164,331 47

5

FOR A 10-FOOT CHANNEL OF SIMILAR WIDTH AND SLOPES.

		Dredging.							*Cost.*
Section	2.	308,786	cu.	yds.	@	10	cents	=	$30,878 60
"	3.	166,550	"	"	@	10	"	=	16,655 50
"	4.	982,970	"	"	@	9	"	=	88,467 30
"	5.	71,856	"	"	@	12	"	=	8,622 72
"	6.	597,942	"	"	@	9	"	=	53,814 78
		2,128,104	"	"					$198,438 90
Contingencies, 10 per cent.									19,843 90
Engineering, &c.									12,000 00
Auxiliaries, &c.									20,000 00
									$250,282 70

TIME TO COMPLETE.

Under competent contractors, with sufficient plant, well organized, this portion of the waterway should be dredged to the full dimensions for the 8-foot channel within a year from the beginning of operations, and for the 10-foot channel it should be completed within twenty months.

It may happen along certain reaches that the spoils dredged from the channel may be utilized for reclamation of lands, which may be made available for building lots, thus reducing the estimates to some extent, but no allowance has been made for this in the estimate.

Respectfully submitted,

LEWIS M. HAUPT, *C. E.*

Through C. C. Vermeule, Consulting Engineer.
Philadelphia, October 1, 1907.

PART II.

Report on the Improvement of Manasquan Inlet.

By Lewis M. Haupt, C. E.

Report on the Improvement of Manasquan Inlet.

INTRODUCTION.

This report has been prepared and is submitted in accordance with chapter 234, laws of 1907, which reads as follows:

"WHEREAS, It is represented by the Geological Reports of New Jersey for the year one thousand nine hundred and five that for a moderate cost the Manasquan inlet can be made available for small craft at all times, and thereby be a great saving to both life and property, as well as promoting pleasure boating and fishing industries along the coast from Sandy Hook to Barnegat; and

"WHEREAS, It is believed that the late plans proposed in the report aforesaid, if adopted, are both feasible and economical; therefore,

"BE IT ENACTED *by the Senate and General Assembly of the State of New Jersey:*

"1. The sum of two hundred dollars, or so much thereof as may be necessary, be and the same is hereby appropriated out of the State fund for the use and purpose of making plans and estimates of cost for the construction of a 'reaction jetty,' as is indicated in the report of the State Geologist, year one thousand nine hundred and five, part one, showing changes on the Jersey coast.

"The aforesaid sum (two hundred dollars) to be used under the direction of the State Geologist, for expenses of survey and estimate, who shall transmit to the Governor a report of the work and his recommendation regarding it.

"2. This act shall take effect immediately.

"Approved June 10, 1907."

This act was introduced by Assemblyman C. E. Taylor, of Ocean county, February 19, 1907, referred to the Committee on Commerce and Navigation, passed the Assembly March 20, the Senate April 3, and was approved by the Governor June 10.

The act specifically calls for a plan and estimate of the cost of constructing a "reaction jetty," and since Prof. Lewis M. Haupt has been for years the conspicuous advocate of this device for harbor improvement, he was requested to undertake the work. The meager appropriation of $200 was, however, insufficient to pay the wages of the necessary field helpers and afford proper compensation to the engineer in charge. In this emergency, however, local parties interested in the improvement volunteered as field assistants, and the necessary soundings and tidal readings were made with their help.

Mr. Haupt's plan and estimate are given in full, but attention may here be called to the following points. While conditions are constantly changing at Manasquan Inlet, as is the case at all the inlets along the New Jersey coast, yet its position has been measurably fixed by the government bulkhead on the north side, which has prevented shifting in that direction. At the present time, however, this is in bad repair, and there is immediate danger that the ebb tide, swirling through the breaches already existing in it, may speedily wash away the beach on the north and permit the inlet to shift in that direction. The repair of this bulkhead is of prime importance in the improvement of this inlet.

Professor Haupt further recommends the construction of a barrier 800 feet long across the beach south of the inlet, and a stone jetty 700 feet in length, continuing the barrier seaward to a depth of 12 feet mean low water, with a stone sill 100 feet in length beyond the end of the jetty to prevent undermining. As shown by the map accompanying his report, these works are to be slightly curved and so placed as—*first,* to prevent the sand which moves northward along the shore from entering the inlet; *second,* to shut off the sand which is blown by the wind across the spit from filling the channel within the inlet; and *third,* to so guide and control the currents at ebb tide that they will scour a channel across the outer bar as well as maintain deep water within the inlet.

In addition to these improvements, a limited amount of dredging will be necessary to hasten the removal of the shoals and to take out the remains of the old south jetty which was destroyed, and which will be a menace and obstruction in any plan of harbor improvement. The estimated cost of these improvements is $30,000, with a margin of $10,000 to provide for contingencies due to possible delays in completing the work.

As Professor Haupt very properly points out, the plan as presented and the estimates made relate to conditions which prevailed last July, and it may not be applicable without modification to conditions prevailing at some future day.

Professor Haupt is responsible for the plans and accuracy of the estimate. The amount involved is much less than demanded by plans for parallel jetties as heretofore made. The fundamental principles seem established beyond cavil, and, judging from a somewhat similar work at Aransas Pass, Texas, involving his system as authorized by congress, there is good reason for believing that improvements carried out along these lines would prove successful. The amount of money involved is not large, and if it seems advisable for the State, either of itself or in co-operation with municipalities or counties, to embark upon a system of coast improvement of this nature, I would recommend that a beginning be made at Manasquan Inlet. If successful there, the work can later be extended to the larger inlets, where the expense would be proportionately greater.

Respectfully submitted,

HENRY B. KÜMMEL,

State Geologist.

November 20, 1907.

Report by Lewis M. Haupt.

CONTENTS.

Dr. Henry B. Kümmel, State Geologist, Trenton, N. J.:

Sir—In compliance with your letter of July 2, 1907, authorizing me to make such a survey, plans and estimates of the Manasquan Inlet as are called for by chapter 234, laws of 1907, approved by his Excellency Edward C. Stokes, Governor of New Jersey, I have the honor to submit the following report:

In accordance with your instructions, the survey was begun on the eighth of July and continued thereafter by the erection of range flags and location of buoys, the measurement of bases and angles, the placing of tide gauges, the measurement of velocities and directions of currents, and the taking of soundings, which were referred to low water. These data, so far as they can be expressed graphically, are submitted on the accompanying drawings to show the relation of the inlet to the obstacles which reduce the tides and currents, upon which the entrance is chiefly dependent for its channel over the bar.

PHYSICAL FEATURES.

With the exception of Shark River, Manasquan Inlet is the only opening remaining in the fifty-three-mile stretch of coast from Sandy Hook to Barnegat Light. It has ruling depths at low water of about three feet or less, with constantly shifting channels, which have at intervals been entirely closed.

It has a drainage area of 80.5 square miles, while the immediate tidal basin covers almost exactly 2 square miles. With this small

Fig. 1. Remains of south dike at low water in Manasquan entrance, looking southwest from the north dike.

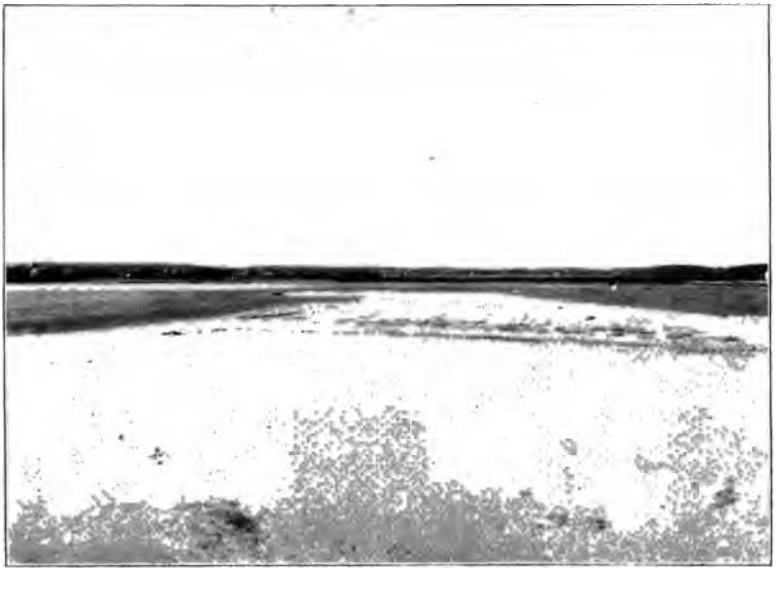


Fig. 2. Shows the recent extension of the south spit inwards, making the cove which reflects *the ebb* currents from Cook's canal against the discharge from the upper Manasquan.

ratio between land and sea-water area, and with the mouth closed by a bar, it would be only a short time before the 6-mile reach constituting the basin would be converted into a fresh-water lake, with an interrupted outflow, to the great detriment of the county. To preserve its maritime features, it is vital that as much sea water be admitted as is possible, and to prevent its gradual shoaling, the tidal currents should be maintained to their fullest extent, without causing too great velocity in the engorged sections, as will appear later in this report.

These results will be accomplished best by admitting as large a volume of the flood tide at the gorge as may be consistent with the physical conditions and riparian interests, and at the same time by so guiding and concentrating the movements of the ebb tide as to create a scour and consequent deepening across the outer bar. Works which throttle the tides and violate the fundamental condition of letting in the largest available amount of water in order to maintain the currents which are the main factors in cutting out the channels at ebb tide must result only in injury.

The physical features at this inlet are typical and suggestive of the appropriate remedy. Here are to be found the prevailing northerly, littoral drift; the angular wave movement, also working to the north; the inwardly-curving, south spit; the large, inner middle ground; the crescent-shaped outer bar, lying close in shore; the diverse channels for the flood and ebb movements, and the deep holes or pockets caused by the reaction of the currents upon obstructing barriers of sand or wood.

Reference to the accompanying map (Plate V.) will show a jetty on the north side about 1,500 feet in length, one of two built by the United States government in 1882, the remains of the south jetty being also shown (Fig. 1, Plate VI.) That portion of the inlet and bay adjacent to the jetty has an average width of nearly 1,000 feet and contains, approximately, 35 acres, of which about 13 acres are bare at low water, while the balance is too shallow for anchorage for coasters.

Near the outer end of the jetty there is a small pocket having a depth of 10 feet for a width of about 100 feet, but this is not accessible from any direction.

The "south spit" of sand projecting into the throat of the inlet and forming what is known as the "gorge," is increasing in extent and curving inward by the deposits carried up by the flood tide, so that at low water the channel is reduced to only 260 feet in width and its cross-sectional area is but 1,260 square feet.

With a 3-foot tide this sectional area would be doubled, but the duration of high water is very short and the current velocities are reduced to nothing. By the improvement proposed and shown on the plan, this cross section at "D-E," as well as the one on the crest of the outer bar, will be more than doubled, thus admitting more water at each tide, increasing the velocity of the currents and creating greater and more permanent depths in the channel.

The south spit and inner middle ground not only interfere with the incoming tide, with its load of sand, but by checking its velocity they invite deposits in the harbor, and create the shoals shown in Plate VII. and Fig. 2, Plate VI. During the ebb movement, too, the effluent on the south side and from Cook's canal is reflected by the south spit and turned backward upon the portion of the ebb discharge which is then endeavoring to effect its escape along the north dike. The cross currents, thus created, are constantly changing the position of the channels, which should be made permanent by regulating works.

On the outer or seaward side of the gorge there is to be noted the crescent bar, with its shoals, cropping above the low-water plane and at present lying in a very favorable position for improvement, there being deeper water channels of about 3 feet M. L. W. at both ends of the shoal, which is only about 700 feet from the inlet, so that it is a very simple and inexpensive problem to secure a good channel for light-draught vessels. Having no artificial aids, however, to protect them, these channels are at present shallow and shifting, and are only navigable for light launches or yachts in good weather. The length of this crest line "A-B-C," measured around the inlet from shore to shore, is 1,400 feet. Its nearness to the low-water shore line is such as to make it possible to control the drifting sand and at the same time to concentrate the ebb currents along a single path over the outer bar by the sand barrier and reaction breakwater, which is shown on the plan.

In considering the remedy for these evils, the State is fortunate in having the benefit of the works constructed in 1882 and the experience then gained, to which brief reference will now be made.

Represents the inner middle ground and the point of the south spit, curving inwards, as seen from the pavilion on the Point Pleasant side of the inlet, taken near high tide.

PREVIOUS SURVEYS AND WORKS.

This problem was considered nearly thirty years ago, and the results of the works subsequently executed are available at the present time, for the records show that the same general conditions then prevailed as at the present. The report states that the tidal range "is about 2.4 feet and the inlet is slowly working to the northward." The depth on the bar at low water varied from 1 foot to 18 inches, increasing to 3 or 4 feet after heavy storms. "The intractability of the inlet has always been the most serious obstacle to the use and improvement of the river."

The plan finally submitted for its improvement consisted of two dikes placed about 200 feet apart at the nearest point, but the south one having flaring ends "for the purpose of controlling the inlet and concentrating the scouring action of the ebb." The report adds: "Assuming that the mean rise and fall in the lower basin will be 1.5 feet, it is estimated that the discharge will be sufficient to maintain a low-water depth of 10 or 12 feet in the middle of the gorge and 6 or 7 feet on the bar, which will form the exterior to the outer wings."

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

These dikes were internal and did not reach across the strand nor project into the sea, and were estimated to cost $52,120. The project was referred to a board of U. S. engineers, which reported in April, 1880, that "the board sees no permanent remedy except to transfer outwards and fix the mouth of the inlet by artificial works, terminating at the depths where the resultant forces of the waves and currents would prevent the formation of a hurtful bar," and it recommended that two dikes should be built out to sea, with a narrow opening between them, and that the north one should be built first.

A minority report was also submitted objecting that a contracted channel would decrease its capacity to admit the tide and diminish the inner tidal prism, upon which alone the channel must depend.

So indefinite were these conflicting reports that they were referred for further consideration, with the result that the views of the majority were indorsed, with the qualifications that "the exterior lines of piers beyond the beach will be of an experimental nature; the effect of storms upon them will prove their stability, and the movable drifting sands will in one way or another decide the problem as to the formation of a new bar across the artificial entrance to the inlet. Owing to the absence and untried character of any similar work along the Atlantic coast * * * a safe estimate cannot be made as to the probable cost."

It resulted, however, that a contract was made July 1, 1881, to build the north dike first and to leave the construction of the south dike to the discretion of the officer in charge. As this north dike was on the far side (or to leeward of the inlet), it failed to protect the entrance from the northwardly moving sand, which was arrested in the channel. Thence it was driven inside by the flood tide and wave action, and rapidly increased the deposits on the inner middle ground, which the ebb currents were unable to displace.

In 1882 it was reported that "to extend the north jetty 255 feet seaward to its fullest projected extent, and to build 905 feet of jetty on the south side will require, it is estimated, the sum of $40,000." A contract was made for the south jetty September 26, 1882, and work was begun in November. Within a few years the river had cut out a new channel south of the dikes, which finally became buried under the sand which had drifted in so that in 1889 only the ends protruded, and gradually the strong cross current at the outer end of the south dike destroyed it, so that to-day only a few of the rocks are left to mark its position. (Fig. 1, Plate VI.)

In spite of its failure to accomplish the desired result, the experiment at Manasquan is worth all it has cost in demonstrating the fallacy of attempting to secure scour from tidal velocities alone, in the face of wave action charged with sediment and a prevailing littoral drift, which is arrested by a "leeward" barrier.

Since sand is twice as heavy as water, and the waves are far more potent as a motor than the currents, it is absolutely essential that the northward drifting sand should be arrested *before* it reaches the entrance to the inlet, and that the barrier for this purpose should be placed on the south side of the inlet. These and other important requirements for the amelioration of bars have been so fully set forth in the report of the Geological Survey for 1905 that it is not deemed necessary to repeat them here, but

Fig. 1. Outer end of north dike in July, when it was surrounded by a sand bar extending 150 feet seaward of its outer end.

Fig. 2. Is a view taken August 28th, from a point on the beach north of the Manasquan, Government dike, looking southeast, across the inlet and the outer end of the sand-spit on the Point Pleasant side, and showing the erosion at the outer end of the dike, due to a northeast storm.

merely to refer to them as a reason for the plan which is now submitted.

Before taking up the proposed remedy, it may be well to emphasize the fact that any plan must be adapted to the conditions prevailing at the time, and when once adopted the works must be put in place as rapidly as possible. The reason for this is apparent. *So rapid are the changes at these inlets that a plan designed for a special condition or location may be absolutely useless a year or so later, when the channel may have greatly changed.* In fact, since this survey was made and the accompanying map drawn, a "northeaster" has cut a new channel immediately in front of the north jetty, where there are depths at time of writing (September, 1907) of 8 feet, instead of there being bare sand at low water, as was the case at the time of the survey (Figs. 1 and 2, Plate VIII.)

GENERAL REQUIREMENTS.

Inasmuch as the two-jetty plan has been proven by experience to be inadequate to meet the problem, it is necessary to consider carefully the general requirements which a successful plan must fulfill. These are: 1st, to keep out the drifting sand; 2d, to let in the flood tide; 3d, to concentrate the energy of the ebb tide over a limited sector of the bar, and 4th, to maintain a continuous reaction upon the ebb currents as they flow seaward.

As the angular wave movements along this part of the coast impel the sand in a northerly direction, it may be arrested readily by any suitable barrier placed across the beach, high and long enough to impound it on the south side. In course of time, when the groin fills and the shore line has advanced, this jetty may be supplemented by one or more to the southward, thus building up valuable lands for the riparian owners. Numerous instances of such jetties successfully arresting the drifting sand can be found along the coast.

To accomplish the double purpose of arresting the northward-moving drift and at the same time preventing the loss of energy by too great an expansion of the ebb tide over the outer bar, as well as to maintain a "continuous reaction" along the channel, the outer end of this barrier must be curved towards the north, so as constantly to change the direction of the currents while passing the bar section. This will cause a natural erosion and automatic maintenance of the channel, which will increase in depth with the sharpness of the curve.

In order to admit as much as possible of the flood tide, this barrier must not be placed so near the old north bulkhead as to throttle the entrance and keep out the flood. In this connection attention may be drawn to the necessity of maintaining in good repair the north dike, which, after having stood securely for over a score of years, is rapidly decaying. In consequence the currents are being forced through the apertures and are cutting out the deposits from the rear, thus tending to create a new channel on the north side. Unless this is checked, it will ultimately close the present inlet entirely.

That the creation and maintenance of channels by tidal currents thus regulated is no mere theory, is well illustrated by the results already obtained at Aransas Pass, Texas, which opens into the Gulf of Mexico, where there is a diurnal tide of only 14 inches, and where, in consequence, the minimum depth of the bar was only from 6½ feet to 8 feet at low water. Here the construction of a reaction breakwater has, in a remarkably short time after its partial completion, increased the depths to over 16 feet at the shoalest point, reaching to nearly 30 at the deepest, and the deepening is still increasing. The well-known fact that the line of deepest water follows the outside of the curve in winding rivers is further proof of the validity of this theory.

TIDES.

This utilization of the tidal energy by a single jetty of curved form, placed on the "driftward" side of the inlet, has given to the problem of opening our harbors a simplicity, economy and value which they have never before possessed, and makes the regulation of the drift and tidal currents the most important factors to be considered. The prevailing direction of the drift and the angular wave movements at Manasquan are well known, but some detailed observations were required to ascertain the action of the tidal currents at this particular inlet.

The United States Coast Survey records and other observed data show the following facts:

	Feet.	Mean Range of Tides.
At Sandy Hook,	4.70.	Six years' observations. Gauge on R. R. wharf, inside.
" Barnegat,	2.04.	In 1866, U. S. C. S. Gauge on boat landing, inside.
" "	2.20.	U. S. C. S. Tide tables.
" Manasquan,	3.19.	Average of 27 low and 7 high tides. Inside north dike, 1907.
" "	2.68.	Annual Report State Geologist, New Jersey, 1903, p. 5. Inside boat landing.
" "	2.40.	U. S. Engineer's Survey of 1879.
" "	2.02.	Average 12 tides at Cook's bridge, near inlet, 1907.
" "	0.75.	Spring tides at highway bridge above R. R., 1907.
" "	0.50.	Neap tides at highway, " "
" "	0.50.	Osbourne's Island, two miles inland, 1907.
" "	0.50.	Old road bridge, three miles inland, 1907.

There are no observations of the tides offshore at this inlet, but the great fluctuations of the readings within the entrance show the serious obstacles to their free admission.

In the hope of demonstrating to some extent its influence on the tides, and to show the weight to be attached to the gauge readings as factors in correcting for depths, two gauges were erected on opposite sides of the river, about 700 feet apart, separated by the "middle ground," as shown on the chart. Only one series of observations has thus far been secured, and during it the wind, which was strong, veered from north to south, yet the differences of level on the gauges, reduced to the same datum, showed that at or near high water the surface on the north or Haberle's gauge was 0.46 feet lower than at Cook's bridge, and shortly before low water this difference had increased steadily to 1.31 feet. The rate or increase in the slope was quite uniform as the tide fell. This is accounted for by the change in direction and greater length of path of the currents issuing from Cook's canal and the southerly side of the basin, they having to make a double turn before passing out to sea.

Because of the large numbers of piles driven to maintain the railroad causeway, the tides above are only about one-fourth of those in the lower basin, and these latter are also much less than those of the open sea, so that to secure the best results, both for the harbor and the upper basin and its navigation, the inlet should be enlarged by the removal of a portion of the shoals and inner middle ground, while the useless piling under the causeway and bridge should be extracted to admit the tide more freely to the upper part of the bay.

The velocity at the entrance gives a maximum movement of

3 feet per second, diminishing from that to zero, but this maximum in itself is unable to remove the sand deposited by the flood tide, save where the ebb currents impinge upon the concavities of the south spit, the material of which is cut away and carried to its point, thus causing constant changes and a gradual closure of the inlet, which the north bulkhead, acting as a revetment, checks by its resistance.

To this extent this bulkhead is useful, and, as already intimated, it should be repaired immediately to hold the inlet from drifting and closing entirely. It does not, however, serve to deepen the water on the bar. This can best be done, as already indicated, by arresting the northwardly-drifting sand by means of the curved barrier shown on the plan, and by preventing the spreading of the ebb currents after they pass the gorge, and by trailing them seaward along the concave face of the proposed reaction jetty until they are beyond the bar and the region of ordinary wave action.

The preponderating influence of wave action and sand drift over mere current action is impressively shown by the changes at Great Bay and New Inlet due to the growth of the north spit. In the report of the Geological Survey, Vol. I., 1888 (page 181), it is stated that in 1871 this inlet was over 2 miles wide, but in 1888 it had narrowed to less than 1 mile, and there was dry beach where formerly there were 60 feet of water. "Observations of tidal bench marks set in 1872 seem to show that this contraction of the inlet has reduced the height of high water in Great Bay at least 6 inches. It has taken place in the face of the scour produced by the passage of 3,000 million cubic feet of water twice at each tide."

It is evident, therefore, that any plan which does not provide for arresting the drifting sand before it reaches the inlet and impounding it is doomed to failure, and the first requisite of a successful plan is to keep the sand out of the inlet.

APPLICATION OF THE REMEDY.

Under present conditions it will require a total length of 1,600 feet of barrier, of which some 800 feet may be of timber, built of piling and sheathing, well braced by batter piles, as shown on the drawings entitled "Plan, Elevation and End View of Sand Barrier" (Plate V.) The outer 700 feet should be of concrete or of rip-rap stone, or of barges filled with sand and covered with rock in such a manner as to constitute a permanent structure capable of resisting storms and having an outer sill of 100 feet and an apron on the channel side, about 12 feet wide, to prevent undermining and to revet the slope of the channel. See plan and type "Cross Section of Reaction Jetty," Plate V.

ESTIMATE OF APPROXIMATE COST.

The essential features of creating a safe entrance for light-draught vessels, giving a channel of about 8 feet depth at mean low water, or about 12 feet at high water on the outer bar, may be secured therefore by the construction of the following works:

800 feet of sand barrier @ $7.00 per lin. ft. (see plan)	$5,600
700 " " stone jetty @ 25.00 " " "	17,500
100 " " stone sill @ 10.00 " " "	1,000
Repairs to north dike (1,200 ft.) @ $2.00	2,400
Removing the old foundation, dredging south spit, engineering and contingencies	3,500
	$30,000

Probable Results.—It is believed that a good, safe, navigable channel, 8 feet deep at low water, may readily be secured at this inlet by the execution of the works as above designed for the limited amount of this estimate, if put in place without unnecessary delays. It must be understood, however, that these plans and estimates are applicable only to conditions as they existed when the survey was made. It is respectfully submitted, moreover, that the inlet is deteriorating, and if it is permitted to drift beyond the control of the north bulkhead, the cost of the work may soon be doubled.

If the improvement is ever undertaken, it is essential that the engineer be given authority to modify the plans as the ever-changing conditions at the entrance may seem to demand, and an additional sum of at least $10,000, over and above the estimates, should be provided to permit such changes should necessity for them arise before the work is completed, and for maintenance.

Respectfully submitted,

LEWIS M. HAUPT, *C. E.*
Consulting Engineer.

Philadelphia, Pa., September 30, 1907.

PART III.

Supplementary Reports

ON

The Inland Waterway from Cape May to Bay Head,

By C. C. VERMEULE,

AND

The Improvement of Manasquan Inlet,

By Lewis M. Haupt.

NEW YORK, February 21, 1908.

Dr. H. B. Kümmel, State Geologist, Trenton, N. J.:

DEAR SIR—I beg to submit the following supplementary report upon the inland waterway from Cape May to Bay Head, providing for a channel six (6) feet deep and 100 feet wide at the bottom. I annex hereto a table showing the details of the amount of dredging, but the substance of the table is given in the following, which corresponds to similar tabulations in the original report:

CAPE MAY TO BAY HEAD.

Bottom width of Channel 100 feet—Side slopes 1 on 3—Under cut one foot.

Depth of Channel 6 feet.

	Length miles.	Cubic yards.	Price.	Cost.
Cape May-Cold Spring	1.3	A		A
Cold Spring-Hereford Inlet	10.6	163,882	12c.	$19,665 84
Hereford-Townsend's Inlet	10.0	81,970	12c.	9,836 40
Townsend's-Great Egg Inlet	18.0	713,224	10c.	71,322 40
Great Egg-Absecon Inlet	14.6	21,190	14c.	2,966 60
Absecon Inlet-Great Bay	11.3	403,586	12c.	48,430 32
Great Bay-Cedar Bonnets	16.3	34,058	18c.	6,130 44
Cedar Bonnets-Barnegat Pier	22.0	160,223	16c.	25,635 68
Barnegat Pier-Bay Head	12.5	224,052	14c.	31,367 28
				$215,354 96
Auxiliary works				15,000 00
Contingencies, 10 per cent.				23,035 48
Engineering, supervision, &c., 10 per cent.				25,339 02
Total cost				$278,729 46

Whole Cost by Sections,
Including Auxiliary Works, Contingencies and Engineering.

Cold Spring-Hereford Inlet	$35,895 66
Hereford-Townsend's Inlet	11,902 04
Townsend's-Great Egg Inlet	86,300 10
Great Egg-Absecon Inlet	3,589 58
Absecon Inlet-Great Bay	58,116 38
Great Bay-Cedar Bonnets	13,952 12
Cedar Bonnets-Barnegat Pier	31,019 17
Barnegat Pier-Bay Head	37,954 41
Total cost	$278,729 46

Please note that I have raised the unit prices in the section between Cape May and Great Bay in order to be more conservative, and it is my opinion that we should not estimate on less than the prices contained in the above table. Even with these increased prices per cubic yard, you will note that the estimate is still somewhat less than the original estimate for a channel 8 feet deep and 50 feet wide at the bottom.

I have no hesitation in recommending this change of depth and width, as I am satisfied that a channel 6 feet deep and 100 feet wide will prove entirely adequate for present purposes, and if the future shall show it to be necessary, the depth can readily be increased to 8 feet or 10 feet.

Respectfully submitted,

C. C. Vermeule,

Consulting Engineer.

For a Channel 6 Feet Deep.

Bottom Width 100 feet, side slopes 1 on 3.

	Miles from Cape May.	*Length of cut—feet.*	*Av. depth of cut—feet.*	*No. of cu. yds.*
(Poverty Beach) south of Cold Spring Inlet	0 – 2.8	4,700	3.84	A
Cold Spring to Hereford Inlets (Two and Five-Mile Beaches)	3. – 10.1	16,100	2.05	163,882
Hereford to Townsend's Inlets (Seven-Mile Beach)..	12.2– 22.1	9,400	1.95	81,970
Townsend to Great Egg Inlets (Ludlam's and Peck's Beaches)	22.1– 37.2	41,400	2.40	713,224
Great Egg to Absecon Inlet,	43.5– 51.3	2,600	1.63	21,190
Absecon Inlet to Great Bay,	55.1– 65.75	27,250	2.83	403,586
Cape May to Great Bay....	0 – 65.75	101,450		1,403,852
Great Bay	65.75– 66.4	3,300	2.2	19,296
Mud Cove	80.4	840	1.0	3,127
Reed's Bay	81.5	780	3.5	11,635
Great Bay to Cedar Bonnets,	65.8 – 82.3	4,920		34,058
Cedar Bonnets	82.3– 82.6	1,530	2.9	18,000
" "	82.6– 83.1	1,590	.9	6,202
" "	83.4– 83.7	1,320	3.8	14,943
Bulk Heads	84.3– 85.9	8,490	2.6	90,341
" "	86.1	300	.4	728
Love Lady	90.8	150	.4	261
" "	91.8– 92.4	2,940	1.1	12,795
Cedar Creek to Barnegat Pier	101.6–103.9	6,450	.8	16,953
Cedar Bonnets to Barnegat Pier	82.3–103.9	22,770		160,223
Sea Side Park	104.2–106	8,760	1.1	37,639
Toms River	106.1–107.3	5,010	.6	11,279
" "	107.7–109.5	7,050	.9	25,852
Kettle Creek to Mantoloking	110.1–115	21,420	1.0	72,137
Bay Head	115.3–116.6	6,540	2.7	77,145
Barnegat Pier to Bay Head..	104.2–116.6	48,780		224,052
Great Bay to Bay Head....	65.8–116.6	76,470		418,338

Supplement to Report on Manasquan River.

Dr. Henry B. Kümmel, State Geologist, Trenton, N. J.:

SIR—Subsequent to the filing of my survey and report in September last my former assistant, Mr. Oliver C. Herbert, a resident at the Manasquan Inlet, noted the frequent changes in the positions of the bars and shoals caused by the storms of last fall and winter, and has made a series of careful sketches, which he has forwarded to me as studies.

These data are so convincing as to the need of regulating works, and so confirm the risks to navigation due to the uncertainties of the entrance, that I have taken the liberty, with his consent, of reducing them to a smaller scale and arranging them in sequence with the former surveys for comparison, and have the honor to submit them to you for record or publication, as you may deem for the best interest of the State.

I know of no instance where so careful a record has been made, and where the changes are more marked and characteristic, so that this series should be of value to those who may hereafter have to deal with the problems connected with the improvement of the inlets along the New Jersey coast.

The United States Government Chart of 1878 (Fig. 1 of Plate IX.) shows three positions for the inlet, from which, if the sequence of their dates be taken, it would appear that the mouth was drifting southward, as the later date indicates a position 2,300 feet south of that of 1868, but the characteristic sand spit, 1,000 feet in length, projecting northward and overlapping the beach with its "S"-shaped channel under its lee, is a sufficient index that such is not the case. The position indicated in 1868 will serve to convey some idea of what would happen soon again were there no regulating works to restrain the littoral drift which drives the effluent waters to the north until their enfeebled currents are unable to maintain an opening in the face of a violent northeast storm. When this has happened, followed by a northwester, the waves break over the narrow spit and reopen the inlet in its normal position, at or near that of "October 23, 1878."

The history of the work constructed by the United States government has already been stated in the body of your report for this year, so that it is only necessary to add that the plan, as proposed originally, shown in Fig. 2, was modified in its execution by changing the form and position of the south dike and omitting the outer extensions of both, as seen in Fig. 3.

The effect of building the north dike first is clearly set forth in Fig. 2. It resulted in the contraction of the mouth of the inlet at low water to only about 60 feet, the filling up of the old channel beyond or to the north of the dike, the rapid shoaling of the depths inside from about 5 to 7 feet to less than zero at low tide, and the growth of the south spit and formation of the inner middle ground, which acted as the nucleus for the obliteration of the channel and destruction of the south jetty after it was built as shown in Figs. 3, 4 and 4*a*.

The sequel to the work done under the government is told in the report of the War Department for the year 1898, page 1070, as follows:

"Congress failed to continue making appropriations for carrying on the work after 1882, and seemed to have abandoned the improvement. In 1890, $2,000 was appropriated, to be expended, at the discretion of the Secretary of War, in removing obstacles placed by the government at the mouth of the river. This expenditure was reported against on the ground that the depth on the bar did not exceed the depth where the channel crossed the ruins of the south dike, and that only slight use was made of the inlet. The Secretary of War did not authorize the expenditure. In October, 1897, the Manasquan Improvement Association requested the Secretary of War to have a survey made in order to determine what should be done to prevent further injury to the Manasquan river and inlet. The survey * * * was made during the month of December, 1897. * * * It was found that the south shore had receded 500 feet since suspension of work in 1883; that the south spit had worn away in the rear a distance of 350 feet normal to its axis; that the north shore had enlarged at a corresponding rate, and that the demolished south dike obstructed the entire channel.

The channel also ran parallel to the shore for a distance of 800 feet before reaching the outlet, which caused a loss of directness in the discharge, thereby impairing its efficiency. * * * Unless improvement of this locality is resumed it will eventually result in the destruction of the north dike, which was built at a cost of $30,000. * * * It is proposed to restore and complete the south dike, and to extend it along the line indicated on the map (see Fig. 4*a*) until it reaches the shore; also to close two small passages between the islands and the main shore. * * * The present condition of the inlet at the mouth of the river is undoubtedly worse than before any attempt was made to improve it, and it would seem only just that relief be given. The estimate for this portion of the work is $20,000. The commerce on this river amounted to practically nothing during 1897, owing to the condition of the inlet at its mouth."

Nothing was done during the year 1899 except to prepare specifications for the south dike, which were opened July 12, but as the bids were too high, nothing was accomplished during the following year but to repair the north dike, at a cost of $734.71, by spiking on some creosoted planks. In the report for 1907 it is stated that "It is now thought that the funds are insufficient to begin the work provided for under the approved project." Thus it appears that no material improvement has been made since 1882, and there will be no River and Harbor bill at this session of Congress (1908).

It is important to observe, in view of results from similar designs of convergent dikes, that if the south one is built on the lines as proposed, it will cross the existing channel in two points and confine the ingress of the flood tide to the narrow space of 200 feet between the outer ends of the dikes, which expand rapidly to over 600 feet at their inner ends. The only available channel will thus be destroyed and rapid shoaling invited between the dikes because the retardation, due to their divergence, will cause deposits between them, such as occurred in the earlier works of 1882. Moreover, the end of the south dike is about 400 feet inside of the shore line, and cannot therefore arrest the prevailing northward drift, nor protect the entrance from the action of the flood or ebb deposits, while it also will reduce greatly the influx of the tides and close several of the back channels. There appears to be no estimate for removing the deposits of sand on the middle ground, nor for the maintenance of the channel through the entrance. The effects to be expected from this project may be anticipated by an examination of the changes which have taken place during the past winter, with no external regulating works in place.

THE CHANGES AT THE INLET.

If a composite plan be made of these several sketches it will be found that the entire area covering the entrance has been masked by shifting bars, bare at low water, within the past six months, so that the construction of the second jetty entirely within the mouth will have no material effect in arresting the drifting sand which is carried in by the flood tide and deposited within the bay. The area of instability extends from the pavilion on the south side to about 300 feet north of the dike, a distance of about a quarter of a mile, and the same distance east and west from a point 800 feet at sea, so that the question of controlling the drift within this area is the vital one at issue. The existing shoals must be removed and the littoral drift be excluded by barriers across the foreshore, as shown in the former report and indicated on Fig. 5 of the accompanying chart.

THE HYDROGRAPHIC FEATURES.

The most striking features of these sketches are the persistence of the south spit overlapping the inner middle ground and forming the "S"-shaped channel; the deposits to the north of the outer end of the dike, sometimes as islands and at others as peninsulas; the appearance and disappearance of oblong or crescent-shaped bars off the entrance, and the shifting of the foreshores, both to the north and south of the inlet. These are all effects for which the causes must be found in the natural agencies of waves, winds, tides and currents, concerning which considerable data have been obtained.

Mr. Herbert secured a table of the "Average Direction of the Winds" since last May, but it is unfortunate that the intensity was not also recorded by the observer, as that is the more important factor. However, an analysis of this table into off and on-shore winds for the several months, taken in connection with the dates of the sketches, will serve to illustrate the operation of some of the forces affecting the mouth of the river.

Analysis of Table Giving Average Direction of Winds per Day.

MONTHS. 1907–8.	ON-SHORE WINDS.					OFF-SHORE WINDS.					
	DIRECTIONS AND NUMBER OF DAYS.										
	NE.	E.	SE.	S.	Total.	SW.	W.	NW.	N.	Total.	Month.
June	3	6	8	5	22	2	5	1	....	8	30
July	1	5	6	8	20	....	9	1	1	11	31
August	3	5	10	1	19	....	5	5	1	11	*30
September	2	2	4	11	19	4	2	5	....	11	30
October	2	2	4	5	13	3	10	5	....	18	31
November	2	3	3	2	10	....	12	7	1	20	30
December	2	1	3	5	11	4	13	2	1	20	31
January	2	1	2	3	8	3	10	2	1	16	24
Totals	17	25	40	40	122	16	66	28	5	115	237

* One out.

From this record it appears that of the on-shore winds, those from the south and southeast were the most prevalent. Their aggregate was 80 days out of the 122, or 65 per cent., and this feature was most notable in the summer and early fall months, while the westerly winds constituted nearly 58 per cent. of those off-shore, and prevailed mainly from September to date (late in January).

EFFECTS OF THE FORCES.

More specifically, from the date of the survey in July (Fig. 5) to August 20 the outer shoal disappeared, the end of the dike was laid bare and a hole 8 feet in depth formed; the south spit was extended to cover the rocky foundation of the former south jetty, and a lunar-shaped bar of more than an acre in extent formed on its flank. These changes were attributed to the severity of the southeast winds on the 15th to 17th of that month.

The forms shown in Figs. 7 and 8, with their long salients extending some 600 feet seaward, are apparently accounted for by the five days of northwest winds, from August 27 to September 2, followed by five days of southerly winds, both of which would drive the sand seaward, while the next exhibit (Fig. 9) shows the complete destruction of this spit, which does not again appear. During this interval of eleven days there were two with northeast winds, which doubtless were sufficiently strong to cut away the deposit. The three days of northwest winds also extended the interior hooks around the remains of the south jetty, which serve as a point of reaction to maintain a pool under ordinary conditions.

Fig. 10 illustrates the results of a southeast gale in erasing the spit north of the dike, denuding its extremity and contracting the entrance, while it also formed the traverse of lunar form across its mouth. Two weeks later, under the influence of the land forces, this outer bar had changed its form and was drawn in towards shore, with which it was again connected by November 7. But the lunar bow again appeared in Fig. 14, under the influence of the west and northwest winds, 100 feet farther out to sea, and formed the nucleus for the accretion driven up by a northeast gale on November 24. This shoal continued to grow until it again entirely masked the channel entrance close in shore. The prevailing west winds of December cut this shoal asunder, and by January 8, after an easterly storm, it disappeared. The northeast wind of January 12 extended the north spit and added to the southerly hook several acres of deposit in the harbor, while a severe gale on the 26th, with its storm tide of nearly 6 feet, wrought much damage not yet reported.

Under the conditions shown by these sketches it appears that the area of instability would be well covered by the works projected in the body of the report previously submitted, since the reaction jetty as described therein would cut off the supply of sand originating south of the inlet, and after the inner middle ground has been sufficiently dredged out and the sand used for reclamation and back filling, the off-shore winds would be deprived of their source of material for the formation of the outer shoals, and the internal changes caused by the reaction of the currents from the north dike and the retardation of the ebb from the cross-current reflected through the S-shaped inner or south channel would cease.

A short spur from the north jetty swinging gradually around to the northeast will sufficiently protect the entrance from the casual drift due to storms from that quarter, and thus leave the gorge of about 500 feet clear for the run of both flood and ebb tides, and greatly increase the quantity of water entering the harbor, to its permanent benefit.

In short, these exhibits serve greatly to confirm the conclusions previously reached as to the proper and most effective remedy to be applied for the opening and maintenance, at least cost, of this important inlet as a harbor of refuge for light-draught vessels and for the preservation of the maritime industries of this portion of the New Jersey seaboard. As before stated, it is important that the work be inaugurated before the north dike fails. It is rapidly going to pieces by the action of the storms and the injuries from floating wrecks.

As it is credibly reported that there will be no River and Harbor bill passed by Congress at the present session, it is not probable that any relief can be expected from that source for several years, if at all, because of the pressing demand for funds at other more important points where large commercial interests are demanding relief from inadequate channels which threaten and retard the vessels.

LEWIS M. HAUPT.

Philadelphia, February 1, 1908.

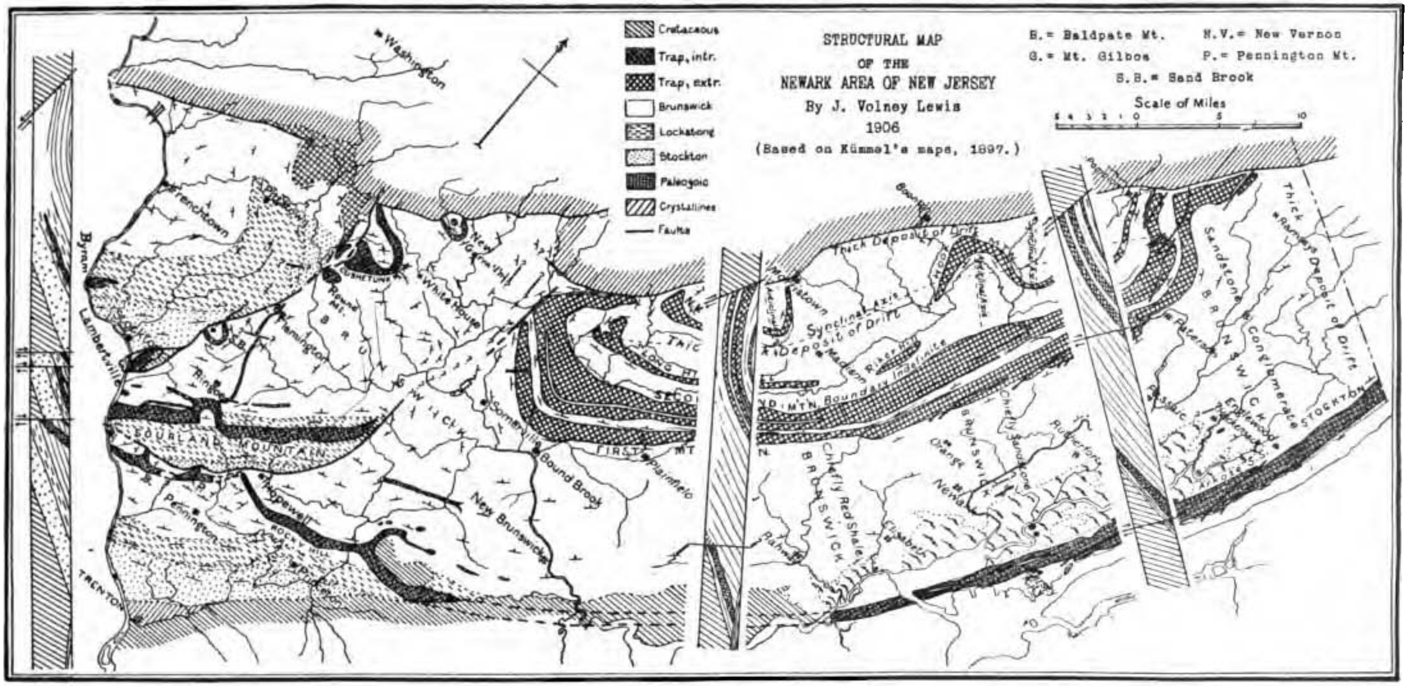
PART IV.

Petrography of the Newark Igneous Rocks of New Jersey.

By J. VOLNEY LEWIS.

Petrography of the Newark Igneous Rocks of New Jersey.

CONTENTS.



Structural Map of the Newark Area of New Jersey.

and the next two in graphic intergrowth, sometimes constituting nearly one-half the bulk of the rock. Near the contacts micropegmatite disappears and olivine occurs in scattering crystals. In the olivine-diabase ledge olivine becomes abundant (up to 15 per cent. or more) as poikilitic inclusions chiefly in the feldspars. Minor constituents are biotite, apatite, pyrite, chalcopyrite and rutile. Augite and the feldspars are subject to a variety of alterations.

Chemically the rocks range from less than 50 per cent. to more than 60 per cent. of silica, generally with a corresponding variation in alumina, ferric iron and the alkalis, while ferrous iron, lime and magnesia vary inversely. The augite is rich in these latter constituents and poor in alumina, giving a great preponderance of the hypersthene and diopside molecules. The feldspars range from orthoclase and albite ($ab_{20}an_1$) to basic labradorite (ab_3an_8). Anorthoclase is doubtless present, as all feldspar analyses show potash.

Augite usually comprises about 50 per cent. of the rock (varying from 25 to 75); feldspars, 40 per cent. (20 to 45); quartz, 5 per cent. (0 to 20); ores, 5 per cent. (1 to 20), constituting a quartz-diabase, with normal diabase and olivine-diabase facies. In the quantitative system the rock is a graphi-ophiti-*camptonose* (III.5.3.4.), with *auvergnose* (III.5.4.4,5.), *dacose* (II.4.2.4.), and *tonalose* (II.4.3.4.) facies. The olivinic ledge is ophiti-poikili-*palisadose* ($IV,1^2,1^2,2$), a name proposed for a hitherto unnamed subrang.

Differentiation by gravity during crystallization, especially by the settling of olivine and the ores, and the rising of the lighter feldspars in the earlier and more liquid stages of the magma, with minor basic concentration at the contacts, perhaps by Soret's principle, satisfactorily accounts for the facies observed and their present relations.

Inclusions of long slabs of arkose in vertical position are found in the trap at several places. These are now in part *recomposed augite-granite*. Some of the augite constituents, however, appear to have been introduced from the inclosing magma.

Contact metamorphism has produced an elaborate series of hornfels characterized by various combinations of feldspar, biotite, quartz, augite, hornblende, tremolite, garnet, spinel, magnetite, muscovite, cordierite, scapolite, vesuvianite, sillimanite, andalusite, chlorite, calcite, analcite, titanite, tourmaline, zircon, apatite, and possibly leucite, the various types within the zone of metamorphism depending entirely on the original composition of the shales and not on relative distances from the contacts or degree of metamorphism. Metamorphic arkose, like the arkose inclusions, contains, besides orthoclase and plagioclase feldspars and usually some quartz, also augite, biotite, epidote, cordierite, chlorite, calcite, tourmaline and apatite.

In the extrusive basalt joints and horizontal lamination are much the same as in the intrusives, and often there is also a well-developed columnar structure. The sheets are probably composite, consisting of 3 or more flows in First and Third Mountains, and 2 or 3 in Second Mountain, the successive flows or pulsations varying slightly in character.

Vesicular and ropy flow-structure are abundant at the upper surfaces of the various flows, and portions are often rolled under the bottom. A breccia at Little Falls is probably due to flow of the lava into a local body of water on a plain of continental deposition. A tuff bed that was cut in the tunnel of the Jersey City pipe line through Hook Mountain consists of fragments of volcanic glass containing minute crystals of feldspar, augite and olivine, and the interstitial spaces are filled with analcite.

Microscopically the rock varies from a brownish structureless or spherulitic glass to a fine-grained granular or ophitic augite-plagioclase-rock with magnetite grains and occasional olivine crystals. Frequent phenocrysts of augite, and less commonly of feldspar, represent an earlier stage of crystallization.

Chemically the basalt is less variable in composition than the diabase, although very similar to it. Small and apparently characteristic differences are found between the successive parts of the various sheets which it is thought possibly represent successive flows. To a certain extent these parts are also different in physical characters. The Third Mountain basalt is notably more basic than that of First Mountain, and lower in alumina, magnesia and lime, but higher in soda, titanium oxide, and much higher in iron.

The rock is *basalt* and *basalt-porphyry,* both glassy and holocrystalline, and often has a diabasic or ophitic texture. In the quantitative classification the analyses fall into the following subrangs: *camptonose* (III.5.3.4.); *ornose* (III.5.3.5.); *auvergnose* (III.5.4.4,5.).

Small inclusions are found in the base of First Mountain, and probably also in the others, consisting of sandstone or shale fragments up to 2 or 3 inches in diameter, which are baked into a hard jaspery condition. An oval sandstone mass, 2 by 4 feet, apparently unaltered, was found in the Third Mountain sheet at Pompton. The only microscopic changes noticeable in the smaller inclusions are a darkening of the red color and the development of crystalline calcite, both chiefly within 2 or 3 millimeters of the contact. Contact effects on the underlying strata are of a similar character where found at all. Often no change whatever is apparent.

The shale 1 to 2½ feet beneath the First Mountain basalt, around the curved southwestern portion, is mottled by partial bleaching and rendered porous by the removal of small calcite crystals which this rock usually contains. In the spaces native copper and chalcocite have been deposited. Nothing comparable to this is found under the other sheets, nor under other portions of this one. The effects are attributed to ore-bearing solutions, probably magmatic waters, that brought up the copper from the intrusive sheet of Palisade diabase below.

INTRODUCTION.

The following paper considers specially the mineral and chemical characters of the igneous rocks (commonly called trap) of the Newark (Triassic) formation, and is thus supplementary to the studies on these rocks that were published in the last Annual Report.[1]

It is only necessary here to recall the location of the belt of Newark red shales, sandstones, etc., which forms an area of about 1,400 square miles across the north central portion of the State, and the distribution of the igneous rocks within it, as shown by the map (Plate X.). The soft shales and sandstones are consolidated beds of mud and sand that were long ago washed over this region. The hard, blackish, igneous rocks are in sharp contrast with these, not only in physical characters, but in origin as well. As the name igneous indicates, they have cooled in their present position from

[1] J. Volney Lewis, "Origin and Relations of the Newark Rocks," Annual Report of the State Geologist for 1906, pp. 99–129.

a molten condition; some as lava flows or *extrusives* (basalt) that spread over the surface, while others, the *intrusives* (diabase, gabbro), were injected into fissures or spread between the strata of the shales and sandstones. These two types are distinguished on the map, and both are extensively represented in the State, the outcrops of intrusive diabase having a linear extent of about 70 miles and covering an area of about 60 square miles, while the corresponding dimensions for the extrusive basalt are 140 miles and over 100 square miles, respectively.

On account of their great resistance to the decomposing influences of the weather, all of the larger masses of these rocks form prominent ridges. The three great extrusive sheets form the Watchung or Orange Mountains and smaller ridges in the vicinity of Flemington, New Germantown and Sand Brook. The intrusives have given rise to the prominent ridge of the Palisades, along the Hudson River, and to Rocky Hill, Sourland, Pennington, Baldpate, Cushetunk and Round mountains, besides a number of smaller prominences. There are also many thin sheets and dikes associated with the larger intrusives, but they are too small to have any notable effect on the topography.

It is noteworthy that the igneous rocks, both intrusive and extrusive, are confined strictly to the area of Newark or Triassic rocks. If any of the dikes penetrated the adjacent areas of older rocks, their continuity has not been traced, and any surface flows that may once have overlapped these areas have since been removed from them by erosion. There is but one small exception to this statement known in New Jersey. Eight miles west of Bernardsville an outcrop of coarse-grained diabase occurs for a short distance in the road as it ascends a hill three-quarters of a mile west of Pottersville. The surrounding rocks are the crystalline gneisses of the Highlands, although the border of the Newark area is very near. Other exposures were not found in the immediate vicinity, and hence the extent of this rock is not known, although it is evidently not great. In thin section this rock is identical in composition and texture with the typical Palisade quartz-diabase and that of Cushetunk Mountain. The latter is 7 miles to the southwest, although the extrusives of New Germantown are only 3 miles distant. This rock is from a magma identical with that of the Newark intrusives, and there can be little doubt that it is part of the same material.

Fig. 1. Cylindrical jointing on the face of the Palisades at Alpine.

Fig. 2. Cylindrical jointing on top of Palisades near Coytesville. (Photograph by G. E. Ashby.)

Small diabase dikes are not infrequently found intersecting the crystalline rocks in many parts of the Highlands, and it is not improbable that many of these are of the same age and origin as those of the Newark area.

INTRUSIVE ROCKS.

The writer has previously shown[1] that, with the possible exception of Cushetunk and Round mountains, all of the larger bodies of intrusive rocks in the State are to be correlated with the great mass of the Palisades, and are continuous with it, except where subsequently cut off by faulting. This is borne out not only by the structural relations, which were made the basis of the correlation, but also by their mineral and chemical characters, as described below. In accordance with this unity of origin and petrographic characters, the term ***Palisade diabase*** is here used in a generic sense, including all of the various connected intrusives, as indicated on the map (Plate X.).

INTRUSIVE DIABASE.

Definition.—Diabase is a rock composed essentially of the minerals augite and plagioclase feldspar, with minor amounts of magnetite, and sometimes a little olivine (chrysolite) and biotite. It is distinguished from other rocks of like composition by the characteristic diabasic or ophitic texture; that is, the feldspars are usually developed in interlacing rod-like and lath-shaped crystals, and the augite fills the irregular spaces between (Plate XV.). This texture results from a reversal of the usual order of crystallization as the rock cooled and solidified, the slender feldspars completing their crystals first and leaving the augite to accommodate itself to the irregular outlines of the interstices, or, if greatly in excess, to form a ground mass in which the feldspars are imbedded.[2] The coarser-grained portions, however, often develop an even granular texture, and thus pass into gabbro.

[1] J. Volney Lewis, Annual Report State Geologist for 1906, pp. 117–121; Bull. Geol. Soc. of Amer., Vol. 18, pp. 204–207, 1907.

[2] Diabasic and ophitic are often used interchangeably, but sometimes a desirable distinction is made (as by Professor Kemp in his Handbook of Rocks) by applying the former term to the case in which the augite forms an interstital filling, and the latter to that in which the feldspars are imbedded in an augite ground mass (Plate XLVI.).

Distribution.—The intrusive diabase is typically developed in the Palisades, along the Hudson River, from Haverstraw, N. Y., southward to Jersey City. As a less conspicuous ridge it continues, however, south of Jersey City to Bergen Point and across Staten Island to Fresh Kills, opposite Carteret, N. J. From this point it is covered for a distance of 20 miles by the sands and clays of the Cretaceous formation, to the vicinity of Deans, 5 miles southwest of New Brunswick. Westward from there it forms, successively, Rocky Hill, Pennington, Baldpate and Sourland mountains, and the trap mass at Byram, making a total length of outcrop in New York and New Jersey of about 100 miles.

Structure.—The diabase is a massive sheet or sill hundreds of feet in thickness intruded between strata of shales and sandstones. Its most prominent structure is the jointing developed at right angles to its upper and lower surfaces (Plates XXI., Fig. 2; XXII., Fig. 2; XXIX., Fig. 1). Since the rock usually dips 10 to 20 degrees toward the northwest, like the strata above and below it, these joints are not quite vertical, but are tilted backward a little, as seen in the cliffs along the Palisades. The more prominent joints usually lie in a north-south direction, N. 20° E., or N. 45° E., in various localities and at right angles to these directions. They are usually quite pronounced in one particular direction, with less prominent jointing at right angles, and sometimes two or more sets of joints are developed together, with minor cracks traversing the rock irregularly. Sometimes, also, jointing of a distinctly curved, cylindrical form is observed (Plate XI., Figs. 1 and 2), giving rise to rounded columns. Other forms of concentric jointing occasionally occur (Plate XII., Fig. 1).

Another structure, less pronounced, but still quite noticeable, is a sheeting or platy jointing parallel to the upper and lower surfaces. These partings are often as near together as one to 4 or 5 feet in the finer-grained portions of the rock near the contacts with the inclosing strata, but they are much less frequent in the coarser-grained rock that constitutes the main mass. A very minute parallel banding or flow-structure is occasionally observed near the contacts, and is sometimes quite noticeable in thin sections without the microscope.

The result of these structures on exposed cliffs of the diabase, like the Palisades, formed by the breaking away of masses of the rock along these natural cracks, is the production of a pronounced vertical columnar appearance, where two or more directions of

Fig. 1. Concentric jointing in diabase, Pa. R. R. cut, Jersey City. (Orphans' Home, beyond, is built of diabase.)

Fig. 2. Faulting in the Palisades, in an old quarry at Guttenburg.

jointing are well developed, or of broad vertical sheets or slabs where only one direction is prominent. Rounded columnar masses sometimes appear as a result of the cylindrical jointing. True columnar structure, however, such as is beautifully developed in many parts of the extrusive rocks of the Watchung Mountains (Plates XXXV. and XXXIX.), is not the result of intersecting continuous joint planes, and is nowhere found in the intrusives.

A crumbling, deeply-weathered layer of olivine-diabase, 10 to 20 feet thick (Plate XIX.), appears in many places along the Palisades for about 20 miles north of Jersey City. It is approximately horizontal, and usually about 40 or 50 feet above the base of the sheet. In many places this ledge, which is invariably coarse-grained, is the first rock of that texture encountered above the base, all below it being quite dense and fine-grained, but this is not without exceptions.

Sometimes the vertical north-south joint-planes have also been planes of slipping or faulting, and contain from an inch or two up to 3 or 4 feet of soft, crushed and decomposed rock. In many cases the frequent repetition of such fault-planes near together has produced *shear-zones* of considerable width, in which the solid rock is thinly sheeted between the vertical layers of softer materials. Veins of calcite, quartz, feldspar, zeolites, and more or less pyrite, chalcopyrite, galenite and sphalerite, are often formed in these fault-planes, but the bulk of the material that they contain is a mass of soft, slippery, greenish-black chloritic minerals, resulting mainly from the decomposition of augite in the crushed rock (Plate XII., Fig. 2). Veinlets of calcite and feldspar also occasionally traverse the solid rock irregularly, but they are insignificant in size and frequency.

Megascopic characters.—The diabase is everywhere a dark colored heavy rock, and in the main coarse-grained, the individual minerals being often more than one-eighth of an inch in diameter. On account of its distinctly granular character it is sometimes called granite, although it is a much darker and heavier rock than true granite. The dark green, nearly black, color of the augite, which is the most abundant constituent, and the black grains of magnetite, with the grayish translucent feldspars, give a dark greenish or bluish-gray color to the rock. The color changes to brighter shades of green as the augite becomes more hydrated, and hence the freshly-broken rock in quarries and other excavations presents some variety of appearance, although always dark.

EXPLANATION OF PLATE XIII.

Photomicrographs of thin sections.

Fig. 1. DIABASE, *Coytesville.* Magnified 18 diameters. The coarse granular (gabbroic) rock immediately above the olivine-diabase ledge, at the east end of the old quarry. The white areas are feldspar, the gray augite, and the black aggregates are iron oxides from incipient alteration of augite. Patches of micropegmatite (quartz and orthoclase intergrown) appear indistinctly near the top of the figure. Thin section No. 303–L.

Fig. 2. OLIVINE-DIABASE, *same locality.* Magnified 18 diameters. The larger grains are feldspar (white) and augite (gray) in granitic texture; the smaller grains, sprinkled plentifully through the feldspars and occasionally in the augite and broken by numerous cracks are olivine. The black crystals and grains are titaniferous magnetite, some of which are surrounded by a thin sheath of biotite. Thin section No. 304–L.

Fig. 3. DIABASE, *same locality.* Magnified 18 diameters. The coarse-grained rock immediately below the olivine-diabase shown in Fig. 2. Consists chiefly of augite (gray) and feldspar (white), with occasional olivine partly altered to bright yellow serpentine. A large oblong olivine grain, with serpentine and black oxide granules on one side, occupies the center of the field. The small black grains are magnetite. Thin section No. 302–L.

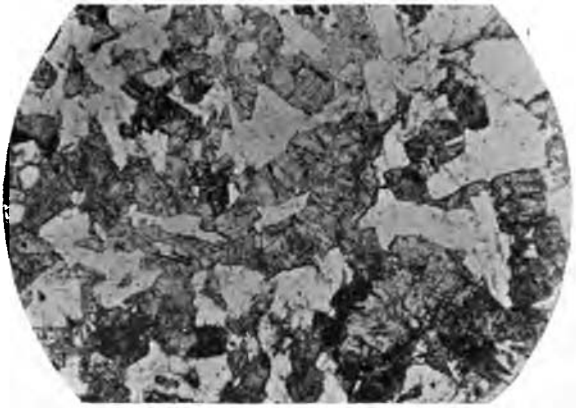


Fig. 1.

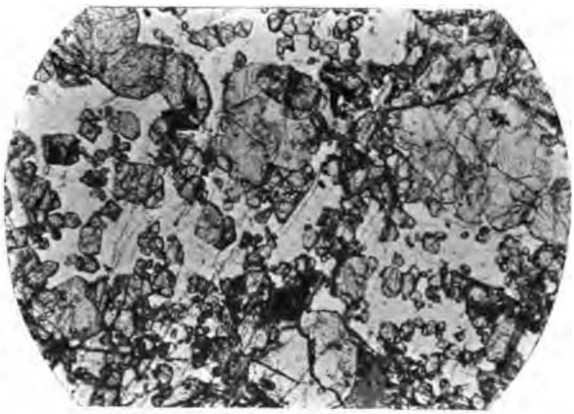


Fig. 2.

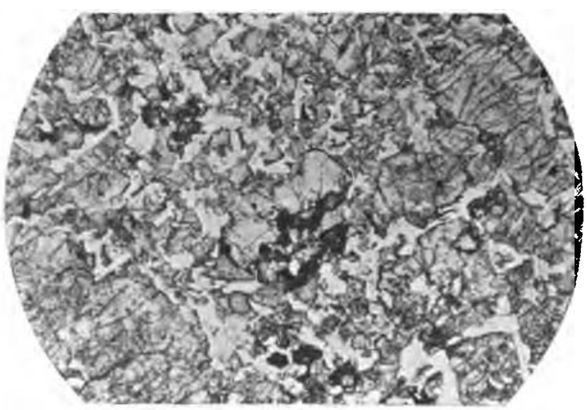


Fig. 3.

Near the contacts with the overlying and underlying strata of shales and sandstones the texture becomes very fine-grained, often with porphyritic crystals of augite and less frequently feldspar, and the rock is very much like the dense extrusive basalt of the Watchung or Orange Mountains. This is particularly noticeable in the basal portions of the palisade diabase, where rock of this character is often 40 or 50 feet in thickness, changing, sometimes gradually, sometimes suddenly, into the coarser-grained facies above. Often this transition occurs at the base of the crumbling olivine-diabase referred to above, but sometimes below it.

Microscopic characters.—When examined in thin sections under the microscope the intrusive rock is found in all cases to contain augite, plagioclase feldspar, magnetite and a little apatite. There are also almost universally some quartz and orthoclase in micrographic intergrowths (Plate XIV.), and these minerals sometimes constitute as much as one-half the bulk of the rock.[1] Less commonly olivine (chrysolite) and biotite are also present in small amounts, and rarely scattering grains of pyrite and chalcopyrite and slender needles of rutile.

The texture of the rock is usually diabasic or ophitic, as explained above; that is, the augite fills the interstices between the interlacing lath-shaped feldspars, or, when greatly in excess, it forms the ground mass in which the feldspars are imbedded (Plate XV.). In the coarser-grained portions of the rock, however, a granitoid texture is often developed, in which the two chief minerals are formed in grains of approximately equal size and of nearly equal dimensions in every direction, constituting a true gabbro (Plate XIII.). In the dense contacts also, the larger

[1] It is noteworthy that one of the results of the British Antarctic expedition, just published, is the discovery of large bodies of a quartz-diabase (dolerite) almost identical in character with that of the great Newark intrusive here described, in King Edward VII. Land, in S. lat. 770° 45′ and E. long. 163°, where it is intrusive in sandstones and granites of undetermined age in the Kukri Hills. "A characteristic feature of most of these dolerites is the presence in patches and in the interstices of the augite and feldspar, of more acid material, showing quartz in radiating (spherulitic) and micropegmatitic intergrowth with feldspar. In the section * * * quartz is seen to have crystallized round prisms of feldspar, from the end of which springs a micropegmatitic intergrowth." *National Antarctic Expedition, Natural History, Vol. I.;* London, 1907, *Petrography*, by G. T. Prior, p. 136.

The analysis of this rock (No. XVI., p. 121) shows a similar correspondence with much of the New Jersey diabase, except in its somewhat higher lime content.

augites and occasional olivines and feldspars scattered through a fine-grained ground mass of feldspar rods, augite and magnetite grains, constitute a basalt-porphyry facies.

Augite, the most abundant constituent, is pale greenish to colorless in the section and sometimes exhibits a slight pleochroism, pale green to light yellow. It occurs in large plates, up to 3 or 4 millimeters in diameter, and in irregular grains whose form is determined by the accompanying feldspars. Crystal outlines are rarely observed. In the finer grained portions near the contacts, augite of two generations usually appears, the earlier as large porphyritic plates scattered through the denser ground mass in which the augite of later crystallization forms a fine granular filling between the feldspars. The augites often show the two forms of pinacoidal twinning, both frequently appearing in the same specimen. That parallel to the orthopinacoid (100) generally produces paired halves, while the basal twinning, parallel to (001), is more commonly repeated in thin lamellae which are sometimes exceedingly minute (Plate XV., Figs. 2, 3). In addition to these there is also an interpenetration twinning that produces an effect between crossed nicols very similar to micrographic intergrowth of quartz and orthoclase (Plate XV., Fig. 3). (For composition of the augite, see analyses page 117.)

Augite sometimes incloses magnetite grains and biotite. Apatite is also occasionally included, but it is found chiefly in the feldspars and quartz. Augite, in several adjacent areas, is often similarly oriented, giving rise to a large individual that incloses numerous slender feldspars. This structure, which is not uncommon in these rocks, has been called micropoikilitic.

Alteration, to a greater or less degree, is nearly always observed in the augite, the earliest traces of it being seen in the dirty greenish to brownish tints assumed, and the slight accompanying decrease in transparency. Three modes of alteration are observed, but one of these usually greatly predominates in any given locality. In the order of their frequency, and designated by their resulting products, these are (1) *chloritization,* or alteration into green chlorite in confused scales or radial clusters; (2) *uralitization,* or change of the augite into pale green fibrous amphibole, oriented with the vertical axis parallel to that of the parent mineral. Along with uralite, more or less secondary biotite is also frequently formed. A second step is often observed whereby the uralite and biotite are in turn altered into chlorite. (3) *Serpentinization,* a process usually beginning in the central portions, by which the augite changes into yellow or brownish yellow, confusedly fibrous serpentine, is less commonly seen. In all of these modes of alteration, black iron oxides are usually deposited in the midst of the secondary mineral. These appear as granular aggregates or as trellis-like skeleton crystals of magnetite, and are sometimes so numerous as to render black and opaque almost the whole of the space originally occupied by the augite. Calcite is rarely found among the products in thin sections, even in the most thoroughly decomposed specimens.

Plagioclase, the chief feldspathic constituent and the second mineral in abundance, occurs characteristically in elongated, relatively narrow forms. In some of the coarser textured rock the elongation is less pronounced than in the finer grained facies, ranging up to 2 millimeters in length, with a breadth as much as one-fifth to one-third as great. These dimensions become more nearly equal in the coarsest textures, with diameters of 3 to 4 millimeters in the granitoid facies of the rock. Often the plagioclase presents complete crystal outlines, but very commonly the terminal planes are lacking, the elongated crystals abutting against each other irregualrly. They are universally made up of thin twinning lamellae, chiefly according to the albite law, but pericline and carlsbad twinning also frequently occur. Zonal structure, consisting of shell-like layers of more and more acid composition from the center outward, is quite commonly developed, and fringing the extreme acid borders a graphic intergrowth of orthoclase and quartz is often found (Plate XIV.).

Maximum extinction angles in sections normal to the albite twinning-plane usually range a little under 30°, corresponding to an acid labradorite. Analyses of the feldspar (see p. 118) have shown that labradorite containing the soda and lime molecules in about equal proportions, is the most abundant plagioclase, but that other members of the series, ranging up to almost pure albite, the soda feldspar, are present in considerable amount.

Plagioclase often incloses minute apatite crystals in considerable numbers, and olivine when present, but seldom any other original constituent. In altering, it usually does not form opaque masses

EXPLANATION OF PLATE XIV.

Photomicrographs of thin sections.

Fig. 1. QUARTZ-DIABASE, *Homestead.* Magnified 18 diameters. From the Pa. R. R. tunnels, 400 feet from the western portal. Consists of coarse-grained feldspar and augite in a matrix of micropegmatite. The large feldspars are considerably altered and appear dark gray in the figure. The augite shows parallel cleavage and irregular cracks. The quartz of the micropegmatite and the larger separate crystals and grains of the same mineral are bright and clear. Thin section No. 315–L.

Fig. 2. QUARTZ-DIABASE, *Pa. R. R. cut 420 feet east of Marion Station, Jersey City.* Photographed with crossed nicols; magnified 18 diameters. The large elongated crystals are striated feldspars, around one of which the area of micropegmatite is clustered. Augite grains appear below the center and near the bottom of the figure. Thin section No. 15–L.

Fig. 1.

Fig. 2.

of kaolinite, although more or less of this is commonly seen, but changes chiefly into fine scaly and confused fibrous masses of colorless mica, probably paragonite or muscovite. Often, when the accompanying augite is altering into chlorite, this mineral is also found developing in minute scales in the plagioclase, owing to migration of iron and magnesia from the decomposing augite.

Orthoclase and quartz, as noted above, usually occur as a fringe or border about the plagioclases, where, in graphic intergrowth, they constitute a micropegmatite that fills many of the triangular and irregular interstices (Plate XIV.). These areas are often small and sparingly scattered through the sections, but they are usually quite a prominent constituent, and are sometimes as much as 3 or 4 millimeters across. In the latter case they are distinctly visible, even in the hand specimen, as in the western portions of the Pennsylvania railroad tunnels at Homestead, where in some of the coarse, granitic facies they constitute about one-half the bulk of the rock. Individual grains of quartz and orthoclase, and occasional microperthite up to 1 millimeter in diameter, are also observed in some instances. In many cases the apatite inclusions in the quartz-orthoclase intergrowths are strikingly abundant, sometimes to their almost total exclusion elsewhere.

Orthoclase is usually much more altered than plagioclase, being often chalky and nearly opaque from the formation of kaolinite. In more extreme cases the mineral gives place entirely to a mass of kaolinite stained brownish with iron oxides from the augite, or to a mixture of such material with secondary chlorite and magnetite from the same source. This condition is observed even in the presence of nearly fresh plagioclase (Plate XIV., Fig. 1).

Magnetite is always present, but in greatly varying amounts. Often only a few scattering small grains will be seen, but, on the other hand, it is frequently so abundant as to give a decidedly black color to the rock, and it then appears thickly sprinkled through the section. Crystals of magnetite are sometimes observed (Plate XV., Fig. 2), but most of the masses, like the augites, are irregularly molded or grouped in clusters of small grains between the plagioclase feldspars. It often partly incloses both the plagioclase and the augite (in such cases probably secondary), but is also sometimes inclosed in the latter. Magnetite is generally in smaller masses than these constituents, but in this respect also it is very variable.

EXPLANATION OF PLATE XV.

Photomicrographs of thin sections.

Fig. 1. DIABASE, ½ *mile south of Rocky Hill.* Photographed with crossed nicols; magnified 18 diameters. From the quarry near the middle of the intrusive sheet. Shows typical diabasic texture, and several small areas of micropegmatite appear indistinctly near the center of the field. Thin section No. 42–L.

Fig. 2. DIABASE, *Wayne St. and Mill Road, Jersey City.* Photographed with crossed nicols; magnified 52 diameters. Typical diabasic texture. Large augite to the right shows combined orthopinacoidal and multiple basal twinning. Micropegmatite occupies large areas in the lower central portion of the field, with an elongated octahedral crystal of magnetite. Thin section No. 22–L.

Fig. 3, DIABASE, *Devil's Half Acre, near the northeast end of Sourland Mountain.* Photographed with crossed nicols; magnified 55 diameters. Shows striated plagioclase feldspars and diabasic texture. The large central augite crystals show a combination of orthopinacoidal, multiple basal, and interpenetration twinning. Thin section No. 13–L.

Fig. 1.

Fig. 2.

Fig. 3.

Secondary magnetite from the alteration of augite and olivine is found in granules and aggregates through the decomposition products of these minerals, and sometimes clustered about the original magnetite grains. Secondary magnetite being one of the first products of incipient decomposition of the augite, it is almost universally present in greater or less amount, and it is often quite impossible to distinguish it with certainty from magnetite of primary origin. It seems quite probable, however, that the masses of magnetite molded about the feldspars and augites described above are largely secondary.

Biotite is often present in small amount, especially in the finer-grained contact facies of the diabase, and is sometimes clustered about the magnetite of the coarser-grained rock in large irregular flakes. It is strongly pleochroic, deep reddish-brown for light polarized parallel to the cleavage, and light yellow at right angles to this direction. In diagonal position a distinct purplish tinge is shown. Biotite is also often secondary after augite, and is itself partly altered in turn to green chlorite.

Olivine is entirely absent from the great bulk of the Palisade diabase. It occurs in small amounts, however, near the contacts with the inclosing strata, both above and below (Plate XVI., Fig. 2), and is exceptionally abundant in the olivine-diabase ledge of the Palisades, constituting as much as 15 per cent. of the whole. In the finer-grained border facies of the rock olivine occurs in scattering porphyritic crystals, which sometimes exhibit resorption phenomena in rounded and embayed outlines. Corrosion mantles or "reaction rims" of radial enstatite sometimes surround the larger crystals (Plate XVI., Fig. 2), and nest-like aggregates entirely replace some of the smaller ones. In these fine-grained portions of the rock olivine is usually altered, wholly or in part, to yellowish or yellowish-brown serpentine. In striking contrast with this, it is found in the olivine-diabase ledge, in numerous perfectly fresh crystals and irregular grains, which are inclosed largely in the feldspars, though occasionally also in the augite (Plate XIII., Fig. 2). As compared with the coarse-grained texture of this rock, the olivines are relatively small, ranging up to 0.3 millimeter by 0.7 millimeter in prismatic sections, which is less than one-fourth the usual size of the augite and feldspars. They also retain a striking freshness and transparency even when the augites have reached an advanced stage of alteration.

EXPLANATION OF PLATE XVI.

Photomicrographs of thin sections.

Fig. 1. Basaltic diabase, *west end of the N. Y., S. & W. R. R. tunnel through the Palisades, near Fairview.* Magnified 42 diameters. The fine-grained porphyritic facies at the contact, showing the diabasic texture of the dense groundmass of elongated feldspars and granular augite. Augite phenocrysts appear to the left. Thin section No. 85–L.

Fig. 2. Diabase, *same thin section as Fig. 1.* Magnified 42 diameters. Shows a serpentine pseudomorph of a large olivine phenocryst in the middle, surrounded by a thick sheath of fine-grained enstatite, biotite and magnetite.

Fig. 3. Diabase, *just north of Granton.* Magnified 42 diameters. Fine-grained rock near the bottom contact in the quarry. Shows a rounded, unstriated feldspar in the center, surrounded by a mantle of augite, biotite and black oxide granules. Nest-like aggregates of these minerals occur in other parts of the section without the central remnant of feldspar. Thin section No. 62–L.

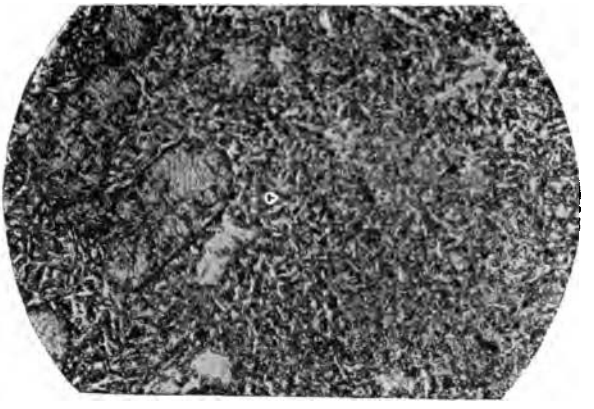


Fig. 1.

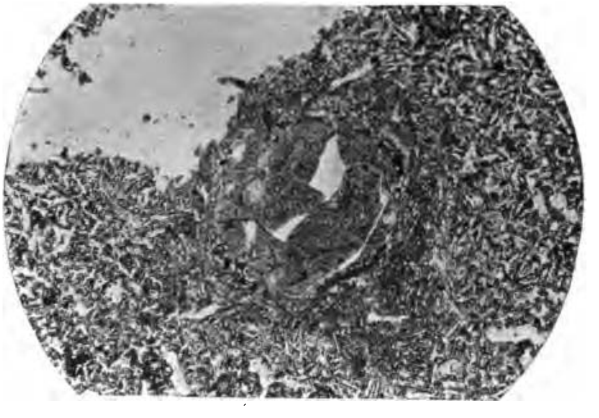


Fig. 2.

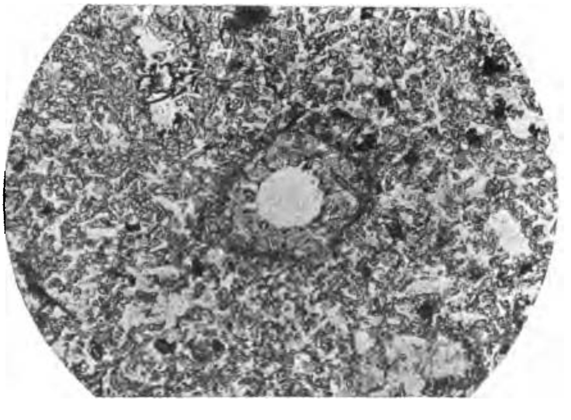


Fig. 3.

Apatite, which has been named as an inclusion occuring chiefly in the feldspars and quartz, is always in well formed prismatic crystals, ranging from very minute up to 1 millimeter in length and 0.06 millimeters in diameter, a size prominently visible with even the lowest powers of the microscope. It is always most abundant in the feldspars and quartz, sometimes chiefly in the plagioclase, sometimes in the quartz-orthoclase intergrowths, and seldom occurs in the other constituents.

Pyrite and chalcopyrite are rarely seen in the thin sections of the diabase. Rutile occurs occasionally in minute slender needles in the micropegmatite, but it has been found in relative abundance in only one place, namely, in the coarse trap adjacent to the sandstone inclusion at Marion, Jersey City.[*] Here the minute slender needles in radial tufts and confused tangled aggregates, are quite numerous in the graphic intergrowths of quartz and orthoclase.

Composition of the Augite.—Analyses of the augite from this rock at Rocky Hill[1] and from the similar intrusive diabase at West Rock, New Haven, Conn.,[2] yielded the following results:

Analysis of augite from the intrusive diabase.

	I.	II.	III.
SiO_2	47.72	48.54	50.71
Al_2O_3	3.44	5.50	3.55
Fe_2O_3	5.93	2.77	n.d.
FeO	18.34	21.25	15.30
MgO	12.89	7.67	13.63
CaO	11.40	10.97	13.35
Na_2O	0.86		
		3.10	1.48[3]
K_2O	0.37		
MnO	n.d.	n.d.	0.81
Ign.	0.00	0.82	1.17
	100.95	100.62	100.00

I. Rocky Hill. Quarry near the middle of the trap. A. H. Phillips, analyst. (Rock analyses No. XIII., p. 121.)

II. Rocky Hill. Old quarry near station, about 420 feet from the upper contact. A. H. Phillips, analyst. (Rock analysis No. XI., p. 121.)

III. New Haven, Conn. From West Rock, a very similar intrusive diabase. G. W. Hawes, analyst. (Rock analysis No. XIV., p. 121.)

[1] A. H. Phillips, Am. Jour. Science, Vol. VIII., 1899, p. 267.

[2] G. W. Hawes, Am. Jour. Science, Vol. IX., 1875, p. 185.

[3] By difference.

In the great excess of ferrous iron and magnesia over lime, alumina and ferric iron, these analyses indicate quite exceptional composition for augite, corresponding to combinations of the hypothetical pyroxene molecules in the following proportions:

[*ac*=acmite, $NaFe(SiO_3)_2$, *hy*=hypersthene, $(Mg,Fe)SiO_3$ *di*=diopside, $Ca(Mg,Fe)(SiO_3)_2$, *al*= $(Mg,Fe)(Al,Fe)_2SiO_6$.]

	ac	hy	di	al		ac	hy	di	al			ac	hy	di	al
I.	108:	640:	816:	159	=	1:	5.93:	7.56:	1.47	=	(approx.)	2:	12:	15:	3
II.	270:	530:	784:	81	=	3.33:	6.54:	9.68:	1	=	"	7:	13:	19:	2
III.	126:	522:	956:	69	=	1.83:	7.72:	13.86:	1	=	"	2:	8:	15:	1

Composition of the Feldspar.—Analyses of the feldspars have also been made from the same localities, Rocky Hill,[1] N. J., and West Rock,[2] New Haven, Conn., with the following results:

Analyses of Feldspars from the Intrusive Diabase.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Sp. Gr.	>2.69	<2.69	>2.69	<2.69	<2.60	=2.577	>2.69	<2.69
SiO_2	53.84	62.26	66.84	71.68	66.28	66.79	52.84	60.54
Al_2O_3	29.30	21.87	17.98	15.02	16.79	19.36	28.62	24.11
Fe_2O_3	0.81	0.54	2.60	2.48	1.60	0.91	1.52	1.14
MgO	0.28	0.15	0.48	0.12	0.13	0.13	0.46	0.27
CaO	10.08	6.53	5.02	3.86	0.71	0.80	11.81	9.15
Na_2O	5.31	7.98	5.46	5.52	9.76	7.34	2.38	4.11
K_2O	1.16	1.20	1.72	1.37	5.31	4.95	0.86	1.06
Ign.	0.44	0.32	0.72	0.00	0.49	....	1.06	0.59
	101.22	100.85	99.82	100.05	101.07	100.28	99.55	100.97

I., II. Rocky Hill. Quarry near the middle of the trap. A. H. Phillips, analyst. (Analysis of the rock, No. XIII., p. 121.)

III., IV., V., VI. Rocky Hill. Old quarry near station. A. H. Phillips, analyst. (Rock analysis No. XI., p. 121.)

VII., VIII. New Haven, Conn., West Rock. G. W. Hawes, analyst. (Rock analysis No. XIV., p. 121.)

Nos. I. and II. constituted 32.2 per cent. and 14.3 per cent., respectively, of the rock from which they were separated. Nos. III. to VI. occurred in the following amounts: Specific gravity above 2.69, 23.1 per cent.; below 2.69, 13.4 per cent.; below 2.60, 6.5 per cent.

[1] A. H. Phillips, Loc. cit.

[2] G. W. Hawes, Loc. cit.

Reckoning the potash as orthoclase, and assigning soda and lime to the end molecules of the plagioclase series, albite and anorthite, these analyses correspond to the following mineral composition:

Mineral Constitution of the Feldspars.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Quartz	0.0	0.0	20.6	26.0	6.4	2.4	7.7	11.0
Orthoclase	7.1	7.2	10.0	8.2	24.8	30.0	5.0	6.1
Albite	44.5	67.1	45.8	46.0	62.3	60.8	20.5	34.4
Anorthite	43.1	19.8	19.8	11.2	3.3	3.9	58.5	43.7
Augite	0.0	5.0	0.0	7.0	0.8	0.0	0.0	1.3
Ores	0.1	0.0	2.6	1.6	1.4	0.9	1.3	0.5
Kaolin	3.2	0.0	0.0	0.0	0.0	1.7	5.7	2.5
Carbonates	2.0	0.9	1.2	0.0	1.0	0.8	1.3	0.5

Omitting the non-feldspathic constituents, and recalculating to 100 per cent., the following values are obtained:

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Orthoclase	7.5	7.7	13.2	12.6	27.4	31.7	6.0	7.2
Albite	47.1	71.3	60.6	70.3	68.9	64.2	24.4	40.9
Anorthite	45.4	21.0	26.2	17.1	3.7	4.1	69.6	51.9

Designating the albite molecule, $NaAlSi_3O_8$, by *Ab*, and the anorthite molecule, $CaAl_2Si_2O_8$, by *An*, the soda-lime constituents correspond very nearly to the following molecular ratios:

I. Ab_1 An_1 = Labradorite.
II. Ab_7 An_2 = Oligoclase.
III. Ab_5 An_2 = Andesine.
IV. Ab_4 An_1 = Oligoclase.
V. Ab_{20} An_1 = Albite.
VI. Ab_{17} An_1 = Albite.
VII. Ab_3 An_9 = Labradorite.
VIII. Ab_5 An_6 = Labradorite.

Order of crystallization.—From the prevailing diabasic or ophitic texture of the intrusive diabase it is evident that the crystallization of the plagioclases was quite generally completed before that of the augite. In the granitoid portions of the rock, however, they have formed more nearly simultaneously, each interfering with the crystal outlines of the other. Moreover, the presence of numerous plates of porphyritic augite in the fine-grained contact facies of the rock, with only rarely a large feldspar, indicates that crystallization had begun before intrusion under conditions that would have led to the formation of the minerals in their usual order in igneous rocks, namely, the augite before the feldspars. Olivine, as shown by its crystalline form and by its indifference to the other constituents, was one of the first minerals to crystallize; orthoclase and quartz were the last. Apatite has usually been formed very early, as shown by its frequent abundance in the plagioclases, but its presence sometimes chiefly in the orthoclase and quartz would indicate that in these cases it has been among the latest products of the cooling magma, forming at least after the plagioclase and augite.

Chemical composition of the diabase.—The range in chemical composition of the intrusive diabase is presented in the analyses of the subjoined table, in which are included for comparison analyses (XIV.–XVI.) of the corresponding intrusive sill and a thin acid dike[1] in the Connecticut Valley Triassic, and the closely similar Antarctic rock described in the footnote on page 109.

[1] The little fine-grained dike described by E. O. Hovey (*Am. Jour. Sci.*, 4th Ser., Vol. III., 1897, pp. 287–292) is the most acidic igneous rock yet observed in the Newark formation. The thin sections showed almost a purely feldspathic rock without augite or recognizable quartz. The high soda and alumina and the low potash, lime and iron are also in striking contrast with the acid facies of the Palisade sill represented by analyses I. and XI.

Analyses of the intrusive diabase.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.
SiO_2	60.05	51.34	53.13	51.88	50.40	52.48	49.62	51.14	51.03	49.02	56.78	51.46	50.34	51.78	60.13	53.26
Al_2O_3	11.88	12.71	13.75	14.53	15.60	14.98	10.51	12.99	11.92	10.14	14.33	13.98	15.23	14.20	20.47	15.64
Fe_2O_3	3.22	2.65	1.07	1.35	3.65	1.13	0.64	1.50	1.52	1.54	5.76	2.66	2.82	3.59	1.04	0.24
FeO	10.21	14.14	9.10	9.14	6.30	9.25	12.02	9.14	10.85	10.46	9.27	8.92	11.17	8.25	0.72	7.44
MgO	0.85	3.66	8.57	7.78	6.08	7.75	15.98	11.58	12.08	17.25	1.58	7.59	5.81	7.64	1.15	8.64
CaO	4.76	7.44	9.47	9.98	10.41	10.83	7.86	10.08	9.22	8.29	5.26	10.49	9.61	10.70	2.59	12.08
Na_2O	4.04	2.43	2.30	2.06	2.57	1.87	1.40	1.72	1.50	1.59	3.43	4.75 (Na₂O + K₂O)	2.93	2.14	9.60	1.25
K_2O	2.10	1.44	1.04	0.93	0.62	0.43	0.55	0.52	0.39	0.40	1.75		1.02	0.39	1.06	0.58
H_2O+	0.66	0.69	0.90 (H_2O+ and H_2O-)	0.97	1.67	0.23	0.49	0.59	0.54	0.59	0.10	......	0.07	0.63 (H_2O+ and H_2O-)	3.44† (H_2O+ and H_2O-)	0.41
H_2O-	0.21	0.18		0.12	1.02	0.18	0.33	0.14	0.17	0.16	0.33	......	0.19			0.35
TiO_2	1.74	3.47	......	1.35	1.35	1.30	1.01	1.13	0.93	0.99	1.44	1.06	1.56	*	tr.	0.70
P_2O_5	0.52	0.20	......	0.14	0.16	0.13	0.16	0.06	0.08	0.11	0.36	0.17	0.20	0.14	......	0.04
MnO	0.28	0.36	0.44	0.10	0.06	0.27	0.09	0.16	0.15	0.16	0.25	......	0.14	0.43	tr.	0.11
	100.52	100.71	99.77	100.33	99.89	100.83	100.71	100.75	100.38	100.70	100.64	101.08	101.09	99.89	100.20	100.74
Sp. Gr.	2.872	3.089	2.96	2.98	2.89	3.110	3.118	3.051	3.122	3.152	......	......	2.968	3.03	2.63	......

* Dr. Howe determined TiO_2 from West Rock 1.41.
† CO_2 and H_2O.

I. Quartz-diabase, Pennsylvania railroad tunnel, Homestead, about 400 feet from western portal. (Anal. No. 119; specimen and thin section No. 315L.) R. B. Gage, analyst.

II. Quartz-diabase, Jersey City, Pennsylvania railroad cut near Marion Station. Coarse-grained rock. (Anal. No. 35; specimen and thin section No. 15L.) R. B. Gage, analyst.

III. Diabase, Jersey City, railroad cut. G. W. Hawes, analyst.[1]

IV. Basaltic diabase, Weehawken, lower contact in Pennsylvania railroad tunnels. (Anal. No. 129; specimen and thin section No. 314L.) R. B. Gage, analyst.

V. Basaltic diabase, New York, Susquehanna and Western railroad tunnel, upper contact at western portal. (Anal. No. 126; specimen and thin section 85L.) R. B. Gage, analyst.

VI. Diabase, Weehawken, road to West Shore Ferry. Fine-grained rock in the midst of the olivine diabase ledge. (Anal. No. 72; specimen and thin section No. 111L.) R. B. Gage, analyst.

VII. Olivine-diabase, Weehawken, road to West Shore Ferry. Typical coarse-grained olivine diabase. (Anal. No. 34; specimen and thin section No. 101L.) R. B. Gage, analyst.

VIII. Diabase, Englewood Cliffs, below the olivine-diabase. (Anal. No. 113; specimen and thin section No. 305L.) R. B. Gage, analyst.

IX. Diabase, Englewood Cliffs. Coarse-grained rock, above the olivine-diabase. (Anal. No. 114; specimen and thin section No. 306L.) R. B. Gage, analyst.

X. Olivine-diabase, Englewood Cliffs. Typical coarse-grained olivine-diabase. (Anal. No. 115; specimen and thin section No. 307L.) R. B. Gage, analyst.

XI. Quartz-diabase (?), Rocky Hill. Old quarry near railroad station, about 420 feet from upper contact; very coarse-grained. A. H. Phillips, analyst.[2]

XII. Basaltic diabase, Rocky Hill. Fine-grained diabase, near the lower contact. A. H. Phillips, analyst.

XIII. Diabase, Rocky Hill. Coarse-grained rock from the quarry near the middle of the sheet. A. H. Phillips, analyst.

XIV. Diabase, West Rock, New Haven, Conn. G. W. Hawes, analyst.

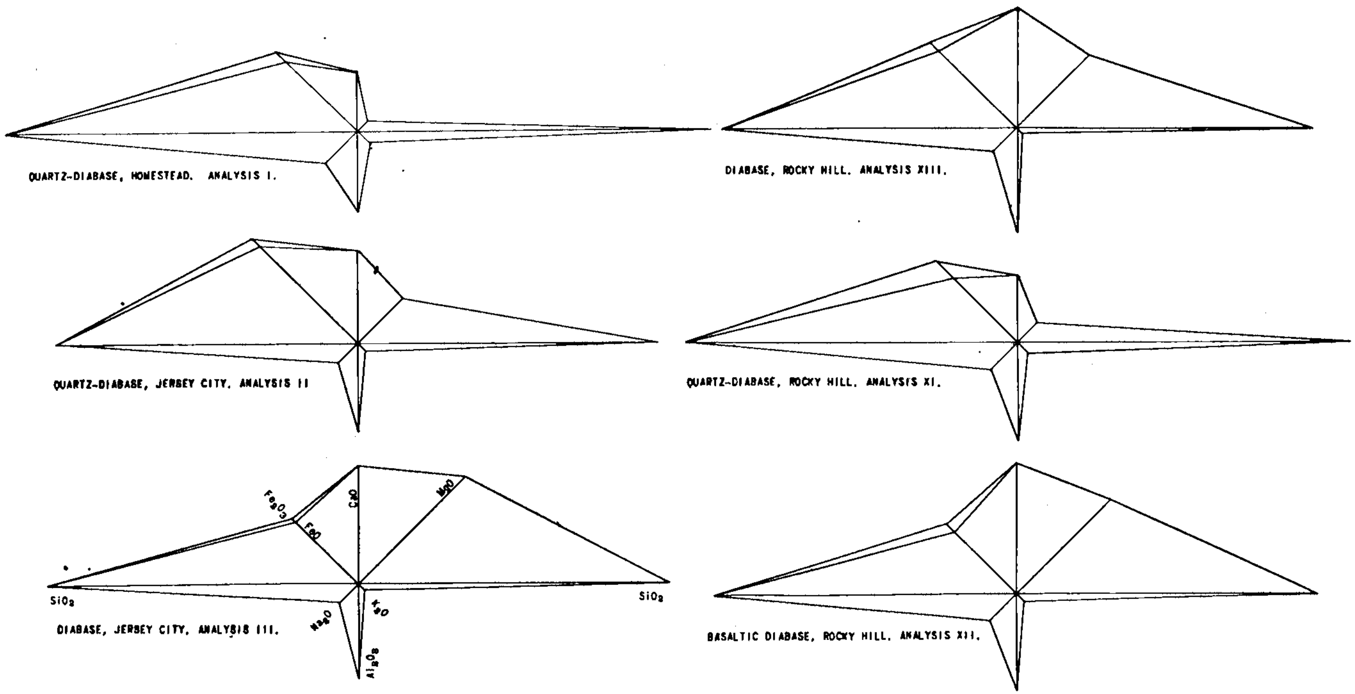
XV. Keratophyre dike, Fair Haven, Conn. H. S. Washington, analyst.

XVI. Quartz-diabase, Kukri Hills, King Edward VII. Land (Antarctic).

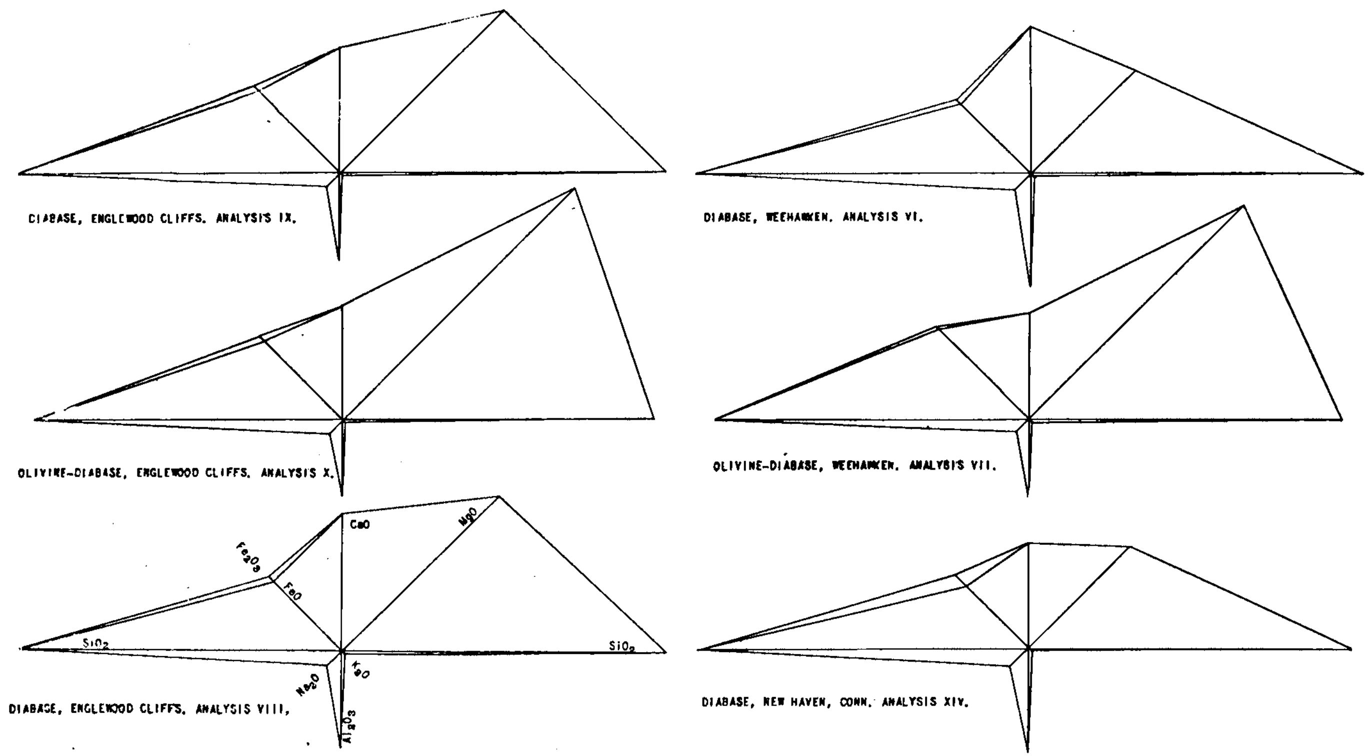
In general, alumina, ferric iron and the alkalis (soda and potash) vary with the silica, while ferrous iron, lime and magnesia vary inversely. The greatest differences occur in magnesia, which ranges from 0.85 per cent. in analysis I. to 17.25 per cent. in

[1] "The Trap Rocks of the Connecticut Valley." G. W. Hawes, Am. Jour. Sci., IX., 1875, pp. 185–192.

[2] "The Mineralogical Structure and the Chemical Composition of the Trap of Rocky Hill, N. J.' A. H. Phillips, Am. Jour Sci., VIII., 1899, pp. 267–285.



Diagrams illustrating the composition of various facies of the diabase. (Compare Plate XVIII.)



Diagrams illustrating the composition of various facies of the diabase. (Compare Plate XVII.)

analysis X. These relations are clearly expressed by the diagrams (Plates XVII., XVIII.). Chemically these rocks overlap the andesite-diorite series, on the one hand, and the most basic olivine-gabbros on the other, and the extremes are characterized by abundance of quartz and olivine, respectively.

Mineral composition.—The mineral constituents of the intrusive diabase, as described above, are quartz, orthoclase, plagioclase, augite, biotite, olivine, magnetite, apatite. The proportions of these minerals vary greatly with the varying chemical composition of the rock. Augite and the plagioclase feldspars usually constitute the great bulk of the rock, but all of the others, except apatite, attain rather notable abundance in certain portions. The mineral constitution of seven specimens has been determined by micrometer measurements of thin sections, with the following results:

Mineral constitution of the intrusive diabase.

	I.	II.	III.	IV.	V.	VI.	VII.
Quartz	19	7	..	..	..	..	..
Feldspar	44	42	37	30	20	38	26
Augite	27	34	59	63	73	46	56
Biotite	3	..	..	..	1	1	1
Olivine	..	..	1	5	4	13	16
Ores	6	17	3	2	2	2	1
Apatite	1	..	..	..	..	..	..

I. Homestead, Pennsylvania R. R. tunnels, 400 feet from west end.
II. Marion Station, Jersey City, coarse-grained rock 420 feet east of platform.
III. Englewood Cliffs, immediately below the olivine-diabase.
IV. Englewood Cliffs, immediately above the olivine-diabase.
V. Weehawken, apparently intruded into the olivine-diabase, in roadside near West Shore ferry.
VI. Weehawken, road near West Shore ferry, olivine-diabase.
VII. Englewood Cliffs, olivine-diabase.

Nos. I. and II. are typical coarse-grained quartz-diabase and gabbro, such as constitute the great bulk of the intrusive sill. The maximum quartz content probably does not greatly exceed that of No. I., the minimum drops to zero, and the average is probably below that of No. II. Nos. VI. and VII. are typical olivine-diabase, and III., IV. and V. are intimately associated with it.

Considering the diabase as a whole quartz is a far more frequent constituent of the rock than olivine, since it occurs quite generally in the coarser-grained portions that make up the bulk of the sill. It is usually found in small amount even immediately above the highly olivinic ledge and in the dike-like and irregular masses of normal diabase that penetrate it, while above this level it is almost universal. Olivine occurs somewhat sparingly in the denser contact facies, and is very abundant only in the olivine-diabase ledge, but sometimes the rock immediately above and below it is also fairly rich in this mineral.

Classification.—The range in mineral composition in the intrusive diabase would be designated in the older terminology by the names *quartz-diabase, diabase* and *olivine-diabase*, the prefixes quartz and olivine denoting special richness in these minerals in the most acidic and most basic portions of the rock, respectively. As already indicated, most of the coarse-grained rock, which constitutes the great bulk of the intrusive sill throughout the State, is somewhat quartzose, this mineral being quite generally present in graphic intergrowth with orthoclase, and to this extent it is not a typical diabase.

In the quantitative classification,[1] as shown in the summary below, eleven of the diabase analyses fall into Class III. (salfemane) and Order 5 (perfelic). Part of these, however, belong to Rang 3 (alkalicalcic) and Subrang 4 (dosodic), and are designated as *camptonose,* while the others go over into Rang 4 (docalcic) and Subrang 4, 5 (presodic), under the name *auvergnose.* Since these subrangs differ only in the relative amounts of alkalis and lime in the normative feldspars, the rocks are very closely similar.

Of the four remaining analyses, two belong to the much more acid Class II. (dosalane) and the other two to the more basic Class IV. (dofemane). The latter fall into a subrang as yet unnamed in the quantitive classification, and it is therefore proposed that rocks of the symbol IV.1².1².2. be designated as *palisadose,* from their typical development in the olivine-diabase ledge of the Palisades.

[1] "Quantitative Classification of Igneous Rocks." By Cross, Iddings, Pirsson, and Washington. Chicago, 1903.

The two extremes, dacose and palisadose, as their analyses and symbols indicate, are considerably removed from each other, corresponding in chemical composition to highly quartzose and olivinic diabases, respectively, under the old nomenclature.

Summary of Quantitative Classification.[1]

Name.	*Symbol.*	*Analyses.*
Dacose	II.4.2.4.	I
Tonalose	II.4.3.4.	XI
Camptonose	III.5.3.4.	II, XII, XIII
Auvergnose	III.5.4.4,5.	III–VI, VIII, IX, XIV, XVI
Palisadose	IV.1².1².2.	VII, X.

The olivine-diabase ledge.—As already explained in casual references to this rock, it is the crumbling, deeply weathered rock which forms a layer 10 to 20 feet thick in the midst of the hard resistant diabase about 40 to 60 feet above the base of the Palisades (Plates XIX., XX., XXI.). It is first clearly seen at the quarry on Paterson Plank Road, Jersey City. Thence northward, it is more or less conspicuous wherever this part of the sill is exposed at least as far as Alpine, a distance of about 20 miles. Where the natural face of the rock has been removed in quarries and in road and railroad cuts, the friable, disintegrating character disappears at once, and within a few inches of the weathered surface this layer seems as hard and tough as the other parts of the sill.

The basal portions of the sill are not exposed in cliffs along Rocky Hill and Sourland Mountain, and hence, it is not known whether such a distinct layer of olivine-diabase occurs in these portions or not. By analogy one would expect to find it even with less satisfactory evidence of their physical continuity.

The boundaries of this olivine-diabase are somewhat variable. Sometimes there is a gradual transition into the normal rock above and below, while at others there seems to be quite a sharp demarcation (Plate XXI., Fig. 1). The latter is usually the case where

[1] The highly sodic feldspathic dike from Connecticut, analysis XV., is not included here, since no similar rock has been found in the area under investigation. Dr. Hovey described it provisionally as a keratophyre, and its position in the quantitative system is indicated by the symbol I.5.2.5., which is a persodic pulaskase.

the subjacent rock is all fine grained, this layer being the first coarse texture encountered above the base. In such cases there is often an irregular interpenetration of these facies, and at times the semblance of a dike or apophysis of the finer texture, penetrating the olivine-diabase (Plate XX., Fig. 2).

Kümmel[1] suggested that this rock is probably of different mineral and chemical composition, and this is borne out by microscopic examination of thin sections (see Plate XIII., Fig. 2; Plate XVIII.; and analyses VII. and X., p. 121). It differs from the great body of the sill in the absence of the usual graphic intergrowth of quartz and orthoclase, and in the presence of abundant olivine in small, perfectly fresh crystals and rounded grains which are only about one-fourth the size of the other constituents, ranging up to a maximum of 0.3 mm. by 0.7 mm. in prismatic sections. Great numbers of these are inclosed in the feldspars, but they also occur occasionally in the augite (Plate XIII., Fig. 2). Their complete inclosure has apparently protected them from alteration, for they retain a notable freshness and clearness even in the presence of considerable decomposition of the augites. Another character of the olivine-diabase is the occasional presence of more resistant streaks and irregular areas within its mass. These, where exposed in the midst of the crumbling weathered surface, often closely resemble dikes (Plate XX., Fig. 2). Microscopic examination shows that they are sometimes normal diabase with a small amount of olivine, like the rock immediately below (and in places above also), and sometimes they are even quartz-diabase, such as forms the great bulk of the overlying mass.

The universally decomposed character of the natural outcrops of this olivine-diabase seems to be due primarily to the disruption of the inclosing feldspar by the expanding of the olivine in the first stages of its change to serpentine. The beginnings of the process are evidently of the nature of mechanical disintegration rather than decomposition, and in favorable situations considerable quantities of coarse granular debris accumulate. It is apparently only after long exposure that this passes into a fine pulverulent, clayey mass of a yellowish brown color.

Contact facies of the diabase.—The trap at the upper and lower

[1] Annual Report of the State Geologist for 1897, p. 72.

Crumbling olivine-diabase ledge and talus, with solid diabase above and below. Weehawken.

Fig. 1. Olivine-diabase ledge in railway cut back of Fort Lee. The normal diabase above shows typical rectangular jointing.

Fig. 2. Olivine-diabase penetrated by normal diabase (above hammer and downward to the right). Weehawken.

Fig. 1. Upper boundary of olivine-diabase, with normal diabase above. Englewood Cliffs.

Fig. 2. Lower contact of Palisade diabase on sandstone (arkose), Pa. R. R. tunnels, Weehawken, 50 feet below mean high tide. The diabase exhibits the typical rectangular jointing. (Reproduced by courtesy of Chas. M. Jacobs, Chief Engineer.)

contacts, which are exposed in many places along the Palisades, is always exceedingly dense (aphanitic) and of a dark grayish to brownish black color. Without the microscope no crystalline structure is visible, but a distinct minute banding resembling flow-structure is sometimes seen in the thin sections. At a distance of a few feet from the contact, however, the granular character of the rock is clearly seen, but usually the individual minerals cannot be recognized within 20 to 40 feet of the contacts. Here the fine-grained rock either passes gradually into the coarse, or else it suddenly gives place to this facies at the base of the olivine-diabase ledge.

The extreme toughness of this dense contact facies is well illustrated by the difficulties encountered in the excavation of the Pennsylvania Railroad tunnels. For a horizontal distance of about 200 feet (corresponding to a thickness of about 50 feet) from the base of the sheet at Weehawken, it is said that the drills could penetrate the rock only about one-fourth or one-fifth as fast as in the normal diabase under similar conditions.

Microscopically, even the dense aphanitic contact facies of the diabase seems to be wholly crystalline, or at most to contain no more than a minute remnant of glass (Plate XVI., Figs. 1, 2). Scattered through the groundmass of slender lath-shaped feldspars in ophitic texture with granular or massive augite, are often larger well formed crystals and plates (phenocrysts) of augite and olivine, the latter often partly or wholly altered to yellowish and brownish serpentine. Biotite is also a frequent constituent, sometimes occurring in minute flakes in the ground mass, sometimes as much larger porphyritic flakes, comparable in size with the larger augites and olivines.

Frequently the olivine phenocrysts, and less commonly the augites, have been more or less rounded and etched into irregular embayed forms by corrosion, due to the dissolving action of the magma after the crystals were formed. In case of the olivines sometimes the dissolved material has recrystallized about the remaining portions in the form of a radial sheath of enstatite and biotite with grains of magnetite (Plate XVI., Fig. 2). These are further discussed under the subject of differentiation.

The blackish color of the dense contact facies seems to be in a large measure due to an abundance of minute magnetite granules throughout the rock, and these, both large and small, are often surrounded by biotite.

Nephelite-syenite at Brookville.—F. L. Ransome[1] has described nephelite-syenite and other syenitic and granitic rocks that occur in small scattered areas in the intrusive diabase near Brookville, on the Delaware river. From data then available the relations of these rocks were quite obscure, but Mr. Ransome concluded that, on the whole, it seemed most likely that the masses are included fragm[illegible]nts [illegible]ught up i[illegible] the trap magma at the time of its intrusion. H[illegible] the question, however, as an open one, requiring furthe[illegible] with other and better exposures.

These rocks are now under investigation, and it is hoped that, with the aid of recent quarry excavations, their exact relations to the intrusive diabase may be [illegible]termined.

Dikes and apophyses.—Numerous dikes and sheets from 1 inch to 4 feet in thickness branch off from the great sill of diabase into the shales and sandstones beneath (Plates XXII., XXIII.). These are exposed at many localities, most of which have been described by Kümmel.[2] Few upper contacts have been found accessible and at none of these have dikes been observed. There are, however, numerous dikes in the overlying strata in the vicinity of all the larger outcrops of this rock from the Hudson to the Delaware. Kümmel has traced some of these to their junction with the main sill on Sourland Mountain, and there is little doubt that all of them are thus connected in depth. The larger oval and irregular masses also, as at Granton, the Snake Hills, Griggstown and Moores on the Delaware River, are to be regarded as apophyses, connected at comparatively shallow depths with the same intrusive sill.[3]

In density and color the dikes and the contacts of the apophyses are like the contact facies of the main mass of the diabase. Under the microscope some of the thinnest dikes and sheets, those less than 6 inches in thickness, are found to contain considerable quantities of brownish glass, which is sometimes nearly black with dust-like granules of magnetite. Otherwise they consist of an ophitic ground mass of slender plagioclase feldspars and augite, sprinkled

[1] Am. Jour. Science, Vol. VIII., 1899, pp. 417–426.

[2] Annual Report of the State Geologist for 1897, pp. 63–65, 68, 69, 92.

[3] J. Volney Lewis, Annual Report of the State Geologist for 1906, pp. 117–121.

Fig. 1. Thin intrusive sheet 1 foot below the base of the Palisade sill, Coytesville. The diabase above shows typical rectangular jointing.

Fig. 2. Intrusive sheet (*d*, *d*) branching off from the Palisade diabase (*D*) into the white underlying sandstone (arkose). Guttenburg.

Fig. 1. Base of Palisade sill (*D*) with 3 intrusive sheets (*d*, *d*, *d*) in underlying sandstone and shale. Foot of Palisades, 2 miles east of Englewood.

Fig. 2. Dike in red shale, ⅓ mile north of Blackwell's Mill. The shale at the left has been bleached 4 or 5 feet from the contact by percolating waters.

with porphyritic crystals of olivine and augite, as in the contacts of the main sill. The coarser central masses of the apophyses consist of typical quartz-diabase, exactly like that of the main body of the sill, having a coarse ophitic to granitic texture and being characterized by the absence of olivine and the constant presence of a notable amount of quartz and orthoclase in graphic intergrowth.

Differentiation.—Inasmuch as the several types of rocks above described occur as continuous portions of a single intrusive sill, they must be regarded as together constituting a unit. There is no evidence that they are products to any extent whatever of separate intrusions, or even of successive pulsations of an extended period of injection. Their present constitution and relations are best understood as the results of differentiation, or separation of the constituents of the molten magma after its intrusion and during the long period required for cooling and solidification.

The thickness of the sill or intrusive sheet varies considerably in its 100 miles of outcrop in New York and New Jersey, but it is everywhere several hundred feet thick, and in places, as along the Palisades above Weehawken, and in the thicker parts of Rocky Hill and Sourland Mountain, it approximates 1,000 feet. Under cover of a great blanket of overlying shales and sandstones, probably many times its own thickness at the time of intrusion, though since partly removed by erosion, this highly-heated molten magma cooled very slowly, and probably remained in a liquid condition for a considerable period. The only exceptions to this are the immediate contacts with the inclosing strata, which must have been quickly chilled; on the other hand, the adjacent shales and sandstones themselves also became highly heated, and subsequent cooling was probably slow. The surrounding rocks are poor conductors of heat, and once a crust had formed, and the strata at the contact were well heated, the inclosed liquid mass became in a measure insulated. Under such conditions the outer crust of the magma would very slowly thicken until the whole mass became solid.

Professor Iddings' conclusion[1] that the process of differentiation which gives rise to variations in the character of different parts of such a magma "must be of a chemico-physical nature;" that is, a chemical process resulting from varying physical conditions, espe-

[1] Bulletin Phil. Soc. Washington, Vol. XII., p. 194.

cially temperature, is doubtless true in most cases, and probably to some extent in all, but in the present state of our knowledge, it seems scarcely justifiable to exclude entirely the possibility of purely physical causes acting alone. This applies particularly to the settling of heavier crystals in the more basic magmas, which are highly fluid, and might well remain so long enough for such a process to produce considerable effect. In fact, the extent of such gravitation of the heavier minerals may be regarded as a measure of the degree and duration of liquidity after the beginning of crystallization, and the absence of such effects only as evidence that the particular magma had become too viscous to permit effective differentiation from this cause.

Further, the time of crystallization of a particular mineral is held to have some definite relation to its concentration in the solution, and this seems to imply that the definite molecular group exists as the point of saturation is approached, ready to crystallize when that point is reached. In acid magmas the proportion of basic constituents is small, and saturation would occur only at a correspondingly lower temperature than in those basaltic magmas that carry basic substances in large amounts. Hence the crystallization of magnetite and augite in rhyolite, for example, would probably not take place before the whole magma had cooled to a highly viscous condition, particularly as this condition would occur at a comparatively early stage of cooling in the more difficultly fusible siliceous solvent.

The basaltic magma, on the other hand, with its low melting point and its high content of dissolved basic constituents, would reach the point of saturation for some of these (magnetite and olivine, for instance) at comparatively high temperatures and while the lava is still quite fluid. If such minerals crystallize any considerable length of time before the other constituents, the magma remaining liquid, their concentration in the lower parts of the mass by gravitation must result as a mechanical necessity, unless there are eddies or other currents sufficiently strong to prevent; and such currents would probably prevent differentiation by any process, in the parts affected. In many rocks the ore grains are much smaller than the silicate minerals, and would therefore offer greater resistance to settling through the magma. In such cases gravitation would affect the larger olivines particularly.

In the next stage of crystallization, there would undoubtedly be the same tendency for the augite crystals to sink and the feldspars to rise toward the top of the sheet, but by this time the increasing viscosity of the magma and the clouds of new minerals forming would doubtless prevent any extensive segregation of these by gravitation.

The degree of concentration finally attained by this process would depend on the fluidity of the magma and the time intervening between the formation of the first minerals and the next succeeding stages of crystallization. Further, the position reached by such descending minerals would be determined by the viscosity of the magma toward its lower contact, that is, by the extent of cooling due to the rocks into which it was intruded.

The basic concentration forming the olivine-diabase ledge in the Palisades was not formed at the cooler contact, nor is it duplicated in the corresponding upper portions of the sill. Its formation cannot, therefore, be attributed to the action of Soret's principle or any other process of concentration due to cooling. If regarded as the result of chemical differentiation before intrusion, it must be an earlier or later injection than the accompanying diabase above and below, but its uniformly coarse texture and its great regularity in thickness and position with reference to the base of the sill would seem to preclude this hypothesis. The great overlying body of diabase, however, has been entirely freed from olivine, except at the upper contact, and this mineral has been lodged in the remarkably distinct zone of olivine-diabase, 10 to 20 feet in thickness and lying 40 to 50 feet above the base of the sill. The bulk of the diabase, however, is somewhat quartzose, but it often passes into normal diabase, and toward the contacts, into a somewhat olivinic facies, which is more basic in character, though much less so than the olivine-diabase ledge referred to above.

This relatively slight contact-differentiation may be quite reasonably attributed to the operation of Soret's principle, that is, to the concentration of the dissolved bases in the cooler parts of the solution. This process was aided perhaps by feeble convection, by which all parts of the magma were successively brought within the range of the more effective temperature differences at the contact. Thus the bases were removed to such an extent that an excess of silica finally remained to crystallize as quartz throughout the greater part of the central and upper portions of the sill.

A hypothesis of stoping or splitting off and engulfing slabs of overlying strata, afterward assimilated by solution in the magma, has been invoked instead of some process of differentiation in explanation of certain facies of eruptive rocks.[1] In case of the Palisade diabase, however, as in some cases at least to which this theory has been applied, the process would seem to be mechanically impossible on any important scale. The diabase is 20 per cent. heavier than the inclosing strata, and unless this was more than offset by expansion in the fused mass, it would be impossible for sandstone or shale to sink into it, even if completely broken away from the parent stratum. If stoping is possible at all in such cases it must be underhand stoping, which the advocates of the hypothesis have not yet claimed.

The first formed crust, chilled quickly by contact with the cold strata at the time of intrusion, is naturally of average composition, or nearly so, with some scattering but not abundant olivine. Forty to 50 feet above the base, however, the crumbling olivine-diabase ledge, 10 to 20 feet thick, is rich in olivine and contains far more augite than feldspars. Above this the great mass of the sill, hundreds of feet in thickness, is entirely free from olivine and contains a notable, though variable, amount of quartz and orthoclase in graphic intergrowth. In a general way the upper portions of this mass are notably richer in feldspars, the lighter sodic plagioclases and orthoclase preponderating, while the lower portions abound in augite and the more calcic plagioclases prevail.

There is, however, some reason for believing that differentiation by some process had made some progress before the intrusion of the sill into its present position, and that therefore even the first chilled contacts do not quite represent the original undifferentiated magma. Evidence of this is found in the rounded and sometimes badly corroded condition of the olivine crystals in the fine-grained contact facies of the rock and in the occasional development of corrosion mantles of more acid constitution about their borders. In sections (Nos. 85L and 114L) from the contact in the western

[1] Daly, Am. Jour. Sci., Vol. XV. (1903), p. 269; Coleman, Jour. Geol., Vol. XV., p. 759.

Fig. 1. Vertical contact of diabase (on the right) with sandstone and shale, southeast side of Snake Hill.

Fig. 2. Vertical contact of diabase (on the left) with sandstone and shale, south end of Snake Hill.

Fig. 1. Vertical contact of diabase (on the right) with shale and sandstone (forming the slope to the left), west side of Snake Hill.

Fig. 2. Dike (*d*, *d*) from diabase boss, intersecting sandstone and shale, southeast side of Snake Hill.

Dikes (*d*, *d*) of diabase intersecting brown sandstone, quarry near copper mine, Arlington.

end of the New York, Susquehanna and Western Railroad tunnel, near New Durham, the larger olivines are surrounded by a narrow border consisting of radial enstatite with irregular grains of magnetite and biotite. The smaller crystals are either wholly replaced by these minerals, or nearly so. The olivine remnants are considerably altered into serpentine, and this may account for the magnetite, but the enstatite and biotite must be the result of crystallization from a more acid magma, which was in the act of dissolving the olivine when the process was stopped by intrusion and solidification, and the olivine crystals must have formed originally in a more basic magma.

The more basic products of such deep-seated differentiation, complementary to the somewhat quartzose diabase which constitutes the bulk of the intrusive sill, as well as any possible highly siliceous or granitic facies, are entirely unknown at the surface, or if known, their relations to the igneous rocks of the Newark formation have not been recognized.

Two unusual microscopic characters, which may also be regarded as evidence of earlier differentiation, were observed in certain thin sections of the dike rocks. (1) A section (No. 62L) from near the contact in the quarry at the south end of the hill at Granton shows an unbanded feldspar in large, rounded grains, presumably orthoclase, surrounded by corrosion mantles of fine granular augite and flakes of biotite (Plate XVI., Fig. 3). Other feldspars have been entirely replaced by nest-like aggregates of these minerals, and similar aggregates, apparently of exactly the same character, were observed in the rock (No. 268L) from the east side of Round Mountain. (2) A section (No. 7L) from one of the thin sheets at Martin's Dock, on the Raritan River, below New Brunswick, shows complete replacement of olivine phenocrysts by fine granular feldspar.

CUSHETUNK AND ROUND MOUNTAINS.

The trap masses of Cushetunk and Round mountains are quartz-diabase of exactly the same character as that of the main mass of the intrusive sill, but their connection with it is not so obvious as in the case of the other intrusive masses of the State, and the question whether they were intruded at the same time or somewhat earlier or later must remain in doubt. Whether or not these rocks contain a subordinate layer of olivine-diabase is uncertain, and the fact that their basal portions are deeply buried in debris would make it difficult if not impossible to determine. That they are undoubtedly parts of the same magma, however, and the fact that they represent the same stage of differentiation as the great bulk of the larger sill, lends probability to the hypothesis of contemporary intrusion.

INCLUSIONS IN THE PALISADE DIABASE.

With the exception of an occasional mention of shale inclusions near the base of the sill, as in Hoboken, by Darton,[1] and at Linnwood, by Kümmel,[2] these seem largely to have escaped observation heretofore. This is particularly true of the extraordinary dike-like inclusions of arkosic sandstone described below, which constitute practically a new set of phenomena for this region.[3]

Slabs or sheets of the sedimentary strata into which the igneous rocks were injected have been frequently split off and engulfed in the molten magma in masses varying from a few inches to many feet in thickness. The first step in such a process is seen in Plate XXII., Fig. 1, where a thin sheet of the diabase has followed a bedding-plane about a foot below the base of the main sill. If any portion of the intervening sedimentary bed had broken or parted along a joint-plane and the edge had tilted up somewhat against the flow of the intruding magma, it would have been raised by the current to a more steeply inclined or even vertical position. Such sedimentary inclusions are found in the Palisades at several localities in addition to that referred to above.

[1] Bulletin U. S. Geological Survey No. 67, 1890, p. 45.

[2] Annual Report of the State Geologist for 1907, p. 66.

[3] Ransome has described (Bulletin U. S. Geological Survey No. 303, p. 47) inclusions of tabular basalt slabs in rhyolite at Bullfrog, Nev., which are remarkably similar in their mode of occurrence to some of these in the Palisades. "Some of these are irregular. Others are thin tabular bodies which stand nearly vertical, and which, did they occur alone, might easily be mistaken for dikes. * * * That the apparent dikes are really inclusions is certain, but no satisfactory explanation has yet been found for their vertical attitude in a flow that must have had a generally horizontal movement, or for the source of the basaltic material."

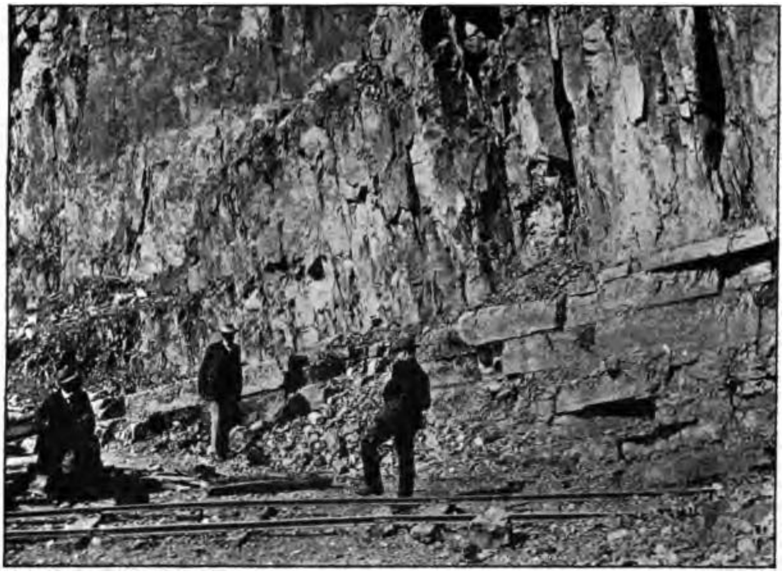


Fig. 1. Base of intrusive diabase on sandstone, quarry near Granton. (Photograph by G. E. Ashby.)

Fig. 2. Base of same diabase sheet as shown above, with detached slab of sandstone floated up into the magma. Quarry, 1 mile north of Granton.

Fig. 1. Arkcse (feldspathic sandstone) inclusion in the Palisade diabase, south side Pa. R. R. cut, 420 feet east of Marion station, Jersey City.

Fig. 2. Arkose inclusion in diabase, north side of Pa. R. R. cut, 45) feet east of Marion station, Jersey City.

The thinner of these inclusions in all cases look remarkably like acid dikes cutting across the dark basic trap rock. This effect is intensified by their originally granitic character and by recrystallization and the development of new minerals by metamorphism. Not even in thin section under the microscope was their true character recognized at first until less altered facies were found.

Megascopic characters.—The thinner portions of the sandstone inclusions, enumerated above, are very hard and compact, and look in all respects like fine-grained, light colored granite with a slight sprinkling of dark constituents. From this facies every gradation is found to apparently normal feldspathic sandstone (arkose) in the thicker portions, showing little sign of alteration. This slightly metamorphosed facies is found abundantly, even in the thicker parts (3 feet) of the inclusion at Marion, and apparently constitutes most of the large mass at Granton. It is a relatively friable rock, crumbling under the blow of the hammer like the similar arkose that forms beds of considerable extent both above and below the diabase of the Palisades along the Hudson.

The shale inclusion at Edgewater, like that at Linwood, has been altered into a dense flinty hornfels of dark gray to black color, so abundantly characteristic of the contacts of these intrusives throughout the State, as described under contact metamorphism below.

Microscopic characters.—In thin sections (Plate XXXI., Fig. 1) the thinner portions of the sandstone inclusions, up to about 2 feet thick, are found to be composed of quartz, both orthoclase and plagioclase feldspars (in very variable proportions), and augite, in a granular aggregate much resembling granite. Plagioclase is sometimes very abundant and at others scarcely present at all. The pale green augite sometimes appears to penetrate the quartz, as though formed at its expense. In smaller amounts occur irregular grains and clusters of titanite, small crystals and granular aggregates of apatite, occasional grains of magnetite, flakes of biotite, and more rarely calcite and pyrite. The feldspars, especially orthoclase, are usually more or less clouded by kaolinization. The augite is apparently identical with that of the inclosing diabase, and often exhibits the same types of alteration to uralitic hornblende, serpentine, chlorite, &c.

Fig. 1. Vertical arkose inclusion (the dark streak near the middle) in the face of the Palisades, Weehawken. The cliff shown is over 50 feet high.

Fig. 2. Arkose inclusion, nearly vertical, in the Palisades. Old quarry at Coytesville.

Composition of arkose inclusions.—Analyses made of thin highly metamorphic portions of two of these inclusions from opposite sides of the State by Mr. R. B. Gage, in the survey laboratory, yielded the following results:

Analyses of arkose inclusions in the intrusive diabase.

	I.	II.
SiO_2	74.99	68.53
Al_2O_3	10.96	12.89
Fe_2O_3	0.36	1.42
FeO	2.70	5.27
MgO	1.37	1.35
CaO	1.80	2.24
Na_2O	4.37	4.90
K_2O	2.21	0.84
H_2O+	0.46	0.74
H_2O-	0.31	0.30
TiO_2	0.74	1.02
P_2O_5	0.08	n.d.
MnO	0.12	n.d.
	100.47	99.50
Sp. Gr.	2.674	2.815

I. Arkose inclusion in Pennsylvania Railroad cut 420 feet east of Marion station, Jersey City. From south wall of the cut about 3 feet above the roadbed (Plate XXVIII., Fig. 1).

II. Arkose inclusion in the east side of the quarry in Belle Mountain, three-quarters of a mile above Moores, on the Delaware river.

The chief constituents, quartz, feldspar and augite, are in fairly uniform equant grains, and the rock in its present holocrystalline condition might be termed a *recomposed augite-granite.* The augite, however, seems to be in part at least the result of constituents derived from the inclosing magma, and to this extent, of course, the rock is not reformed in the sense of having taken again its original character. Evidence of this appears in the manner in which this mineral penetrates the quartz, and also in the numerous tufts of slender rutile needles in the adjacent trap at Marion, indicating apparently the withdrawal of ferrous iron from the titaniferous ores by the acid inclusion, leaving the titanium oxide to crystallize as rutile.

Considered as recomposed granites, however, these rocks would be designated in the quantitative system of classification by the symbols, I.3.2.4. (alsbachose) and II.4.2.5., respectively, the former being the dosodic subrang of the rang *alaskase,* and the latter the presodic subrang of the rang *dacase.*

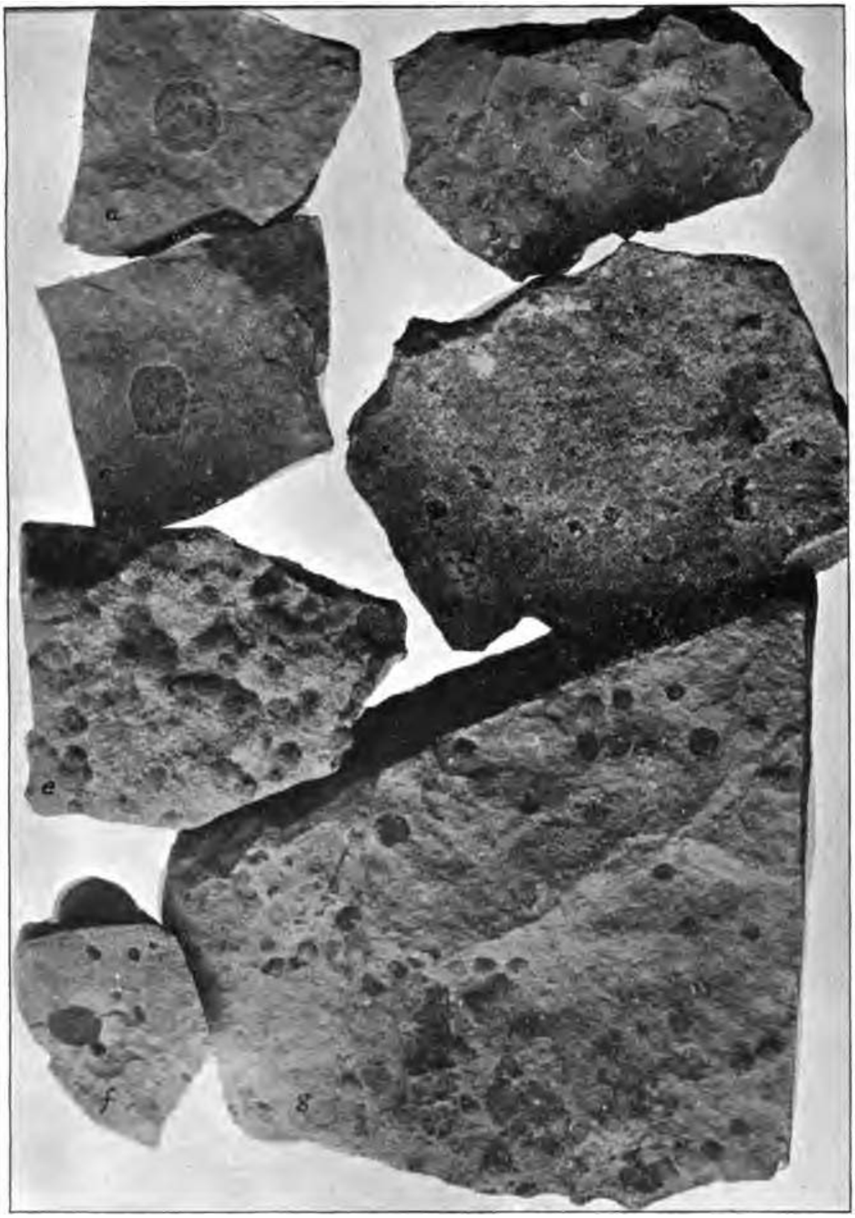
CONTACT METAMORPHISM OF THE INTRUSIVE DIABASE.

In the immediate vicinity of the great intrusive sill, both along the Hudson and in its westward extension across the State, and also about the larger apophyses and the intrusive masses of Cushetunk and Round mountains, the stratified rocks show abundant effects of the "baking" action of the molten magma during the prolonged stages of its cooling under deep cover. This is particularly true of the shale, which constitutes the most abundant constituent of the Newark formation in New Jersey. From the contacts, outward, through a thickness of several hundred feet, the shale has been everywhere changed into a hard flinty gray to brown and black hornfels, having the hardness of slate but lacking its splitting qualities, and the original lamination is preserved only in the banding of the colors.

Back of the Palisade ridge this hornfels is well shown in the few contacts that are known,[1] especially in the railroad cuts approaching the tunnels north of Jersey City, and the buried extension of this belt to the southwest has been found in well borings and in dredging operations in the Raritan river.[2] Again, north of Rocky Hill and Sourland Mountain, similar effects are observed, often with the added character of rounded, shot-like chlorite nodules, up to an inch in diameter, sprinkled plentifully through the rock, producing a type of spotted hornfels that has been called *spilosite,* and with slender crystals and radial clusters of tourmaline (Plate XXX.). These characters are particularly well exhibited about the old copper workings, near Griggstown, where also the gradual transition from black and dark brown or gray hornfels, through various shades of purple, to the normal brick-red color of the Brunswick shale, can be perfectly observed.

In all of these cases the effects are prominent only on the back slope of the ridge. This is due to the flat slope (the low angle of dip toward the northwest), which broadens out the metamorphic belt over the gently dipping sheet of diabase as it gradually passes to greater depths. On the under side the effects are exactly the same, apparently, but the front slopes of the ridges are much

[1] Kümmel, Annual Report of the State Geologist for 1897, pp. 61–72.
[2] J. Volney Lewis, Annual Report of the State Geologist for 1906, pp. 117–121.



Cordierite-hornfels in which cordierite is replaced by chlorite nodules, forming the "spotted slate" (spilosite) of the slopes of Rocky Hill, Sourland and Round Mountains; *a*, *b*, *c*, *f*, from old copper mine near Griggstown; *d*, ¾ mile south of mine, chlorite nodules very small, black tourmaline crystals prominent; *e*. west side of Round Mountain, weathered surface with projecting nodules; *g*. ¼ mile south of Round Mountain, ⅓ mile east of Rowland's Mills. Three-fourths natural size.

steeper and the width of outcrop is correspondingly narrower. At certain points along the Hudson, however, more than 100 feet of shale and sandstone are exposed under the Palisades, and in all cases the shale is strongly metamorphosed.

The feldspathic sandstone (arkose) which is quite abundant in many places along the Hudson, both above and below the diabase, seems remarkably indifferent to the influence of the igneous rock, except within a few inches of the actual contact. This is well illustrated in the sandstone inclusions described above, in which only the thin parts (less than 1 foot thick) are distinctly metamorphic, while masses only 3 feet in thickness are largely almost unaltered sediment. The same is true of this rock at the contacts, where the sandstone only a few feet away shows no visible effect of the proximity of the igneous rock, while the shale associated with it is intensely metamorphosed for hundreds of feet. Manifestly the feldspar and quartz which constitute the arkose are very stable minerals at high temperatures, while the hydrous clayey materials composing the shale are readily altered by heat and recrystallized as anhydrous silicates.

MICROSCOPIC CHARACTERS AND VARIETIES OF HORNFELS.

The microscope shows great variety in the mineral constitution of the dense aphanitic hornfels, including many different combinations of feldspar (both orthoclase and plagioclase), biotite, augite, hornblende, tremolite, garnet, spinel, magnetite, quartz, muscovite, cordierite, scapolite, vesuvianite, sillimanite, andalusite, chlorite, calcite, analcite, titanite, tourmaline, zircon, apatite and possibly leucite. The common groupings of these minerals are described below under designations of the most prominent or characteristic constituent. It should be clearly understood, however, that these are not sharply defined types, but present various degrees of gradation from one to another. Furthermore, they do not form zones or belts in any consecutive order or other systematic relation to the intrusive rock, but alternate irregularly throughout all parts of the zone of metamorphism. It is evident, therefore, that the several types of hornfels are not the result of varying degrees of metamorphism, but are dependent only on original differences in the composition of the shales themselves.

Several facies of these rocks have been described by former observers. Thus Andreae and Osann[1] found the following types at the lower contact of the Palisades:

1. *Normal hornfels;* that is, a dense feldspar-biotite rock without quartz. This is essentially the biotite-hornfels described below.

2. A similar rock with numerous gray to reddish brown zonal *tourmaline* crystals at various angles to the lamination. Each crystal is surrounded by a clear zone, free from biotite.

3. A *quartz-feldspar* variety, considered to be a metamorphic arkose, with green shredded hornblende and occasional zircons.

4. A *lime silicate hornfels* consisting of colorless pyroxene, tremolite, garnet, vesuvianite, epidote, biotite, with some feldspar, titanite and calcite. This rock is banded by the preponderance of diopside and biotite in the lighter and darker layers, respectively.

To these J. D. Irving[2] adds the following varieties, the first three being from the lower contact and the other two from the upper contact in the New York, Susquehanna and Western Railroad tunnel:

1. A hornfels composed chiefly of *biotite* with subordinate *feldspar,* and rich in dark bottle-green *spinel.* The latter occurs in grains and crystals 0.12–0.16 millimeters in diameter, which appear megascopically as black dots, like magnetite.

2. A *lime silicate hornfels,* like No. 4 above, consisting chiefly of colorless diopside, but grading toward the normal biotite-hornfels by increase in the biotite and the feldspar. Thickly scattered through the rocks are flakes of brown *basaltic hornblende,* ranging from minute specks to 3 millimeters in diameter. These are surrounded and seemingly more or less replaced by irregular scales of biotite. The rock also contains augite, sillimanite and apatite.

3. A *biotite-hornfels* with layers and lenticular masses ("augen") of a brownish *green hornblende,* with much chlorite and some feldspar.

4. Hornfels rich in imperfect crystals of the chiastolite variety of *andalusite,* varying from 1 to 4 millimeters long and one-third as broad.

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[1] A. Andreae and A. Osann: Tiefencontacte an den intrusiven Diabasen von New Jersey. Verhandlungen des Naturhist.-Med. Ver. zu Heidelberg. N. F. V. 1.

[2] School of Mines Quarterly, XX., 1899, pp. 213–223.

5. *Arkose-hornfels* containing the same.

Numbers 4 and 5 grade into each other. About the andalusite crystals there is a clear rim in the thin section, the main body of the rock being dark with magnetite and biotite. Inside of this clear rim and immediately about the crystals, however, there is a chain of large magnetite grains arranged like a necklace. The andalusite seems to occur as abundantly in the feldspathic facies of the rock as in the darker portions, although the crystals are of somewhat smaller size.

In addition to these Irving also describes a rock from the lower contact which is largely composed of minute rounded crystals, apparently leucite, although the identification was not entirely conclusive.

In the further descriptions that are added here no attempt has been made to find every contact-product. Representative specimens were collected in order to determine something of the nature and extent of the metamorphism, and it happened that most of these were distinctly different from those that had been described before.

Biotite-hornfels.—Several sections from the cut west of the New York, Susquehanna and Western Railroad tunnel and from the north slopes of Rocky Hill show a dense aggregate of biotite flakes and minute grains of feldspar with scattering magnetite and occasional quartz-bearing layers, the latter usually coarser grained. Frequent alternating bands of lighter and darker colors are due to the varying proportions of biotite to feldspar developed in alternate laminæ of the shale. Chlorite is often present in minute flakes, and with increasing proportions it forms a transition to the chlorite-hornfels described below. Veinlets of quartz sometimes intersect the lamination.

Chlorite-hornfels.—This is similar to the facies just described, except that chlorite takes the place of biotite, and in the transition stages occurs in varying proportions with this mineral. Sections of this variety from the old copper mine at Griggstown show numerous grains and crystals of titanite and are occasionally traversed by veinlets of feldspar and radial fibrous hornblende.

Augite-hornfels.—Sections from various points in the cut west of the New York, Susquehanna and Western Railroad tunnel show a dense augite-feldspar aggregate thickly sprinkled with granules of magnetite. Occasional grains of the augite are considerably larger. Augite and magnetite are often concentrated along dark bands and

EXPLANATION OF PLATE XXXI.

Photomicrographs of thin sections.

Fig. 1. METAMORPHIC ARKOSE (FELDSPATHIC SANDSTONE), *Jersey City*. Magnified 60 diameters. From the dike-like inclusion shown in Plate XXVIII., Fig. 1. A granitic aggregate of quartz, feldspar (both orthoclase and plagioclase), and secondary augite. The feldspars are crowded with alteration products. Thin section No. 297–L.

Fig. 2. DENSE METAMORPHIC ARKOSE, OR ARKOSIC HORNFELS, *old quarry under the Palisades, 2 miles east of Englewood,* 3 feet below the base of the main sheet of diabase. Photographed with crossed nicols; magnified 50 diameters. Shows several cordierite crystals; a pseudo-hexagonal trilling appears to the left. Thin section No. 90–L.

Fig. 3. ALTERED CORDIERITE-HORNFELS, OR "SPOTTED SLATE," *Ten-Mile Run, 2 miles northeast of Griggstown.* Magnified 18 diameters. Shows hexagonal and rounded chlorite pseudomorphs of cordierite. Thin section No. 277–L.

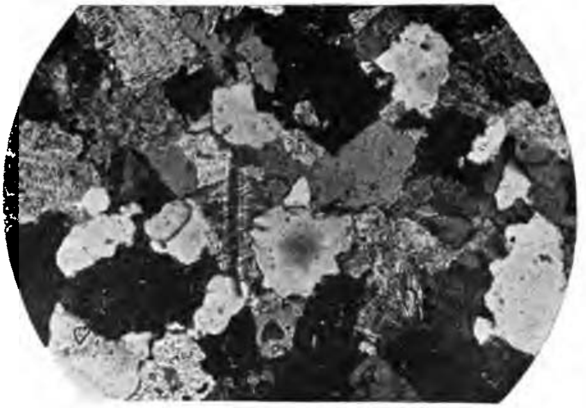


Fig. 1.

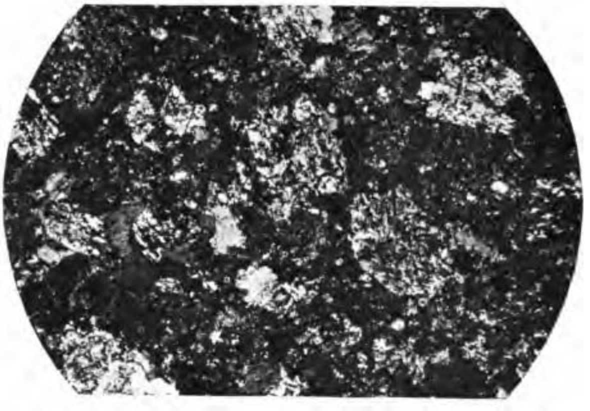


Fig. 2.

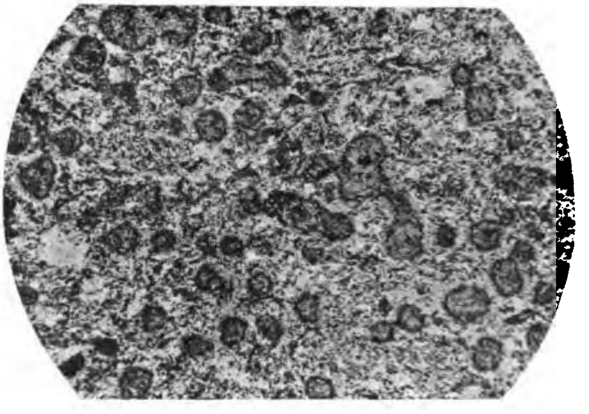


Fig. 3.

irregular splotches, giving rise to corresponding variations in the color of the rock.

Augite-biotite-hornfels.—Several sections from near the under contacts in the eastern portal of the West Shore Railroad tunnel and the head of Fourteenth street, Hoboken, show dense augite-feldspar aggregates alternating with darker bands and splotches of augite, biotite and feldspar. Larger ragged areas of augite and biotite occasionally occur and these minerals are sometimes thickly sprinkled (poikilitic) with inclusions of the other constituents. The biotite is pleochroic, pale yellow to dark reddish brown, and often nearly opaque. The pale green augite is sometimes partly altered to chlorite, sometimes to yellow serpentine, and the larger grains are frequently grouped in radiating rosettes. Magnetite occurs in scattering grains and occasional veinlets are filled with augite and chlorite.

Cordierite-hornfels (*spilosite*).—This type occurs at numerous localities both above and below the great intrusive sill along the Palisades, and spilosite, in which the muscovite and chlorite nodules are apparently pseudomorphs after cordierite, is abundant along Rocky Hill and Pennington and Sourland mountains. Cordierite hornfels consists of a dense groundmass of feldspar and biotite or chlorite (or both) abundantly sprinkled with rectangular, hexagonal, rounded and irregular sections of cordierite. Occasional larger biotite and feldspar grains occur and some magnetite with rarely shreds of muscovite. On the other hand, biotite sometimes entirely disappears from the groundmass. Cordierite is found in all stages of development from perfectly-formed crystals and pseudo-hexagonal trillings to roundish, ill-defined clearer patches in the dense groundmass, with indistinct radial extinction (Plate XXXI.). It also exhibits all stages of alteration to confused scaly aggregates of hornblende, muscovite (pinite), biotite or chlorite, and sometimes feldspar and calcite (Plate XXXII.). Granules of magnetite are usually abundant in all cases. The cordierite crystals are often of minute microscopic size, but the chlorite and muscovite pseudomorphs at Griggstown Mine, which probably represent original cordierite, sometimes attain a diameter of about 25 millimeters (1 inch), although usually less than one-fourth that size. Biotite and magnetite are frequently more abundant in the hornfels immediately about the cordierite crystals, although the latter are sometimes surrounded by narrow interven-

ing clear spaces. The segments of the pseudo-hexagonal trillings are also sometimes outlined by magnetite granules. Chalcocite crystals occur in some of the chlorite pseudomorphs of cordierite and other parts of the hornfels (spilosite) at the Griggstown copper mine (Plate XXXII., Fig. 5). Tourmaline (pleochroic, yellow to dark brown) is also sometimes abundant in the rock of this locality (Plate XXX.), and microscopic crystals frequently cluster about or penetrate the chlorite pseudomorphs.

The dense *cordierite-arkose,* described below, might, with equal propriety, be included here as a feldspathic *cordierite-hornfels.*

Scapolite-hornfels.—Sections from the lower contact at the east end of the West Shore Railroad tunnel and at Byram, on the Delaware, show large irregular areas of scapolite in a dense groundmass of feldspar, biotite, hornblende and augite (Plate XXXII., Fig. 6). The feldspar, chiefly orthoclase, is the most abundant constituent and often contains inclusions of apatite in slender needles. Biotite, the next in amount, is pleochroic, pale yellow to dark brown. Hornblende, which is nearly as abundant as biotite, occurs in rounded grains with a pale-yellow to dark-green pleochroism and often has a reddish-brown central core. Pale green augite varies from occasional scattering grains to considerable abundance. Oval areas of much finer texture in the sections are composed of the same minerals. The scapolite forms numerous large irregular areas, which are often elongated parallel to the cleavage. In some sections biotite is present in both large and small flakes, partly altered to chlorite sometimes, and magnetite grains are usually numerous.

Vesuvianite-hornfels.—In the cut approaching the western portal of the New York, Susquehanna and Western Railroad tunnel, 400 feet west of the contact, a laminated feldspar-augite-hornfels occurs, with darker and lighter layers according as one or the other constituent preponderates. The augite varies from minute grains to clusters and individual crystals of much larger size in irregular spots and bands. In the midst of the other constituents, vesuvianite forms large irregular areas of parallel columnar structure and incloses biotite, augite and magnetite. Analcite also forms irregular patches with rectangular cleavage, and occasional grains of epidote and calcite occur.

Calcareous hornfels-breccia.—A mile and three-fourths south of Lebanon, a blackish brecciated hornfels, which occurs near the diabase of Cushetunk Mountain, is composed largely of calcite and chlorite with smaller amounts of biotite and plagioclase feldspar. The whole is thickly set with minute dull black grains and aggregates that appear to be carbon.

MICROSCOPIC CHARACTERS AND VARIETIES OF METAMORPHIC ARKOSE.

Some extremely metamorphic facies of arkose were described above under the head of inclusions, and it was pointed out in that connection that visible effects in rocks of this character are confined to the immediate vicinity of the contacts. This is true also of the contacts above and below the trap, and even microscopic effects are scarcely noticeable at a distance of a few feet. Besides the feldspars, orthoclase and the plagioclases, which in varying proportions, and with or without quartz, form the essential constituents of the unchanged rock, the microscope reveals in the metamorphic arkose varying quantities of the following minerals: Augite, biotite, epidote, cordierite, chlorite, calcite, tourmaline and apatite.

As in the case of the hornfels, described above, the usual groupings of these minerals are made the basis of several varieties, which are described here under names that indicate the prevailing or characteristic constituents.

Augite-arkose.—At Homestead, 80 feet south of Hose Company No. 3, a patch of arkose is firmly welded to the surface of the diabase, a small remnant of the overlying strata that have been otherwise removed by erosion. Among the much kaolinized feldspars are numerous short prismatic augites with some biotite, magnetite and minute crystals of apatite. In some parts large augites and biotites are developed, some of which inclose numerous grains of the other constituents. The rock is made up of light and dark bands in which the feldspars and the augite, respectively, preponderate. Augite and biotite often show considerable alteration to chlorite, and veinlets of feldspar (chiefly orthoclase) and augite sometimes traverse the rock.

Epidote-chlorite-arkose.—At the old Brown & Fleming quarry under the cliffs of the Palisades due east of Englewood, the arkose

6 inches below a 2-foot diabase sheet that branches off from the main sill, is a much kaolinized quartzose rock, with considerable secondary epidote and chlorite. Another section from the contact at the west end of the New York, Susquehanna and Western Railroad tunnel bears epidote, chlorite and calcite, and 10 feet horizontally west of the contact another layer has the same constituents. Forty feet farther west the microscope shows occasional remnants of augite altering to chlorite, and this may be considered as the probable source of much of the chlorite in these rocks. Occasional crystals of pyrite also occur.

Tourmaline-arkose.—In the cliffs of the old Brown & Fleming quarry, and within 6 inches below the 2-foot diabase sheet referred to above, the quartzose arkose contains frequent thick crystals of tourmaline, besides biotite and clusters of granular epidote. The original feldspars are chiefly orthoclase. It is quite possible that this tourmaline has come from the original granitic source of the arkose, and further microscopic study of the unmetamorphic rock would be necessary in order to determine this question.

Cordierite-arkose.—Three feet below the 2-foot diabase sheet in the old Brown & Fleming quarry above referred to, an 18-inch bed of gray sandy shale is penetrated by two 6-inch diabase sheets. A section from this bed shows it to be essentially a fine-grained orthoclase-arkose, considerably kaolinized and thickly set with cordierite in rectangular sections and pseudo-hexagonal trillings. The mineral is largely altered to confused aggregates of muscovite (pinite) and granules of magnetite, but some pale yellow to colorless crystals and numerous remnants of the unaltered cordierite still remain (Plate XXXI., Fig. 2).

This rock might, with equal propriety, be called an arkosic hornfels.

EXTRUSIVE ROCKS.

The extrusive igneous rocks (basalts) are the finer grained and usually darker rocks that solidified from surface flows of lava. Such lava was repeatedly spread over the surface (probably a land surface) of the accumulating Newark sediments, and was in turn buried by later sediments. The appearance of these ancient lavas at the present surface is due to the subsequent tilting of the whole series toward the northwest whereby the strata and the included lava sheets have been exposed to vigorous erosion and thus beveled off and their edges laid bare (see sections on Plate X.). The more enduring basalt sheets, in the same manner as the great intrusive diabase sill of the Palisades, Rocky Hill and Sourland Mountain, persist above the general level as low ridges (mountains they are called in the Watchungs) which stretch northward from Somerville and Bound Brook almost to the New York State line (map, Plate X.). Smaller masses form low ridges and knobs about New Germantown, Sand Brook and Flemington.

THE BASALT FLOWS.

Definition.—Basalt is a volcanic or extrusive rock, formed by the outflow of the lava over the surface, in contrast with the intrusive diabase, which has essentially the same chemical composition and was formed from a closely similar magma. The rapid cooling of the exposed basalt sheets produced a much denser rock, the texture being compact (aphanitic) to fine granular, and sometimes part of the lava has solidified without crystallizing, forming glass intermingled with the minute crystals. There are often larger visible crystals (phenocrysts), however, sprinkled through the dense groundmass, producing a porphyritic texture similar to that of the contact facies of the diabase. The phenocrysts are usually augite, but some of them are also feldspars, and the microscope reveals the same minerals as the chief constituents of the groundmass, with small variable proportions of magnetite and occasionally olivine, and often more or less glass, especially near the upper and lower surfaces of the various flows.

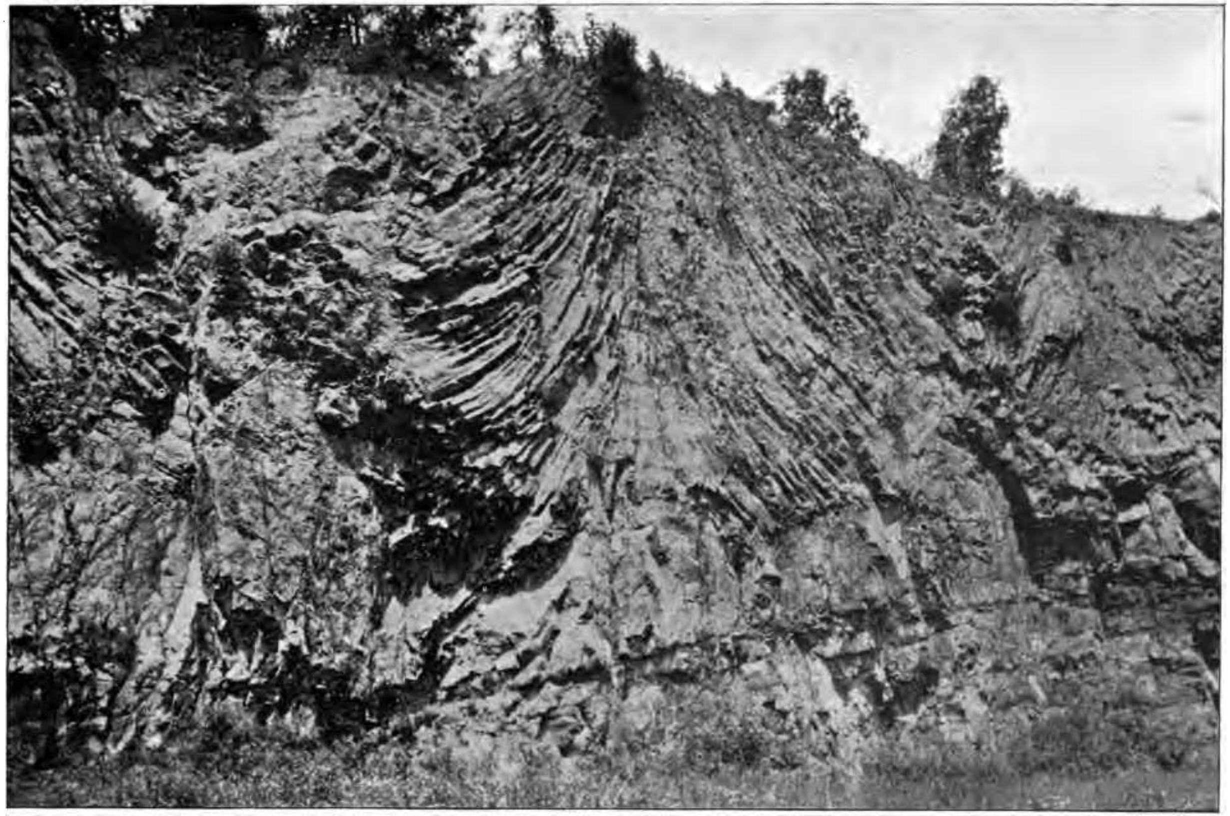
Structure.—The Watchung sheets vary in thickness from less than 300 feet in parts of the Long Hill (Third Mountain) flow to a maximum of about 1,200 feet in the thickest parts of the double flow of Second Mountain. It has been shown[1] that there are probably two sheets here separated by a thin stratum of shales; and hence the thickest undivided sheet would be the upper or second flow of Second Mountain, which attains a maximum of approximately 800 feet in the region just north of Bound Brook.

A horizontal sheeting or platy jointing, comparable to that of

[1] J. Volney Lewis, Annual Report of the State Geologist for 1906, pp. 110–115.

Vertical joints in the basalt of First Mountain at Great Falls, Paterson. Columnar jointing also appears near the water to the right and left of the gorge.

Columnar and plane jointing in the basalt of First Mountain, North Plainfield.



Curved radial columnar jointing above, with platy lamination and irregular joints below, First Mountain basalt, Eagle Rock.

Sandstone at the base, overlain by basalt showing horizontal lamination near the contact, with large columns above and small columns at the top. Below Great Falls, Paterson

Fig. 1. Ball-and-socket joints in large columns of basalt, O'Rourke's quarry, West Orange. (Hammer, 1 foot long.)

Fig. 2. Sphenoidal, or wedge-shaped, jointing in large columns. Same locality.

Fig. 1. Spherical jointing in basalt of Second Mountain. Quarry, 2½ miles south of Stirling

Fig. 2. Irregular jointing in basalt of Second Mountain. Quarry, 1 mile south of West Summit.

the intrusive diabase is distinctly developed in all of the basalt sheets, most prominently near their upper and lower surfaces (Plates XXXV., XXXVI.). The layers are usually thinnest near the bottom, where they are sometimes only 1 or 2 feet thick, but the structure quickly disappears in passing upward into the central massive portions of the sheets.

Jointing and faulting in these rocks are also very similar to those of the intrusives, which may be said to characterize the Newark region as a whole (Plate XXXIII.). Both joints and faults are prevailingly north-south or within 15 degrees of this direction, and approximately at right angles to the upper and lower surfaces of the sheets. Occasionally well-developed jointing is observed in the directions about N. 40° E. and N. 70° E. Joints at right angles to the prevailing direction are sometimes quite prominent, but they are usually much less numerous and often lacking altogether. More or less irregular jointing is usually present, and this increases to such an extent in some localities as to break the rock into small wedge-shaped pieces that readily fall apart in quarrying (Plate XXXVIII., Fig. 2). Many of the north-south joints have developed into faults and carry from an inch or so to more than a foot of crushed and slickensided material. Faults in other directions are much less common.

Columnar jointing (Plates XXXIV.-XXXIX.) is beautifully exhibited in many parts of the Watchung basalt sheets, and particularly well shown near Orange where exposed by extensive quarry excavations along the escarpment of First Mountain. In such cases the basalt is broken into more or less regular polygonal columns, often six-sided, in addition to the continuous joint-planes which intersect it. In many places where only regular joints appear in quarries, the shock of blasting in the quarries and the effects of weathering on exposed ledges bring out the columnar structure distinctly. Other portions of the sheets, however, seem to be entirely free from such structure. The most satisfactory explanation of its cause is that which attributes it to shrinkage-cracks formed while cooling, such cracks developing and extending themselves downward and upward from the cooling surfaces of the lava.[1] The larger columns below are due to the slower rate of cooling and the fewer cracks developed, as compared with the upper surface, which was exposed to the air. It is difficult to understand,

[1] Iddings, Am. Jour. Sci., 3d Ser., Vol. 31, p. 321.

however, why such structure should not have been produced uniformly in sheets which are of uniform composition and approximately the same thickness over wide areas, and are presumed to have solidified under the same conditions in all parts.

Composite character of the trap sheets.—A horizontal structure on a much larger scale than the platy jointing described above is also observed in the Watchung basalt sheets. It is characterized by variations in color and other physical characters and also in chemical composition and seems to correspond to successive flows of lava or to successive pulsations of an irregular eruption.

In First Mountain the basal division is bluish gray in color. It is usually more or less sheeted near the base, while the upper, more massive portions are intersected by parallel vertical joints with sometimes a set at right angles, many feet apart, or are sometimes broken into large polygonal columns 2 to 4 feet in diameter at right angles to the base (Plate XXXVI.). The thickness of this portion is variable, though usually less than 50 feet. It is quite distinctly marked northward as far as Paterson and southward to Scotch Plains, and a ropy, vesicular upper surface sometimes separates it from the next overlying division.

The middle and most important division of the First Mountain sheet is a dark gray to black rock with usually a well developed columnar structure. The columns vary between 6 and 12 inches in diameter, and are often grouped in clusters radiating downward (Plate XXXV.). In many quarries where only a parallel vertical jointing is prominent in the fresh rock of this division, the effects of weathering about the borders of the quarry and the shock of blasting will often disclose the columnar structure. The characters of this division persist through the greater part of the First Mountain trap and in many places pass into vesicular and ropy structure which separates it from the next overlying division (Plate XLII.).

A third and uppermost division is found in quarries near Springfield and in the northern part of the city of Paterson, having an exposed thickness of 35 feet at the former locality and 10 feet at the latter. In both localities, however, this division constitutes the surface, and has been subjected to erosion to an unknown extent. It is a fine-grained grayish stone, and in the thicker exposure the upper part is highly vesicular.

Fault in columnar basalt of First Mountain. Old quarry at Eagle Rock.

Fault in basalt of First Mountain, Bradford Avenue, Upper Montclair. Irregular columnar jointing appears to the right. (Hammer, 1 foot long.)

Fig. 1. Undulating contact (decomposed) of two successive flows (?) of basalt. First Mountain, Bradford Avenue, Upper Montclair.

Fig. 2. Another portion of the contact shown above.

In Second Mountain there are few large quarry excavations, such as abound along the front of the more accessible First Mountain, and there is correspondingly less opportunity to observe the relations. The writer has previously shown, however, that the double crest of Second Mountain in its broad curved southern portion is probably due to two extensive flows of lava, with an intervening period during which the warping of the Passaic Basin, or Watchung, syncline was feebly begun, with the consequent concentration of sediments in the trough of the depression. This period was probably short so that only a very thin body of sediments was formed, and over these the next lava flow spread, resting over large parts of the area on the naked surface of the preceding flow.[1] Darton[2] also observed evidence of the compound character of the Second Mountain sheet at Bernardsville, Little Falls and Pompton Lake, where massive rock of slightly different characters is separated by an undulating vesicular surface. At the last-named locality there seems to be evidence also of a third thinner flow overlying the others.

In Third Mountain the quarry near Millington exposes 50 to 60 feet of the basalt in which an eroded upper gray layer 10 to 20 feet thick is separated from the nearly black rock beneath by an undulating surface that is well marked by rusty ferruginous products of alteration. In the bottom of the quarry gray rock again appears, separated from the black by one of the numerous horizontal division-planes that give a bedded or stratified appearance to the rock. At Pompton there is a distinct development of a double crest on both sides of the notch cut by the Ramapo river, and an exposure by the roadside shows soft decomposed material separating the two corresponding bodies of solid basalt.

Surface characters of the basalts.—Characters due to the extrusion of the lava at the surface and to its flow as a viscous liquid over large areas are found in the vesicular structure (Plate XLII.), the ropy flow-structure (the *pa-hoe-hoe* of the Hawaiian lavas) (Plate XLIII.), and in the occasional formation of volcanic tuff and breccia (Plate XLIV.).

Small bubble-cavities ranging in size up to about one-fourth inch in diameter are found frequently scattered through the

[1] J. Volney Lewis, Annual Report of the State Geologist for 1906, p. 113.
[2] N. H. Darton, U. S. Geological Survey Bulletin No. 67, p. 24.

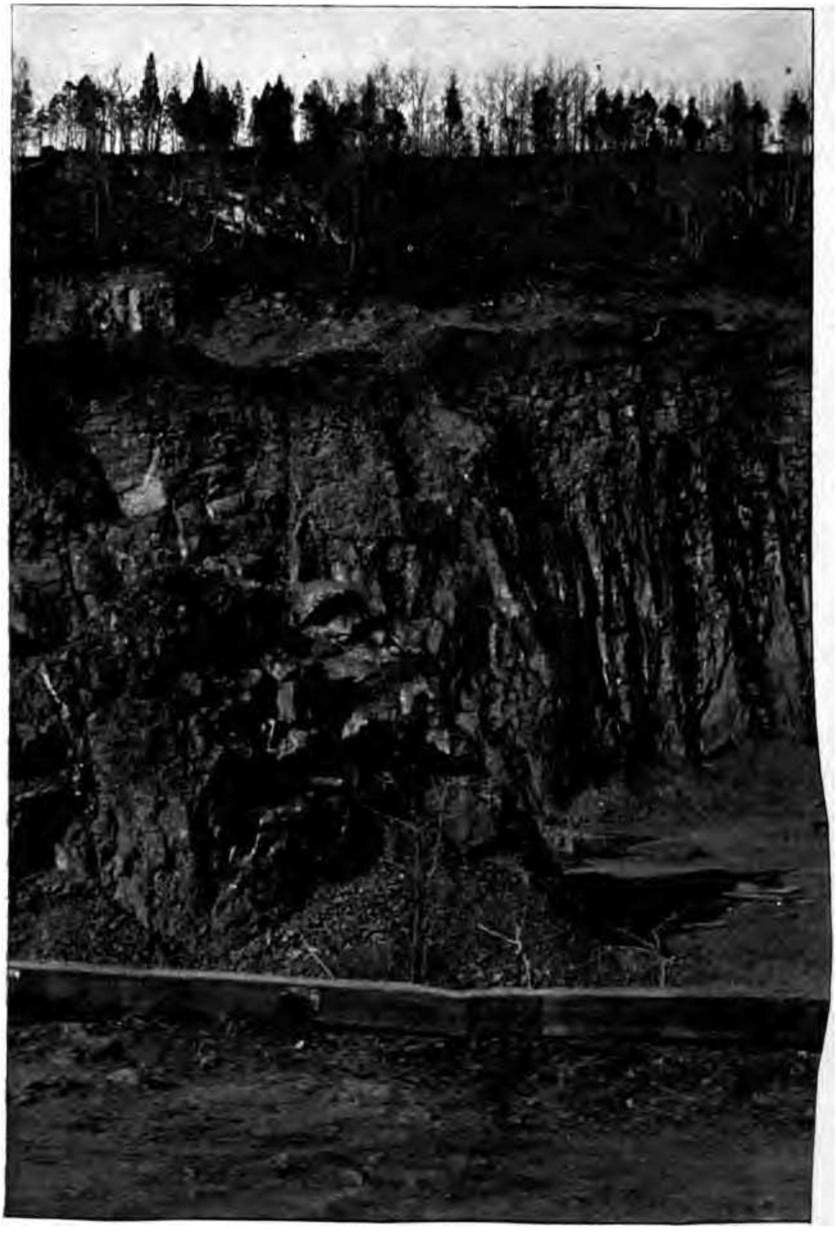
upper portions of all the extrusive sheets and of their several divisions that appear to mark successive flows or pulsations, sometimes in such numbers as thoroughly to honeycomb the rock to a depth of 10 feet or more. Such cavities are due to the rise of steam bubbles toward the surface of the viscous lava, but portions of the vesicular rock are often observed also at the base of the sheets and sometimes in the midst of the massive rock, apparently having been rolled under by continued flow after the frothy surface had solidified. Most of the cavities in this vesicular lava have been filled with secondary calcite, serpentine or zeolites, forming an amygdaloid. Where exposed to weathering such rock is highly permeable by water and rapidly decays to a soft rusty yellowish mass.

Pa-hoe-hoe, or the ropy rolling surfaces produced by the flowing of the viscous lava has been described by Kümmel[1] from many localities in the Watchung Mountains. It is often well preserved in natural exposures, especially in the southwestern part of the city of Paterson, and in the fresher exposures in the quarries, the rounded billowy forms are covered with dark glass one-half inch to one inch thick. Often these ropy, glassy surfaces are also vesicular or amygdaloidal. In some of the quarries such rounded forms are superimposed to a depth of 50 to 75 feet (Plate XLIII.), and the cavernous spaces between have been partially filled with calcite and quartz, the latter often amethystine, and the beautifully crystallized zeolites for which this locality has long been famous. The waters that formed these minerals by leaching their constituents from the inclosing trap and depositing them as crystals in the cavities, have also converted much of the glass into a dark green chloritic material (diabantite?).

Breccia and tuff.—Beneath the Second Mountain diabase at Little Falls a mass of angular and rounded blocks interspersed with finer material constitutes a thickness of 20 to 30 feet immediately overlying the sandstone in an old quarry near the pump station (Plate XLIV.).

More or less breaking of the outer crust of the lava would naturally result from the continued creep of the viscous interior after the outer parts had solidified, and at the front of the advancing sheet such fragments would be gradually rolled downward to

[1] Annual Report of the State Geologist for 1897.



Vesicular basalt (at top of cliffs) separating two successive flows. First Mountain, North Plainfield.

Rolling flow structure (pa-hoe-hoe) in First Mountain basalt, West Paterson.

Basalt breccia (or tuff ?) in contact with underlying sandstone, Little Falls.

the bottom. No great thickness of such material could accumulate in this way, however, and it is possible that we have here the products of local explosive eruption, afterward covered and more or less penetrated by a liquid flow, as suggested by Darton.[1] The absence of such material, however, from the greater part of the contact, which is here exposed for several hundred feet, is unfavorable to this hypothesis. It seems more probable that the lava here encountered a small local body of water, such as a stream or shallow pond, in the broad belt of continental sedimentation[2] over which the eruption spread; the waters suddenly chilled and shattered the mass into angular glassy fragments and these were later invaded and covered by the advancing flow.

A tuff consisting of small particles of volcanic glass, which show under the microscope inclusions of feldspar and augite crystals with occasionally pseudomorphs after olivine, was found on the dump from the tunnel of the Jersey City pipe line through Hook Mountain (a part of the Third Watchung Mountain) 1¼ miles north of Pine Brook and 5 miles southwest of Mountain View. The interstices between the glass fragments are filled with colorless to brownish radial natrolite (Plate XLVIII., Fig. 4). Numerous masses of this material were seen, but no adequate estimate could be made as to the thickness encountered, and nothing is known of its position in the section through the mountain.

Megascopic characters.—The extrusive rocks are all of very fine texture, varying from dense flinty-looking (aphanitic) and occasionally glassy, to fine granular texture in which the glistening cleavage planes of the minerals are distinct and sometimes the individual grains of lighter feldspars and darker augite. In all variations of texture larger visible crystals (phenocrysts) of augite, and sometimes of feldspar, are not uncommon. Augite, the most abundant constituent, is dark green to greenish black in mass and the feldspar is usually of a neutral grayish tint and more or less translucent; hence the rock itself is invariably of dark color, varying from dark greenish gray to brownish black and almost black. Some of the more altered portions, especially in much faulted and sheared areas, are brighter green to greenish black from the development of large amounts of secondary chlorite.

[1] N. H. Darton, Bull. U. S. Geological Survey No. 67, p. 32.

[2] On the continental origin of these rocks, see J. Volney Lewis, Annual Report of the State Geologist for 1906, p. 106.

EXPLANATION OF PLATE XLV.

Photomicrographs of thin sections.

Fig. 1. Basalt glass, *West Paterson.* Magnified 60 diameters. Scattering crystals of olivine, augite and feldspar appear in the field, besides numerous dark greenish globulitic bodies. Thin section No. 291–L.

Fig. 2. Basalt glass, *same locality.* Magnified 125 diameters. Shows scattering crystals of feldspar in large areas of dark spherulitic groundmass. The spherulitic structure has been largely lost in reproduction. Thin section No. 146–L.

Fig. 3. Glassy basalt, *Great Notch, quarry 3/8 of a mile south of the station.* Magnified 40 diameters. Shows slender and curved interlacing feldspars and granular augite set in a groundmass of dark glass. Lighter colored patches in the glass are altered to a greenish yellow serpentine-like substance. Thin section No. 170–L.

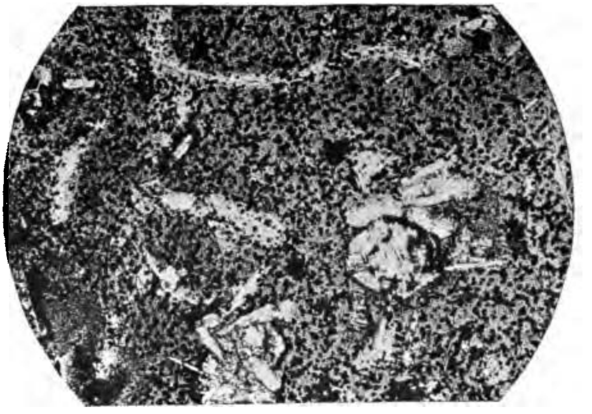


Fig. 1.

Fig. 2.

Fig. 3.

Weathered surfaces assume various tints of brown and yellow as the iron of the dark silicates is converted into the hydroxide (limonite), and soil resulting from the decay of the basalt, when not well supplied with vegetable matter, is generally quite yellowish.

Microscopic characters.—In thin section augite and plagioclase feldspar are found to be the chief constituents, with small amounts of magnetite and sometimes of olivine, and often considerable amounts of glass. The feldspars vary from short, stout, rectangular forms to slender, lath-shaped crystals, and the augite from granular aggregates to broad, irregular areas. Slender feldspar laths with granular augite filling the interstices gives a *diabasic* texture, while large augites inclosing numerous feldspar crystals produces the typical *ophitic* texture (Plate XLVI.).

Augite in granular aggregates preponderates in the normal basalt and, with magnetite and usually more or less glass, fills the spaces between the slender interlacing crystals of plagioclase feldspar, constituting a diabasic texture on a very small scale. Magnetite in crystals and irregular grains is often abundant in the midst of the augite or is included by it and less commonly by the feldspars in dendritic aggregates. Often larger crystals (phenocrysts) of the augite and feldspars produce a porphyritic texture, and hence a large part of the rock is a basalt-porphyry. Sometimes these phenocrysts are sprinkled with poikilitic inclusions of the other minerals and glass, and sometimes stellate aggregates of augite and feldspar indicate simultaneous crystallization (Plate XLVIII., Fig. 3). In the larger feldspars a zonal structure is not uncommon.

Near the bottom of the various sheets and their constituent flows, and near their vesicular or ropy upper surfaces grayish and brownish glass, sometimes highly spherulitic, becomes very abundant. It is usually thickly crowded with dust-like and minute dendritic magnetite crystals and unindividualized microlites (Plate XLV., Figs. 1, 2). With great increase of glass augite entirely disappears and minute feathery feldspar, often curved or in radiate and sheaf-like clusters is the only mineral present (Plate XLV., Fig. 3). On the outer surfaces of the ropy flow-structure there is often as much as 25 mm. (1 inch) of glass alone, as at West Paterson and Feltville. Among the felsdpars orthoclase is rarely recognizable. Scattering olivine crystals are some-

EXPLANATION OF PLATE XLVI.

Photomicrographs of thin sections.

Fig. 1. GLASSY BASALT, *West Paterson.* Magnified 40 diameters. Typical diabasic texture of feldspars and augite in dark glass. Thin section No. 145–L.

Fig. 2. GLASSY BASALT, *same locality as Fig. 1.* Magnified 40 diameters. Texture in part diabasic, in part ophitic (feldspars inclosed in the larger augites), with abundant black glass. Thin section No. 118–L.

Fig. 3. GLASSY BASALT, *Scotch Plains.* Magnified 40 diameters. From the bottom "gray" layer, 15 to 20 feet thick. Typical ophitic texture. Thin section No. 34–L.

Fig. 1.

Fig. 2.

Fig. 3.

times present, although rarely abundant, and are usually altered wholly or in part to yellowish or greenish serpentine. Often much of the glassy base is also altered to greenish or yellowish serpentine, frequently with some chlorite, and sometimes it has been entirely replaced by granular calcite (Plate XLVIII., Figs. 1, 2,).

The alteration of augite is in part to fibrous uralitic hornblende (pleochroic, colorless or pale yellow to emerald green) or to chlorite or dirty brownish serpentine and granular magnetite or, in some cases, to a mixture of all these. In some localities, especially at Chimney Rock, near Bound Brook, parallel narrow bright red bands in the trap are found to be due to minute flakes of hematite (probably from augite) along several parallel zones near the joint-planes. The feldspars frequently show a more advanced stage of alteration than the augite, being clouded with kaolin-like material or partly replaced by calcite and analcite. Sometimes the feldspars and occasional olivine crystals as well as the glassy base, are entirely replaced by calcite.

Amygdules filling the bubble-cavities in the cellular varieties of the basalt are composed of radial or banded concentric calcite or of serpentine, chlorite and zeolites. Sometimes the cavity is lined with a film of quartz, calcite or feldspar or with metallic copper in parts of First Mountain (Plate XLIX., Fig. 1), and the rest of the space filled with serpentine. Veinlets of calcite, chlorite and serpentine, with sometimes a little hematite occasionally traverse the sections.

Order of crystallization.—Magnetite was the first mineral to form in the process of solidification, as shown by its constant presence as inclusions in the other minerals. Olivine, when present, is automorphic and must have crystallized among the first products, doubtless immediately following the magnetite. The feldspars, however, crystallized in a comparatively free liquid magma, and therefore do not include the magnetites in large numbers. The formation of augite, however, followed rapidly, and in filling the remaining space crowded the magnetite granules about its borders and included them in large numbers. But it is quite probable that much of the magnetite now seen is secondary and due to incipient alteration of the inclosing augite. The large porphyritic plates of augite and feldspar, like those in the basaltic contact facies of the Palisade diabase, are undoubtedly the begin-

EXPLANATION OF PLATE XLVII.

Photomicrographs of thin sections.

Fig. 1. BASALT, *1 mile south of Short Hills.* Magnified 40 diameters. From the upper "gray" layer in Hartshorn's quarry. Predominant slender feldspars, granular and elongated augite and gray glass. Thin section No. 310–L.

Fig. 2. GLASSY BASALT, *same locality.* Magnified 45 diameters. From the middle "black" layer, showing the clear-cut feldspar laths, the granular augite and abundant nearly black glass. Thin section No. 308–L.

Fig. 3. BASALT, *same locality.* Magnified 40 diameters. From the bottom "gray" layer, showing the coarser texture, broad augites and stubby feldspars. Much of the glass is globulitic and considerably altered to greenish yellow serpentine. Thin section No. 309–L.

Fig. 1.

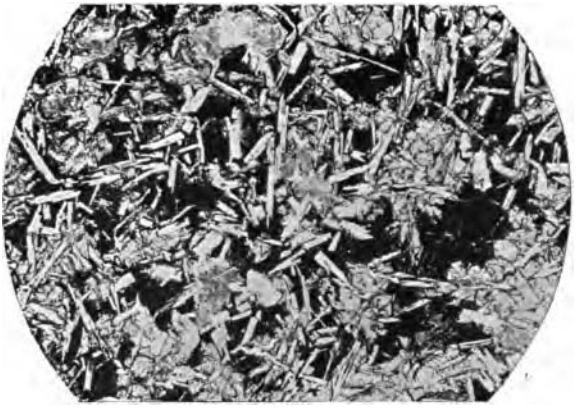


Fig. 2.

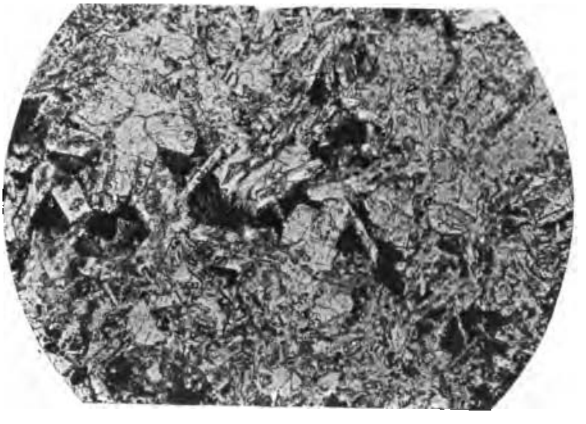


Fig. 3.

ning of a slower deep-seated crystallization in which augite was forming first. This was interrupted and the order of crystallization reversed by the eruption of the lava and its subsequent rapid cooling under very different physical conditions.

Chemical composition.—Chemically the basalts vary but little from the average composition of the diabase, as would be surmised from the identical mineral constitution and texture of the finer grained crystalline parts of the two types. The different sheets and the successive flows of which they are composed vary among themselves (Plate L.), but not to the extent that is found in the several differentiated types of the diabase.

Analyses of Watchung Basalt.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
SiO_2	50.19	51.09	51.77	51.82	51.84	51.86	49.68	49.17	49.71
Al_2O_3	14.65	14.23	14.59	14.18	15.11	16.25	14.02	13.80	13.66
Fe_2O_3	3.41	2.56	3.62	0.57	1.78	2.14	4.97	4.90	5.49
FeO	6.96	7.74	6.90	9.07	8.31	8.24	9.52	10.61	9.51
MgO	7.95	7.56	7.18	8.39	7.27	7.97	5.80	5.04	6.13
CaO	9.33	10.35	7.79	8.60	10.47	10.27	6.50	9.87	5.85
Na_2O	2.64	1.92	3.92	2.79	1.87	1.54	3.49	2.21	4.51
K_2O	0.75	0.42	0.64	1.26	0.34	1.06	1.41	0.54	0.37
H_2O+	2.38	1.01	1.85	1.40	1.33	1.33	1.89	0.73	2.66
H_2O-	0.66	1.66	0.46	0.30	0.56	......	0.54	1.04	0.48
TiO_2	1.13	1.30	1.13	1.17	1.22	......	1.39	1.50	1.53
P_2O_5	0.18	0.16	0.18	0.17	0.13	......	0.21	0.24	0.10
MnO	0.07	0.25	0.05	0.13	0.09	0.09	0.18	0.07	0.13
	100.30	100.25	100.08	99.85	100.32	100.28[1]	99.60[2]	99.75[3]	100.13
Sp. Gr.	2.92	2.936	2.91	2.95	2.93	......	2.949	2.997	2.91

I. Hartshorn's quarry, near Springfield and Short Hills. Lower "gray" layer. (Analysis No. 121, specimen and thin section No. 309-L.) R. B. Gage, analyst.

II. Same locality, middle "black" layer. (Analysis No. 120, specimen and thin section No. 308-L.) R. B. Gage, analyst.

III. Same locality, upper "gray" layer. (Analysis No. 122, specimen and thin section No. 310-L.) R. B. Gage, analyst.

IV. Hatfield & Weldon's quarry, Scotch Plains. Lower "gray" layer. (Analysis No. 130, specimen and thin section No. 35-L.) R. B. Gage, analyst.

V. Same locality, "black" rock above. (Analysis No. 131, specimen and thin section No. 36-L.) R. B. Gage, analyst.

VI. O'Rourke's quarry, West Orange. Large columns near the bottom. (Bull. U. S. Geol. Sur. No. 150, p. 255.) L. G. Eakins, analyst.

[1] Including NiO 0.03.
[2] Trace of SrO.
[3] Including SrO 0.03.

EXPLANATION OF PLATE XLVIII.

Photomicrographs of thin sections.

Fig. 1. GLASSY BASALT, *3 miles north of Somerville.* Magnified 30 diameters. From the bottom contact at the copper mine, showing fresh feldspar crystals and occasional augite, while the glassy base has been wholly replaced by calcite (compare Fig. 2). Thin section No. 205–L.

Fig. 2. GLASSY BASALT, *same as Fig. 1,* photographed with crossed nicols, showing the coarse granular texture and wavy extinction of the calcite replacing the glass.

Fig. 3. COARSE-GRAINED BASALT, ½ *mile southwest of Bernardsville.* Magnified 11 diameters. Stellate grouping of feldspar intergrown with augite. The latter is somewhat altered and appears very dark in the figure. Thin section No. 240–L.

Fig. 4. BASALT TUFF, *Towackhow or Hook Mountain, 1 mile north of Pine Brook,* from the tunnel of the Jersey City pipe line. Magnified 11 diameters. Black angular fragments of glassy basalt with interstices filled with radial colorless to brownish natrolite. Thin section No. 256–L.

Fig. 5. SHALE INCLUSION IN BASALT, *3 miles north of Somerville,* from the base of the basalt sheet at the copper mine. Magnified 11 diameters. Numerous scalenohedral calcite crystals are developed in the shale. Thin section No. 204–L.

Fig. 6. SHALE INCLUSION, *quarry ¼ mile south of Great Notch.* Magnified 11 diameters. A minute faulted dike of glassy basalt crosses the field. The glass has been entirely replaced by calcite, as in Figs. 1 and 2 above. Thin section No. 172–L.

Fig. 1.

Fig. 2.

Fig. 3.

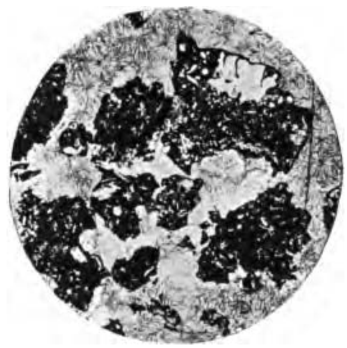


Fig. 4.

Fig. 5.

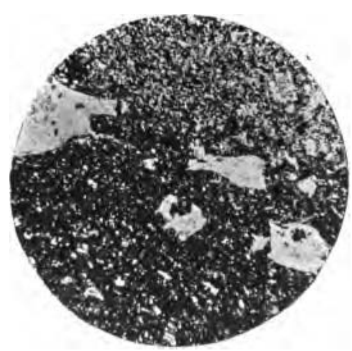


Fig. 6.

VII. Morris County Crushed Stone Co.'s quarry, Millington. Lower "gray" layer. (Analysis No. 123, specimen and thin section No. 245-L.) R. B. Gage, analyst.

VIII. Same locality, middle "black" layer. (Analysis No. 124, specimen and thin section No. 246-L.) R. B. Gage, analyst.

IX. Same locality, upper "gray" layer. (Analysis No. 125, specimen and thin section No. 247-L.) R. B. Gage, analyst.

Other analyses published in the earlier reports of this Survey and in the Twentieth Annual Report of the U. S. Geological Survey (Vol. VI., p. 419) are not sufficiently accurate or complete for present purposes.

The first five analyses above represent the lower "gray" (I., IV.), the middle "black" (II., V.), and the upper "gray" (III.) layers, respectively, of the First Mountain sheet. In these the alumina and iron (taking the ferric and ferrous together) are almost constant, and the silica shows only a slight increase upward. The characteristic differences appear in the variations of magnesia, lime and the alkalis, the magnesia decreasing upward, while the lime is highest and the alkalis the lowest in the middle layer (Plate L.). The ratios of lime to the sum of the soda and potash are also striking, namely, 3.32, 5.29 and 2.01 at Hartshorn's quarry, and 2.61 and 6.06 for the first and second layers at Scotch Plains.

No. VI. represents the large columns near the bottom of the quarry at West Orange (O'Rourke's), but chemically it clearly belongs to the second layer at the other localities. The first layer, which is always thin and quite variable, is here probably reduced to the thin platy layer at the contact with the sandstone or is absent altogether. On the other hand, if the whole sheet be regarded as the result of one continuous flow of lava, instead of successive flows or pulsations, this analysis simply means that the variations in chemical character of the basalt are not so regular as analyses I.-V. would seem to indicate.

Nos. VII.-IX. represent what appear to be separate layers of the basalt of Third Mountain (including Long Hill, Hook and Packanack Mountains) at Millington (Plate L.). As compared with the analyses of the First Mountain basalt, these are notably lower in silica, somewhat lower in alumina, magnesia and lime, but higher in soda and titanium and much higher in iron. The striking differences again appear in the magnesia, lime, soda and potash, particularly in the higher lime and the lower magnesia and soda in the second layer. The potash decreases upward and the

EXPLANATION OF PLATE XLIX.

Photomicrographs of thin sections.

Fig. 1. AMYGDALOIDAL BASALT, *copper mine 3 miles north of Somerville.* Magnified 18 diameters. Unsymmetrical calcite amygdules, both radial fibrous and concentric banded, appear in the field. Metallic copper (black in the figure) lines some of the amygdaloidal cavities. Thin section No. 320–L.

Fig. 2. AMYGDALOIDAL BASALT, *same section as Fig. 1.* Magnified 18 diameters. The black veinlets are metallic copper.

Fig. 3. BLEACHED SHALE IMPREGNATED WITH METALLIC COPPER (black areas), *same locality as Figs. 1 and 2.* Magnified 18 diameters. Thin section No. 321–L.

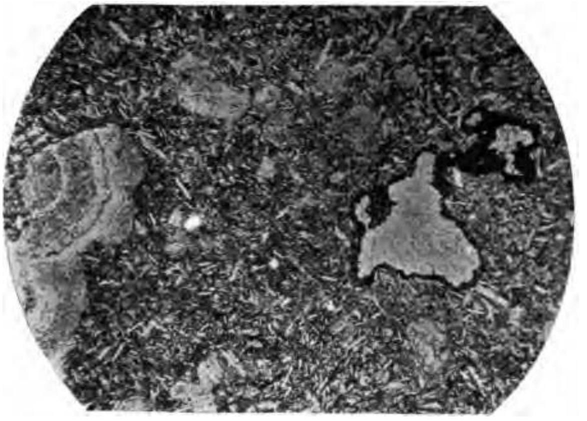


Fig. 1.

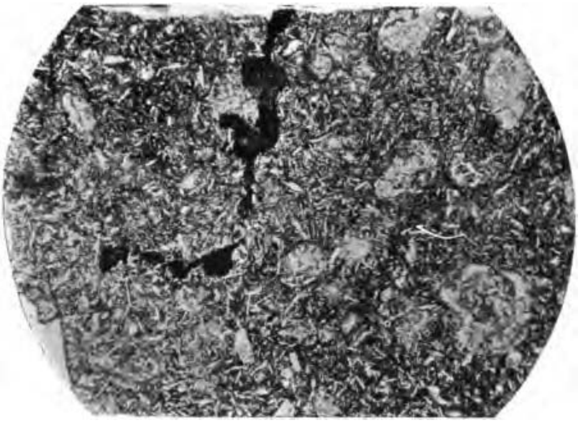
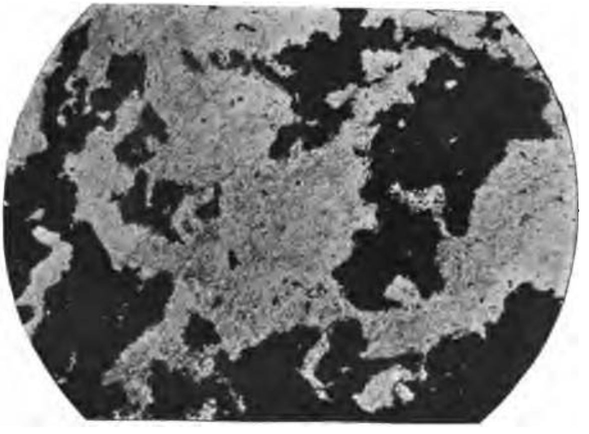
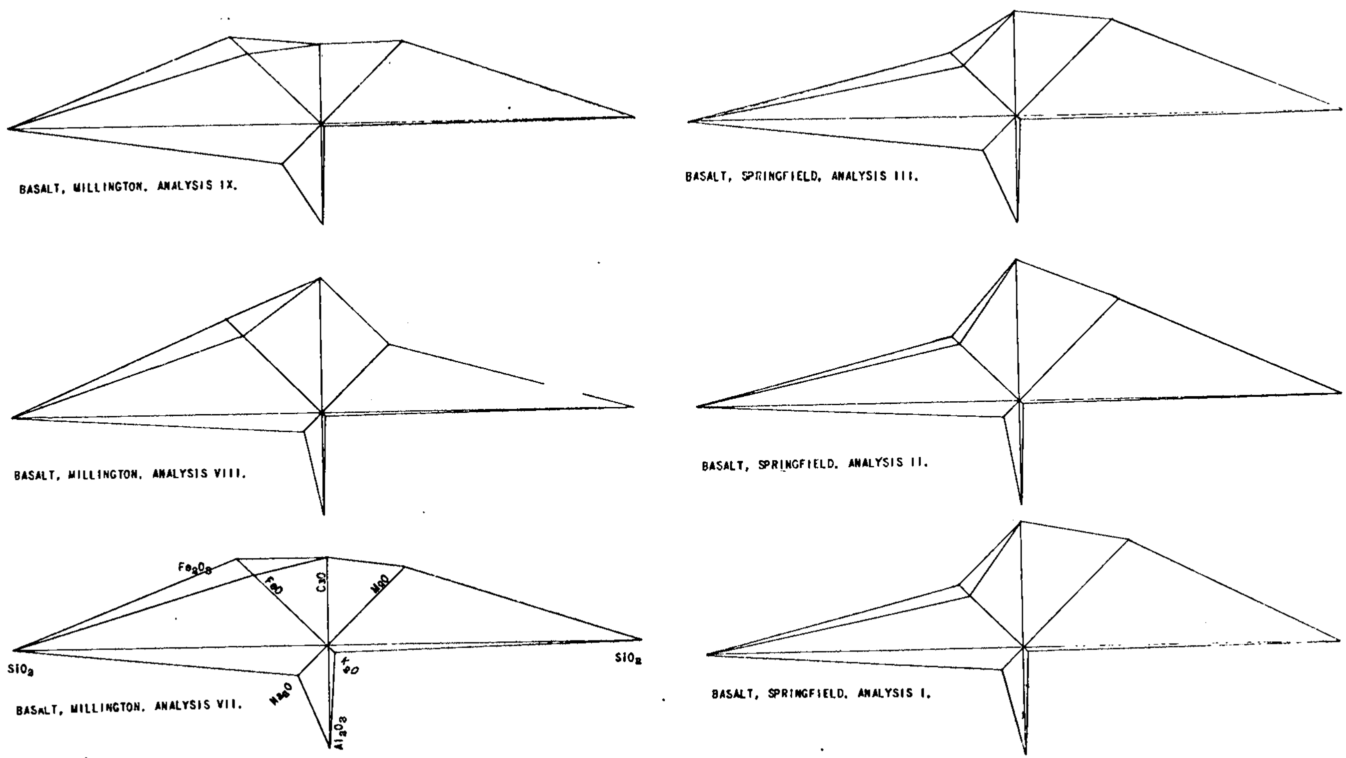


Fig. 2.





Diagrams showing composition of different facies, possibly successive flow of Third Mountain (Long Hill) at Millington and First Mountain at Spring.

iron shows the opposite variation from magnesia. The ratios of lime to the sums of the soda and potash are 1.63, 4.42 and 1.36, respectively.

Classification.—In the older nomenclature these rocks are classed as *basalt,* or when visible crystals of augite are scattered through the groundmass of finer grained or glassy materials, as *basalt porphyry.* Both types are abundant, and in both the groundmass varies from holocrystalline to spherulitic and glassy, and in the latter cases it is often vesicular. The porphyritic type often contains occasional olivine crystals, and this mineral is sometimes sufficiently abundant to constitute an *olivine-basalt,* which corresponds to the olivine-diabase of the intrusives, although never so rich in olivine. On the other hand, no quartz-basalt, corresponding to the quartz-diabase of the Palisade sill, has been found.

Owing to the evident similarity between the basalts and diabases, in chemical, mineral and physical characteristics, they have often been grouped together under the name diabase, and still more commonly they are called simply "trap rocks."

In the quantitative system[1] all of the analyses are found to fall into Class III., Salfemane, and Order 5, Gallare. The distinctions appear, however, in their distribution between Rangs 3 and 4, as shown by the following summary:

Summary of Classification of the Watchung Basalt.

Name.	*Symbol.*	*Analyses.*
Camptonose	III.5.3.4.	Nos. V, VII.
Ornose	III.5.3.5.	III, IX.
Auvergnose	III.5.4.4,5.	I, II, IV, VI, VIII.

Inclusions in the basalt.—Small irregular masses of sandstone and shale, varying in size from microscopic dimensions to a maximum thickness of about 2 feet, have been observed in various parts of the extrusive basalts. They are usually not over 2 or 3 inches thick, however, and are chiefly confined to the bases of the sheets, within a few inches of the underlying strata, although this is not without exceptions. The smaller ones are baked into a hard jaspery condition and are usually a little darker in color. Since

[1] Quantitative Classification of Igneous Rocks. By Cross, Iddings, Pirsson, and Washington. Chicago, 1903.

the contemporary origin of the Watchung basalts and the inclosing sediments has been well established, it has been recognized that the unconsolidated sand and mud over which the lava flowed were too incoherent to be taken up in large masses. Such parts as did become involved in the lava readily fell apart into small earthy clods during the continued flow.

The only inclusion noted of greater extent than 2 or 3 inches is exposed in the roadside near the dam at Pompton, in the trap of Packanack Mountain, a part of Third Mountain. Here an oval space, about 2 feet in diameter by 4 feet in length, has been hollowed out in the basalt from the almost complete crumbling away of the original sandstone contents. The portion that remains is friable and apparently entirely unaffected by the inclosing igneous rock. The possibility of later introduction of loose sands into a cavity here is to be borne in mind, especially as the inclusion is near the base of what appears to be a second flow of lava in the Third Mountain sheet. Inasmuch as this inclusion seems to be entirely isolated, however, it seems more likely that it was taken up from deposits over which the lava moved in some part of its course.

Thin sections have been prepared of a number of small shale inclusions in the basalt of First Mountain, chiefly from the base of the sheet at the Somerville copper mine. At the immediate contact the color of the shale is dark red, sometimes even brownish black, but this penetrates to a depth of only 2 or 3 mm. ($^1/_{12}$th to ⅛th inch) and the color of the rest of the inclusion is the usual brownish red of the Brunswick shales. Accompanying the superficial color change there is a development of calcite, sometimes in relatively large scalenohedral (dog-tooth) crystals (Plate XLVIII., Fig. 5), and some crystalline calcite usually permeates the whole mass of the smaller inclusions. Crystalline quartz is also formed in some cases. Vein-like aggregates of these minerals and zeolites may be of contemporaneous origin from the action of vapors and heated waters excluded during the crystallization of the inclosing basalt.

In one section a faulted microscopic dike of glassy basalt penetrates the shale inclusion (Plate XLVIII., Fig. 6). In polarized light the glass is found to have been entirely replaced by calcite. (Compare Plate XLVIII., Figs. 1, 2).

Contact effects of the basalt.—In the sudden chilling of the base of the lava as it flowed over the surface of the country there was little time for the "baking" effects of metamorphism; hence we do not find the shale changed into dense hard hornfels, as we do about the large intrusive masses, and it is often impossible to detect any change whatever from the normal color, texture or hardness of the strata. Where any effect is noticeable it is only at the lower contact, since the overlying strata were deposited later than the lava sheets that they cover. Sometimes the underlying shale is found adhering firmly to the igneous rock and is noticeably harder and of deeper color at the immediate contact. These effects, however, scarcely extend as far as an inch into the shale in the majority of cases, and probably never more than 3 inches. Under the microscope the characters are identical with those of inclusions described above.

In many places beneath the basalt of First Mountain (but not under the other extrusives) the shale 1 to 2½ feet from the contact has been partially bleached by the leaching out of the iron coloring and rendered porous by the solution and removal of the numerous little crystals of calcite. In the spaces thus formed copper and chalcocite have been deposited, as at the old Bridgewater mine near Somerville and for 15 miles along the mountain to the northeast (Plate XLIX., Fig. 3). Nothing in any way comparable to this condition is found in connection with any other extrusive sheet of the State although the rocks of all are practically identical, nor, indeed, at any other part of the First Mountain sheet itself. These effects are not attributable to the influences of the overlying lava sheet, but have been produced by ore-bearing solutions, probably magmatic, that brought up copper from the slowly cooling intrusive sill below.[1]

Origin of the zeolites.—The origin of the secondary minerals is still under investigation, but observations in quarries, which penetrate to depths of 100 feet or more below the surface in some instances, point strongly to their formation entirely beyond the range of surface conditions. Meteoric waters are now dissolving and removing calcite and oxidizing the chlorite and other ferrous minerals. Furthermore, the secondary minerals seem to have been

[1] J. Volney Lewis, Origin of the Newark Copper Ores. Annual Report of the State Geologist for 1906, pp. 156–164. Also Economic Geology, Vol. II., pp. 252–257, 1907; and Engineering and Mining Journal, October 12th, 1907, p. 688.

derived chiefly from the ropy glass, in the cavernous spaces of which they are found, and the conversion of much of the glass into a massive chloritic substance appears to be one of the results of the process.

Carbonated but not oxygenated water must have been the agent, and the most available, as well as most efficient supply, because highly heated, seems to be the magmatic or juvenile waters expelled from the great bulk of the basalt sheets during the crystallization of their anhydrous constituents. The high content of combined water still retained by the more glassy facies, even when little altered, seems to indicate the hydrous condition of the whole liquid mass at the time of extrusion. The fresh-looking glass sometimes found also gives off large quantities of water at a red heat. The hypothesis is therefore suggested that the formation of the bulk of the zeolites, calcite, quartz, hematite, chlorite, &c., took place during the cooling of the lava, through the agency of magmatic vapors and hot waters circulating through the cavities.

This or some similar mode of origin is also indicated by the universal presence of apophyllite and datolite in association with the zeolites. The former contains fluorine and the latter boron, and it is difficult to account for the widespread occurrence of these elements except through the emission of fumarolic vapors by the cooling lavas.

It is hoped that the study of these minerals and their relations may furnish evidence for somewhat more positive conclusions in the near future.

OTHER EXTRUSIVE SHEETS.

No other extrusives comparable in extent with the great sheets of the Watchung area are found in the Newark or Triassic formation of the State. Smaller masses occur, however, at Flemington, New Germantown and Sand Brook. An oval area of basalt little more than one-fourth of a mile in diameter forms Prospect Hill, just west of the town of Flemington. It is highly vesicular on its upper surface, has had little if any effect on the adjacent shale, and is probably extrusive. There are several dikes in the vicinity and southward toward Sourland Mountain, and one of these is doubtless the source of this small lava flow. Some of these dikes which are somewhat discontinuous in outcrop, Kümmel has traced into direct connection with the great mass of the Palisade diabase that forms Sourland Mountain. It is probable, therefore, that this little flow is of the same age as the great intrusive sill, in fact merely a small part of it that reached the surface, and, therefore, probably later than the First Mountain basalt at least.[1]

Other small basalt areas that are unmistakably extrusive form the little semi-circular ridges at New Germantown and Sand Brook, and the smaller remnants at the center of the curve in each case. The relations are similar to those observed along the Watchung ridges, except that the sheets are much thinner, and it has been shown[2] that they may be reasonably supposed to represent portions of the flows that constitute First and Second Mountains.

April 1, 1908.

[1] J. Volney Lewis, Age of the Intrusives. Bulletin Geol. Society of America, Vol. 18, pp. 209, 210, 1907.

[2] J. Volney Lewis, Annual Report of the State Geologist for 1906, pp. 115–117.

PART V.

Notes on the Mineral Industry, with Mineral Statistics.

By Henry B. Kümmel.

Mineral Industry.

IRON-ORE MINES.

During 1907 the iron-mining industry of New Jersey experienced the depression, in common with all lines of industry, resulting from the panic of October, and some of the mines were partially or completely shut down during November and December. In spite, however, of this depression and of severe accidents at some of the mines which seriously interfered with their operation, the total tonnage produced for 1907 was greater than for 1906 and greater than for any year since 1882. The production as reported to this office by the various mining companies amounted to 558,137 gross tons valued at the mines at $1,773,260.19, or an average of $3.18 per ton. Seventeen mines were reported as having been producers during the year, as follows: The Andover, Wood, DeCamp, Wharton and Hurd mines, controlled by the Wharton Steel Company; the Washington, Elizabeth, Leonard and Carlton mines of the Empire Steel and Iron Company; the Richard mine of the Thomas Iron Company; the Hude and Dickerson operated by the Musconetcong Iron Company; the Ahles at Oxford and the Peters at Ringwood, operated by the Pequest Iron Company; the Hoff mine by the Hoff Mining and Realty Improvement Company, and the Beatyestown and the Shoemaker mines at Belvidere, by the Hudson Iron Company. The ore from all of these, except the Ahles, Beatyestown and Shoemaker mines, is magnetite. The Ahles ore is a manganese-bearing mixture of magnetite and limonite, while that from the two latter mines is limonite.

A fire at the Richard mine injuring slope No. 5 reduced somewhat the annual production which in previous years has put this mine among the leaders. The maximum tonnage was shown by the Washington mine at Oxford, while the Wharton mine at Hibernia and the Hurd mine at Wharton were among the large producers. In fact the record of the Hurd mine since its acquisition by the Wharton interests is most surprising, the annual production having been increased several hundred per cent.

Early in the year the Andover mine was permanently shut down, and its production was only a few hundred tons. This mine is located at the southwestern end of the great Hibernia ore body and with increasing depth, the pitch of the deposit has carried the ore so far to the northeast that there has been less and less which could be profitably worked from the Andover openings. Work at the Teabo mine, which for a number of years has consisted chiefly in sinking a new shaft, was suspended about the middle of the year.

At Mount Hope extensive surveys have been made and large improvements commenced on the surface, with a view of substituting magnetic cobbing and separation for the hand breaking and cobbing heretofore practiced. A new mine, the Carlton, was opened at Mount Hope in August, and became a producer the latter part of the year. The Beatyestown mine was operated by the Hudson Iron Company for a few months during the year and then abandoned. The same company also reopened the old Shoemaker mine near Belvidere, and were operating it at the close of the year.

ZINC MINES.

The zinc mines at Franklin Furnace and Ogdensburg, both controlled by the New Jersey Zinc Company, are the only mines of this character in the State, and during 1907, as for a number of years past, only the Franklin deposit was worked, the mines at Ogdensburg having been indefinitely closed down a number of years ago. The richness of this ore, the great size of the ore body and the large rewards awaiting the discoverer of additional deposits, have led, first and last, to the expenditure of large sums of money in prospecting the adjoining territory. The zinc deposits occur only in the white crystalline limestone, *the limits of which are accurately known.*[1] It is safe to say that every foot of this belt has been carefully examined on the surface without revealing any evidence of additional deposits. In addition to this thousands of dollars have been spent in diamond drilling on all sides of the

[1] For a map see Annual Report of the State Geologist for 1905.

known deposits, but without avail. It is unquestionably true that in some instances the drilling ceased before the ground had been thoroughly tested, *i. e.*, before the holes reached the bottom of the limestone, but, since the holes were in some instances at least 1,300 or 1,400 feet deep, it was demonstrated that no zinc deposits occurred within easy reach of the surface where they were drilled. The absence of any surface indications of zinc ore, and the utter failure of all the drilling to reveal a deposit other than those which have been mined for many years, affords at least very strong presumptive evidence that no other deposits exist. And, while there is always the possibility that zinc ore similar in character to the Franklin ore may occur somewhere within the limits of the white limestone, yet the probabilities of finding it by a few diamond drill holes put down at random are so remote that any exploration of that character must be regarded as a highly speculative venture in which the chances are against success. It seems advisable to make these emphatic statements in view of the large sums of money recently obtained by a mining company on the alleged occurrence of valuable zinc deposits on property adjacent to the established mines.

The New Jersey Zinc Company report their production for the past year as 329,205 tons of ore, a little less than half of this having been taken from the open cut at the south end. This is a decrease of 32,120 tons as compared with the year 1906.

The Palmer shaft,[1] started in 1906, enters the blue limestone of the footwall, near the mill, at an angle of 47½°. At the close of the year, it had been sunk 580 feet and was in the gneiss underlying the white limestone. Since the blue limestone and associated sedimentary beds dip to the westward, at an angle of about 50°, the shaft crosses the bedding planes nearly at right angles. The gneiss was reached 230 feet from the collar of the shaft, and from that point to 580 feet and beyond the rock was gneiss, the foliation and fracture planes of which dip eastward at an angle of 70°. At 402 feet from the collar of the shaft, a small vein of zinc blend, which dipped about 50° to the west, was struck. It measured from 1 to 3 inches in width and was associated with quartz and flourite. The following samples of rock from shaft have been examined:

[1] These details were kindly furnished by R. M. Catlin, Superintendent.

1. Gray, finely crystalline sandy limestone	at	10 feet.
2. Gray, siliceous limestone	at	31 feet.
3. Gray, siliceous limestone	at	70 feet.
4. Gray slate	at	81 feet.
5. Gray, fine-grained quartzite	at	215 feet.
Gneiss reached	at	230 feet.
6. Light gray, fine-grained gneiss	at	260 feet.
7. Dark, micaceous and hornblendic gneiss, schistose structure	at	325 feet.
Zinc blende in vein 1 to 3 inches wide	at	402 feet.
8. Medium coarse-grained granite	at	420 feet.
9. White, fine-grained granite-gneiss	at	460 feet.

Specimens 1 to 4 are from the basal portion of the Kittatinny (blue limestone or magnesian of older reports), and represent the transition beds into the Hardyston quartzite (specimen 5) which rests upon the gneiss (specimens 6–9).

THE LIMESTONE INDUSTRY.

Limestone.—The limestone industry of New Jersey presents three distinct phases: (1) The white crystalline limestone; (2) cement rock; (3) the blue magnesian limestone. The first and second are localized at definite centers in Sussex and Warren counties respectively; the third is widely scattered in the two counties mentioned and in Hunterdon.

The white limestone industry.—A narrow belt[1] of white coarsely crystalline limestone extends from Sparta north through Franklin, Hamburg, McAfee to the New York State line. In addition to the main belt there are several isolated areas near the larger one. This stone is extensively quarried near Franklin, Hamburg and McAfee, the product being used chiefly for flux and large amounts being shipped to the foundries at South Bethlehem, Wharton, Stanhope and Phillipsburg. A much less amount is sold to the Portland cement manufacturers for use in raising the lime content in their raw mixture. Two firms quarry and burn the limestone in the manufacture of a high-grade white lime.

There are very great variations in the chemical composition of this limestone, and it ranges from a dolomite, carrying over 44 per cent. magnesian carbonate, to a limestone with over 98 per

[1] See Annual Report of the State Geologist for 1905 for map and many analyses.

cent. of calcium carbonate and one per cent. or less of magnesian carbonate, while there are many analyses which show 3 per cent. or less of magnesian carbonate. Experience has demonstrated that the amount of magnesian carbonate varies greatly in the rock so that it necessitates constant watchfulness in most quarries to maintain a product with low magnesia, such as is required for Portland cement. This is rendered the more difficult since it is impossible by the eye to differentiate the magnesian stone from that which is very low in magnesia. In many quarries the variation in composition is so great that a low magnesia product cannot be economically mined at the prices paid. The requirements for fluxing stone are much less rigid than those insisted upon by cement manufacturers and can be readily met by a much larger number of quarries.

During 1907 the total product was 552,565 tons, as compared to 459,927 for 1906.

Cement rock.—The chief deposit of cement rock in New Jersey is found in Warren County, in a narrow belt which extends from Carpentersville, N. J., northeastward for several miles. Three large cement plants, whose combined output last year was over 4,000,000 barrels, are located in this vicinity, and obtain 80 per cent. or more of their raw material from this deposit.

Composition.—The cement rock is an earthy limestone which contains 60 to 70 per cent. of lime carbonate, less than 4 or 5 per cent. of magnesian carbonate, 14 to 20 per cent. silica and 6 to 10 per cent. alumina and iron. It is dark gray to slaty black in color, breaking with an even fracture into flat pieces. The basal portion of the formation usually contains more lime than the middle and upper portion and more than enough for a correct cement mixture, so that by combining the rock from different parts of a quarry it is sometimes possible to get a mixture of the right composition. At all three of the New Jersey plants, however, it is necessary to import some pure limestone from other districts.

During 1907 the production of cement rock is estimated at 971,008 long tons, all of which was used at the adjoining cement plants.

Magnesian limestone.—By far the greater part of the limestone found in New Jersey is of the magnesian variety, having from 14 to 21 per cent. of magnesia or 27 to 40 per cent. of magnesian carbonate. This rock has been variously known as the "blue" limestone, in contradistinction to the white limestone near Franklin; as the "magnesian" limestone, and in later reports of the State Survey as the "Kittatinny" limestone.

Commercially, this limestone is now of little value, although formerly extensively utilized. Locally, it is quarried in a small way for foundation stones; years ago, when the use of lime as fertilizer was more prevalent than at present, a considerable amount in the aggregate was burned in many small kilns scattered through Hunterdon, Warren and Sussex counties; large quantities (judging from the size of abandoned quarries) have been used in the iron furnaces as flux. At present it is quarried chiefly at Clinton, Califon, Riegelsville and perhaps other points. Most of the product is burned for lime to meet local markets. Some is shipped. Figures showing the total production are not available, but they are far less than for the two classes previously mentioned.

THE PORTLAND CEMENT INDUSTRY.

The Portland cement industry of New Jersey is an important one, in fact the State is second only to Pennsylvania in the amount annually produced, and in 1907 manufactured about 9 per cent. of the total for the United States. There are at present three active plants, all of them in Warren County near Phillipsburg. During the past year three new kilns were added at one of these plants, making a total in operation of 55 kilns. These plants used upwards of 971,000 tons of cement rock and 195,000 tons of pure limestone and produced 4,517,453 barrels of cement valued at the mill in bulk at $4,344,090. Comparing these figures with those of 1906, as reported by the United States Geological Survey, we find an increase in production of 93,805 barrels and a decrease in value of $101,274. The small increase in production and the decrease in values find explanation, of course, in the general stagnation in all lines of business during the last two months of the year and the consequent cut in prices. This resulted in at least the partial shutdown of all the mills for varying periods during November and December. During 1906 prices averaged $1.00½ per barrel at the mill exclusive of the package, while during 1907 the average price, as compiled from the above returns, was

96.2 cents, and during December prices were quoted as low as 75 to 85 cents per barrel net.

In New Jersey, as in nearly all the Lehigh region of Pennsylvania, the cement rock used is somewhat deficient in lime, which necessitates the addition of a certain percentage of high-grade limestone to the raw material. Naturally for this purpose the attempt is made to secure as pure a limestone as possible. The amount added to the cement rock varies from 18 to 22 per cent. of the total mix and the aggregate amounted last year to about 195,000 tons. The greater part of this is obtained from quarries at Annville and Palmyra, Penna., but about one-third or less is supplied from New Jersey, chiefly from the white limestone quarries near Franklin Furnace.

Reference has been made elsewhere in this report (pp. 15–19) to the exploitation of this industry by highly exaggerated statements regarding expected profits. It is hardly necessary to say that no one acquainted with the actual conditions is deceived for a moment thereby.

GRAPHITE.

Numerous attempts have been made to mine graphite in New Jersey, but none of them have been commercially successful, since the deposits are in general lean and scattered.

The most recent experiment was made at High Bridge last year where a graphite-bearing bed of gneiss 30 to 50 feet wide was opened by a tunnel driven along the strike of the bed for a distance of about 400 feet. The ore-bed is reported to dip 70 degrees westward with a strike west of north. It is covered by about 6 feet of soil, mostly disintegrated rock. Pronounced weathering extends to a depth of 30 feet. The ore was reported to contain from 4 to 8 per cent. graphite and the mill test gave about 4 per cent. extraction, but considerable was lost in the process. The graphite recovered was divided into four grades. The only ore mined was that taken out in driving the tunnel, and during the seven months that work was continued about three and a-half carloads of graphite were obtained and shipped. The plant was closed down in November. The enterprise seems to have been ill-advised in that a costly plant was erected before much development work had been done.

March 18th, 1908.

Mineral Statistics.

For the Year 1907.

IRON ORE.

The total production of the mines, as reported by the several mining companies, was 558,137 gross tons.

The table of statistics is reprinted, with the total amount for 1907 added.

TABLE OF STATISTICS.

Year.	*Iron Ore.*	*Authority.*
1790	10,000 tons	Morse's estimate.
1830	20,000 tons	Gordon's Gazetteer.
1855	100,000 tons	Dr. Kitchell's estimate.
1860	164,900 tons	U. S. census.
1864	226,000 tons	Annual Report State Geologist.
1867	275,067 tons	" " "
1870	362,636 tons	U. S. Census.
1871	450,000 tons	Annual Report State Geologist.
1872	600,000 tons	" " "
1873	665,000 tons	" " "
1874	525,000 tons	" " "
1875	390,000 tons	" " "
1876	285,000 tons	" " "
1877	315,000 tons*	" " "
1878	409,674 tons*	" " "
1879	488,028 tons	" " "
1880	745,000 tons	" " "
1881	737,052 tons	" " "
1882	932,762 tons	" " "
1883	521,416 tons	" " "
1884	393,710 tons	" " "
1885	330,000 tons	" " "
1886	500,501 tons	" " "
1887	547,889 tons	" " "
1888	447,738 tons	" " "
1889	482,109 tons	" " "
1890	552,996 tons	" " "

*From statistics collected later.

Year.	*Iron Ore.*	*Authority.*
1891	551,358 tons	Annual Report State Geologist.
1892	465,455 tons	" " "
1893	356,150 tons	" " "
1894	277,483 tons	" " "
1895	282,433 tons	" " "
1896	264,999 tons	" " "
1897	257,235 tons	" " "
1898	275,378 tons	" " "
1899	300,757 tons	" " "
1900	342,390 tons*	" " "
1901	401,151 tons	" " "
1902	443,728 tons	" " "
1903	484,796 tons*	" " "
1904	499,952 tons	" " "
1905	500,541 tons	" " "
1906	542,488 tons	" " "
1907	558,137 tons	" " "

ZINC ORE.

The production of the New Jersey Zinc Company's mines is reported by the company to be 329,205 gross tons of zinc and franklinite ore. It was chiefly separated at the company's mills. This report shows a decrease of 32,120 tons as compared with the year 1906.

The statistics for a period of years are reprinted from the last annual report.

ZINC ORE.

Year.	*Zinc Ore.*	*Authority.*
1868	25,000 tons†	Annual Report State Geologist.
1871	22,000 tons†	" " "
1873	17,500 tons	" " "
1874	13,500 tons	" " "
1878	14,467 tons	" " "
1879	21,937 tons	" " "
1880	28,311 tons	" " "
1881	49,178 tons	" " "
1882	40,138 tons	" " "
1883	56,085 tons	" " "
1884	40,094 tons	" " "

* The figures, 407,596 tons, given in the report for 1900, included 75,206 tons of crude material which should have been reduced to its equivalent in concentrates. The figures for 1903, given in the report for that year, were incorrect.

† Estimated for 1868 and 1871. Statistics for 1873–1890, inclusive, are for shipments by railway companies. The later reports are from zinc-mining companies.

Year.	Zinc Ore.	Authority.
1885	38,526 tons	Annual Report State Geologist.
1886	43,877 tons	" " "
1887	50,220 tons	" " "
1888	46,377 tons	" " "
1889	56,154 tons	" " "
1890	49,618 tons	" " "
1891	76,032 tons	" " "
1892	77,298 tons	" " "
1893	55,852 tons	" " "
1894	59,382 tons	" " "
1895*		
1896	78,080 tons	" " "
1897	76,973 tons	" " "
1898	99,419 tons	" " "
1899	154,447 tons	" " "
1900	194,881 tons	" " "
1901	191,221 tons	" " "
1902	209,386 tons	" " "
1903	279,419 tons	" " "
1904	250,025 tons	" " "
1905	323,062 tons	" " "
1906	361,330 tons	" " "
1907	329,205 tons	" " "

OTHER PRODUCTS.

LIMESTONE.

Year.	Limestone.	Authority.
1906	459,927 tons	Annual Report State Geologist.
1907	552,565 tons	" " "

CEMENT ROCK.

Year.	Cement Rock.	Authority.
1907	971,008 long tons	Annual Report State Geologist.

PORTLAND CEMENT.

Year.	Portland Cement.	Authority.
1907	4,517,453 barrels	Annual Report State Geologist.

* No statistics were published in the Annual Report for 1895.

Publications.

It is the wish of the Board of Managers to complete, so far as possible, incomplete sets of the publications of the Survey, chiefly files of the Annual Reports in public libraries, and librarians are urged to correspond with the State Geologist concerning this matter.

The Annual Reports of the State Geologist are printed by order of the Legislature as a part of the legislative documents. They are distributed by the State Geologist to libraries and public institutions, and, so far as possible, to any who may be interested in the subjects of which they treat.

Six volumes of the Final Report series have been issued. Volume I., published in 1888, has been very scarce for several years, but all the valuable tables were reprinted in an appendix of Volume IV., of which a few copies still remain, although the supply of this volume is so far reduced that indiscriminate requests cannot be granted.

The appended list makes brief mention of all the publications of the present Survey since its inception in 1864, with a statement of the editions now out of print. The reports of the Survey are distributed without further expense than that of transportation. Single reports can usually be sent more cheaply by *mail* than otherwise, and requests should be accompanied by the proper postage as indicated in the list. Otherwise they are sent *express collect. 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, 8vo., xxiv+899 pp. Out of print.

PORTFOLIO OF MAPS accompanying the same, as follows:

1. Azoic and paleozoic formations, including the iron-ore and limestone districts; colored. Scale, 2 miles to an inch.
2. Triassic formation, including the red sandstone and trap-rocks of Central New Jersey; colored. Scale, 2 miles to an inch.
3. Cretaceous formation, including the greensand-marl beds; colored. Scale, 2 miles to an inch.
4. Tertiary and recent formations of Southern New Jersey; colored. Scale, 2 miles to an inch.
5. Map of a group of iron mines in Morris County; printed in two colors. Scale, 3 inches to 1 mile.
6. Map of the Ringwood iron mines; printed in two colors. Scale, 8 inches to 1 mile.
7. Map of Oxford Furnace iron-ore veins; colored. Scale, 8 inches to 1 mile.
8. Map of the zinc mines, Sussex County; colored. Scale, 8 inches to 1 mile.

A few copies can be distributed at $2.00 per set.

REPORT ON THE CLAY DEPOSITS of Woodbridge, South Amboy and other places in New Jersey, together with their uses for firebrick, pottery, &c. Trenton, 1878, 8vo., viii+381 pp., with map. Out of print.

A PRELIMINARY CATALOGUE of the Flora of New Jersey, compiled by N. L. Britton, Ph.D. New Brunswick, 1881, 8vo., xi+233 pp. Out of print.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. I. Topography. Magnetism. Climate. Trenton, 1888, 8vo., xi+439 pp. Out of print.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. II. Part I. Mineralogy. Botany. Trenton, 1889, 8vo., x+642 pp. Unbound copies, postage 22 cents. Bound copies, $1.50.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. II. Part II. Zoology. Trenton, 1890, 8vo., x+824 pp. (Postage, 30 cents.)

REPORT ON WATER-SUPPLY. Vol. III. of the Final Reports of the State Geologist. Trenton, 1894, 8vo., xvi+352 and 96 pp. (Postage, 21 cents.)

REPORT ON THE PHYSICAL GEOGRAPHY of New Jersey. Vol. IV. of the Final Reports of the State Geologist. Trenton, 1898, 8vo., xvi+170+200 pp. Unbound copies, postage 24 cents; cloth bound, $1.35, with photo-relief map of State, $2.85. Map separate, $1.50. Scarce.

REPORT ON THE GLACIAL GEOLOGY of New Jersey. Vol. V. of the Final Reports of the State Geologist. Trenton, 1902, 8vo., xxvii+802 pp. (Sent by express, 35 cents if prepaid, or charges collect.)

REPORT ON CLAYS AND CLAY INDUSTRY of New Jersey. Vol. VI. of the Final Reports of the State Geologist. Trenton, 1904, 8vo., xxviii+548 pp. (Sent by express, 30 cents if prepaid, or charges collect.)

BRACHIOPODA AND LAMELLIBRANCHIATA of the Raritan Clays and Greensand Marls of New Jersey. Trenton, 1886, quarto, pp. 338, plates XXXV. and Map. (Paleontology, Vol. I.) (By express.)

GASTEROPODA AND CEPHALOPODA of the Raritan Clays and Greensand Marls of New Jersey. Trenton, 1892, quarto, pp. 402, Plates L. (Paleontology, Vol. II.) (By express.)

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

CRETACEOUS PALEONTOLOGY. Trenton, 1907, 8vo., ix+1106 pp., Plates CXI. (Paleontology, Vol. IV.) (Sent by express, 45 cents if prepaid, or charges collect.)

ATLAS OF NEW JERSEY. The complete work is made up of twenty sheets, each about 27 by 37 inches, including margin. Seventeen sheets are on a scale of 1 inch per mile and three on a scale of 5 miles per inch. It is the purpose of the Survey gradually to replace Sheets 1-17 by a new series of maps, upon the same scale, but somewhat differently arranged so as not to overlap. The new sheets will be numbered from 21-37, and will be subject to extensive revision before publication. These sheets will each cover the same territory as eight of the large maps, on a scale of 2,000 feet per inch. Nos. 1, 2, 3, 4, 5, 6, 7, 8, 11, 12, 13, 15, 16 and 17 have already been replaced as explained below.

No. 9. Monmouth Shore, with the interior from Metuchen to Lakewood.

No. 10. Vicinity of Salem, from Swedesboro and Bridgeton westward to the Delaware.

No. 14. Vicinity of Bridgeton, from Allowaystown and Vineland southward to the Delaware Bay shore.

No. 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.

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

No. 31. Vicinity of Camden, to Mount Holly, Hammonton and Elmer. Replaces Sheet 11.

No. 32. Part of Burlington and Ocean counties, from Pemberton and Whitings to Egg Harbor City and Tuckerton. Replaces Sheet 12.

No. 33. Southern Ocean County—Tuckerton to Tom's River and Chadwicks. Replaces Sheet 13.

No. 35. Vicinity of Millville, from Newfield to Port Norris and Cape May Court House.

No. 36. Parts of Atlantic and Cape May counties—Egg Harbor City to Townsend's Inlet, with inset of New Inlet and Great Bay.

No. 37. Cape May—Cape May City to Ocean City and Mauricetown.

No. 38. New Jersey State Map. Scale, 5 miles to the inch. Shows all municipalities.

Other sheets of the new series, Nos. 21–37, will be printed from time to time, as the older sheets become out of print. All the maps are sold at the uniform price of twenty-five cents per sheet, either singly or in lots. Since the Survey cannot open small accounts, and the charge is merely nominal, remittance should be made with the order. Order by *number* of the State Geologist, Trenton, N. J.

TOPOGRAPHIC MAPS, NEW SERIES.

These maps are the result of recent revision of the earlier surveys, and contain practically all of the features of the one-inch scale maps, with much new material. They are published on a scale of 2,000 feet to an inch, and the sheets measure 26 by 34 inches. The Hackensack, Paterson, Boonton, Dover, Jersey City, Newark, Morristown, Chester, New York Bay, Elizabeth, Plainfield, Pluckemin, Amboy, New Brunswick, Somerville, Navesink, Long Branch, Shark River, Trenton, Camden, Mt. Holly, Woodbury, Taunton and Atlantic City sheets have been published and are now on sale. The price is twenty-five cents per sheet, *payable in advance*. Order by *name* any of the sheets above indicated as ready, of the State Geologist, Trenton, New Jersey.

ANNUAL REPORTS.

REPORT OF PROFESSOR GEORGE H. COOK upon the Geological Survey of New Jersey and its progress during the year 1863. Trenton, 1864, 8vo., 13 pp. Out of print.

THE ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, to his Excellency Joel Parker, President of the Board of Managers of the Geological Survey of New Jersey, for the year 1864. Trenton, 1865, 8vo., 24 pp. Out of print.

ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, to his Excellency Joel Parker, President of the Board of Managers of the Geological Survey of New Jersey, for the year 1865. Trenton, 1866, 8vo., 12 pp. Out of print.

ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, on the Geological Survey of New Jersey, for the year 1866. Trenton, 1867, 8vo., 28 pp. Out of print.

REPORT OF THE STATE GEOLOGIST, Prof. Geo. H. Cook, for the year of 1867. Trenton, 1868, 8vo., 28 pp. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1869. Trenton, 1870, 8vo., 57 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1870. New Brunswick, 1871, 8vo., 75 pp., with maps. 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. Scarce.*

ANNUAL REPORT of the State Geologist of New Jersey for 1884. Trenton, 1884, 8vo., 168 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1885. Trenton, 1885, 8vo., 228 pp., with maps.

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

ANNUAL REPORT of the State Geologist of New Jersey for 1887. Trenton, 1887, 8vo., 45 pp., with maps.

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

ANNUAL REPORT of the State Geologist of New Jersey for 1889. Camden, 1889, 8vo., 112 pp.

ANNUAL REPORT of the State Geologist of New Jersey for 1890. Trenton, 1891, 8vo., 305 pp., with maps. (Postage, 10 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1891. Trenton, 1892, 8vo., xii+270 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1892. Trenton, 1893, 8vo., x+368 pp., with maps. (Postage, 10 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1893. Trenton, 1894, 8vo., x+452 pp., with maps. (Postage, 18 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1894. Trenton, 1895, 8vo., x+304 pp., with geological map. (Postage, 11 cents.)

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

ANNUAL REPORT of the State Geologist of New Jersey for 1896. Trenton, 1897, 8vo., xxviii+377 pp., with map of Hackensack meadows. (Postage, 15 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1897. Trenton, 1898, 8vo., xl+368 pp. (Postage, 12 cents.)

ANNUAL REPORT of the State Geologist for 1898. Trenton, 1899, 8vo., xxxii+244 pp., with Appendix, 102 pp. (Postage, 14 cents.)

ANNUAL REPORT of the State Geologist for 1899 and REPORT ON FORESTS. Trenton, 1900, 2 vols., 8vo., Annual Report, xliii+192 pp. FORESTS, xvi+327 pp., with seven maps in a roll. (Postage, 8 and 22 cents.)

ANNUAL REPORT of the State Geologist for 1900. Trenton, 1901, 8vo., xl+231 pp. (Postage, 10 cents.)

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

ANNUAL REPORT of the State Geologist for 1902. Trenton, 1903, 8vo., viii+155 pp. (Postage, 6 cents.)

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* This report can be supplied only to libraries.

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

ANNUAL REPORT of the State Geologist for 1904. Trenton, 1905, 8vo., x+317 pp. (Postage, 11 cents.)

ANNUAL REPORT of the State Geologist for 1905. Trenton, 1906, 8vo., x+338 pp., with three maps in a pocket. (Postage, 14 cents.)

ANNUAL REPORT of the State Geologist for 1906. Trenton, 1907, 8vo., vii+192 pp. (Postage, 9 cents.)

INDEX.

PLATE V


SURVEY AND PLAN
FOR THE IMPROVEMENT OF
MANASQUAN INLET, N. J.
SCALE
Feet 0 200 400 Feet.
Made by Lewis M. Haupt, C.E.
July. 1907.
Under the direction of the
STATE GEOLOGICAL SURVEY,
Henry B. Kümmel, State Geologist.
PLAN
30'
10'
ELEVATION OF SAND BARRIER
M.L.T.
END VIEW
CROSS SECTION OF REACTION JETTY
M.L.T.
10'
12'
1 : 1.5
1 : 2
SCALE
8 4 0 8 Feet
U. S. BULKHEAD OF 1882.
INNER MIDDLE GROUND
COVERED AT HIGH TIDES
HABERLE'S GAUGE
JETTY
SPUR
South Spit
LOW WATER LINE
BREAKERS
SAND BARRIER AND REACTION JETTY
CHANNEL
SILL
buoy
Shells
CEDAR GROVE
CHIMNEY
TANK
GAUGE
FLAG
B.M.
COOK'S BRIDGE GAUGE
To Point Pleasant
LOW
ATLANTIC OCEAN
M.H.W.
M.L.W.
Gorge D-E.
Profile on F-G
Profile on Crest of Bar A-B-C.
Low-water section 1200 sq'
SCALE { Vertical - - - 10 Feet = One Inch
Horizontal - 200 " " "

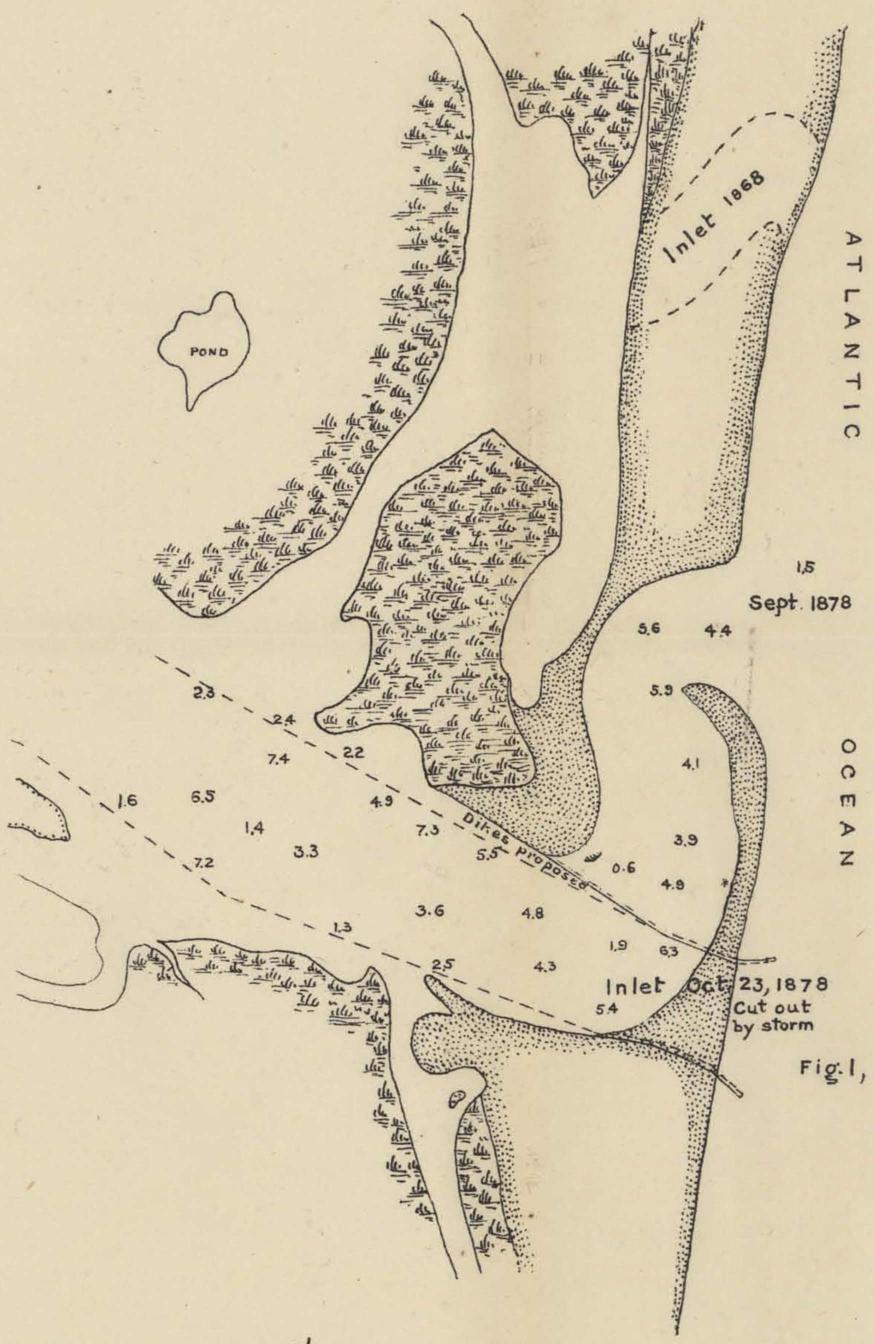


Fig. 1,

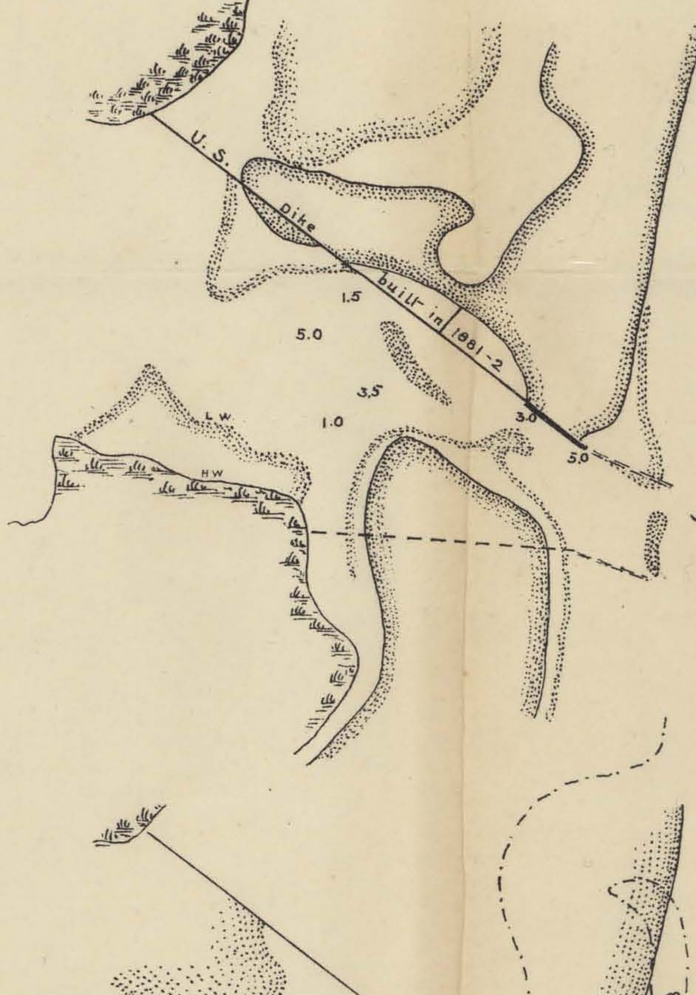


Fig. 2,

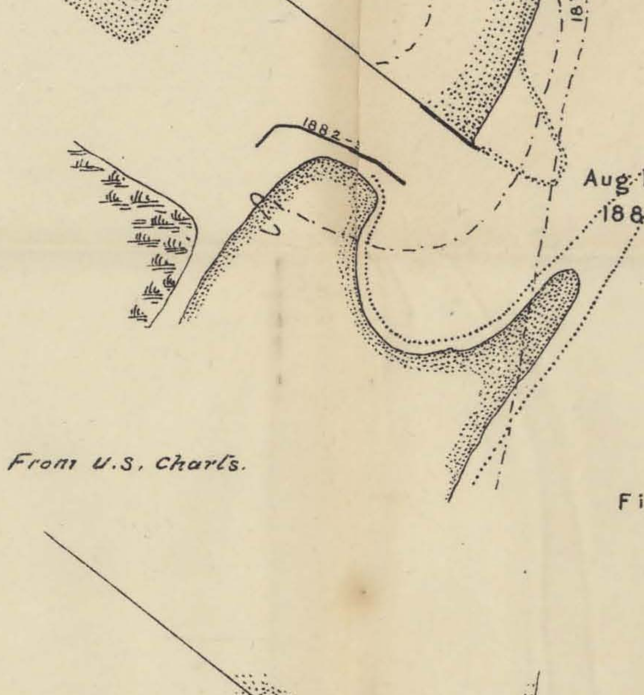


Fig. 3,

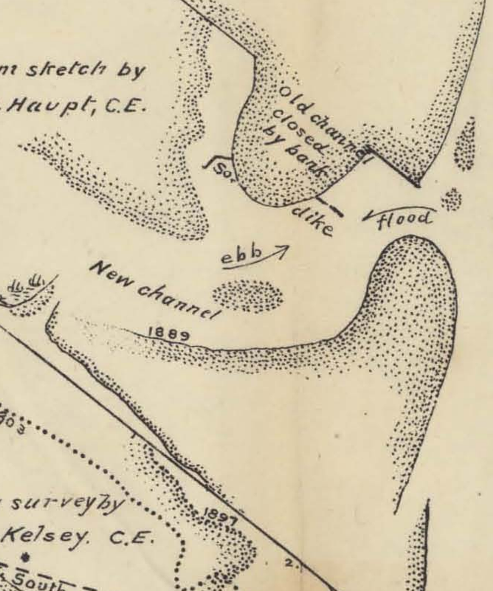


Fig. 4,

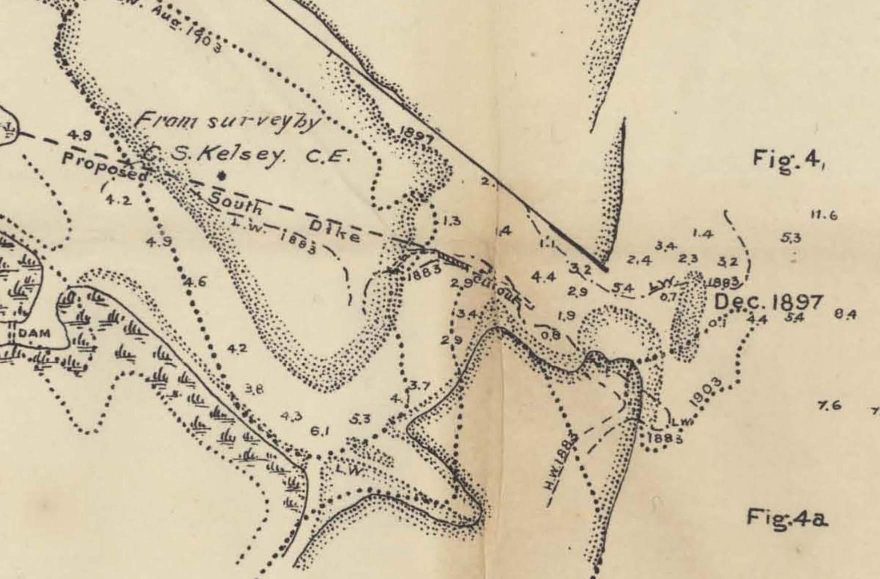


Fig. 4a

SURVEYS AND SKETCHES

OF THE CHANGES AT THE MOUTH OF THE

MANASQUAN RIVER, N. J.

AND ITS PROPOSED IMPROVEMENT BY THE

REACTION JETTY

AS DESIGNED BY LEWIS M. HAUPT, C.E.

— NOTES —

The Government report of 1879 says "The intractibility of the inlet has always been the most serious obstacle to the use and improvement of the river."

The North dike as built in 1882, has in a measure fixed the position of the inlet, but the Report of 1887 says "No permanent improvement has been effected." A few years later the South dike was destroyed by a storm - only its rock filling remains.

The frequent changes at the mouth are clearly shown by the careful sketches made by Oliver C. Herbert, during the past six months, and indicate the necessity of the "driftward" reaction jetty to protect the inlet from sand, admit the flood tide, and control the ebb currents more completely.

SCALE - 400 FEET TO ONE INCH.

JAN. 1908

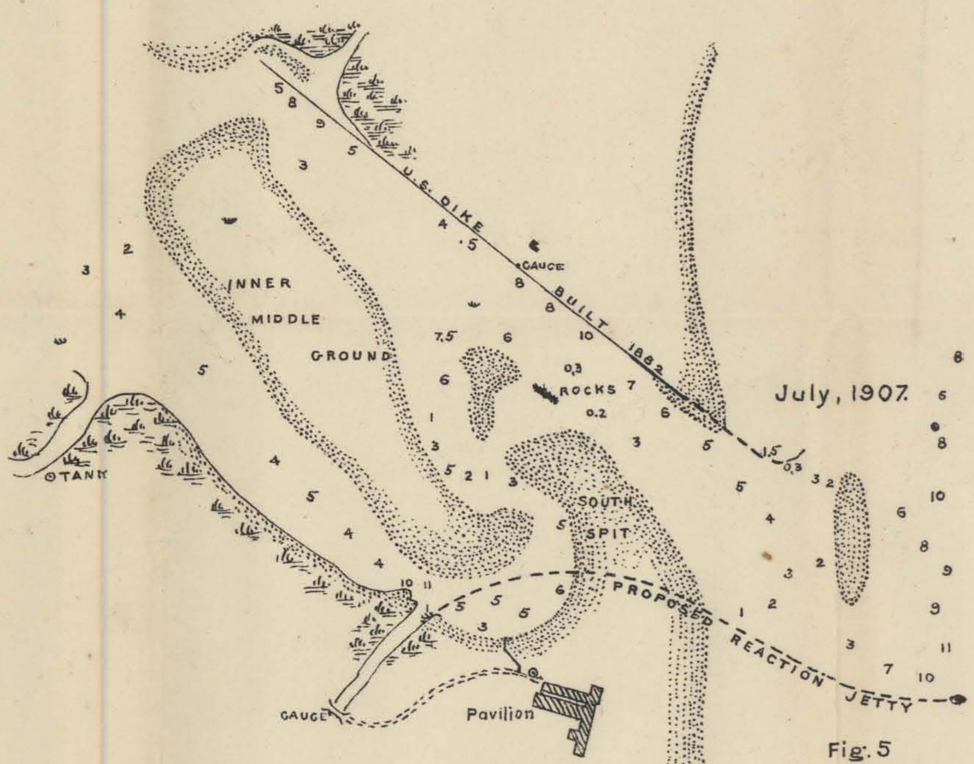


Fig. 5

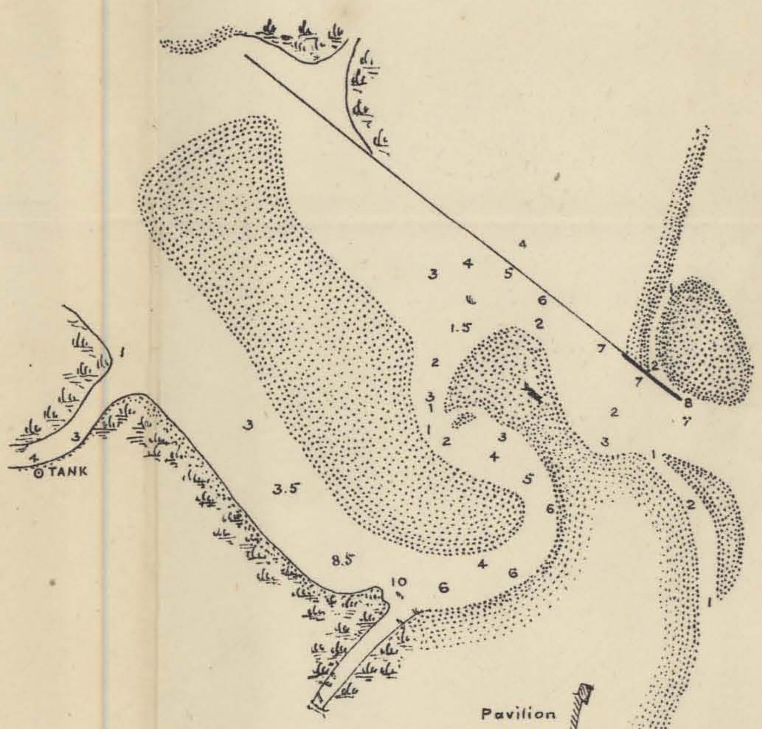


Fig. 6,

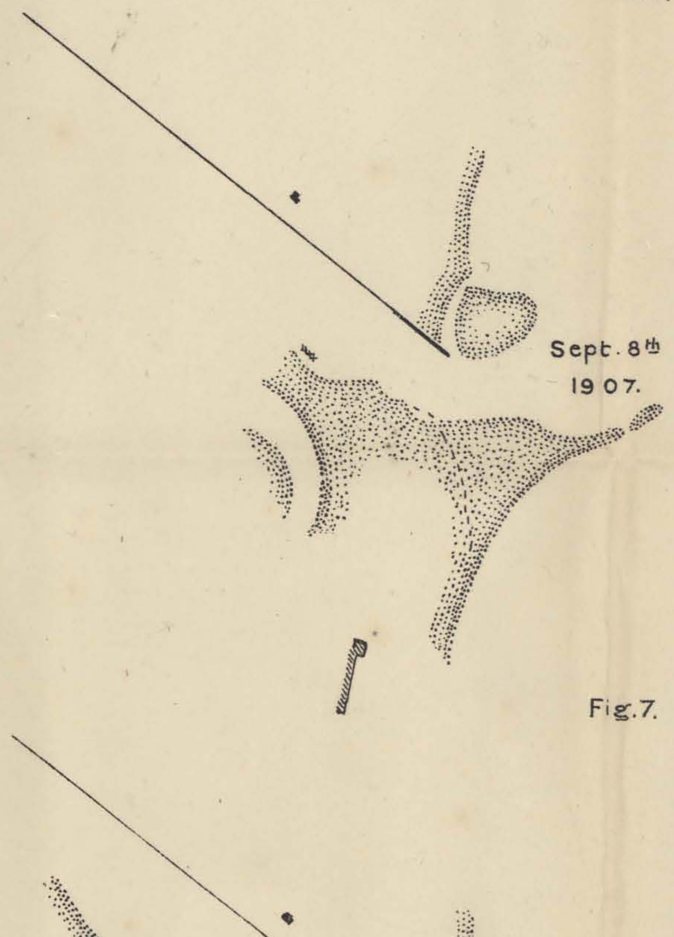


Fig. 7.

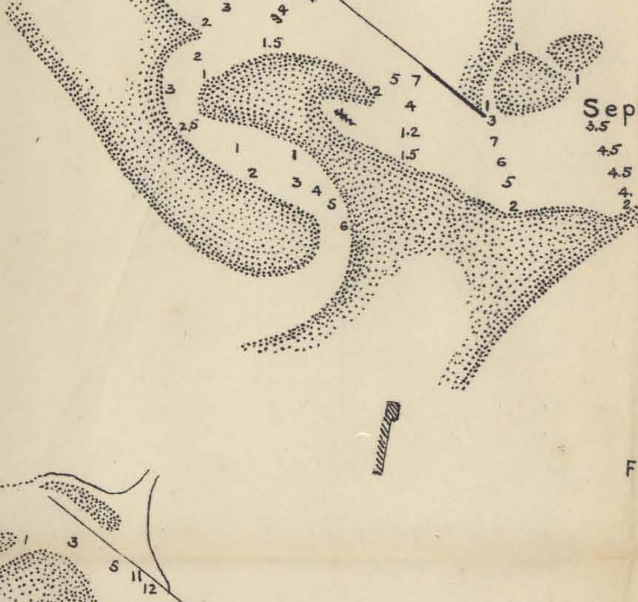


Fig. 8,

Fig. 9,

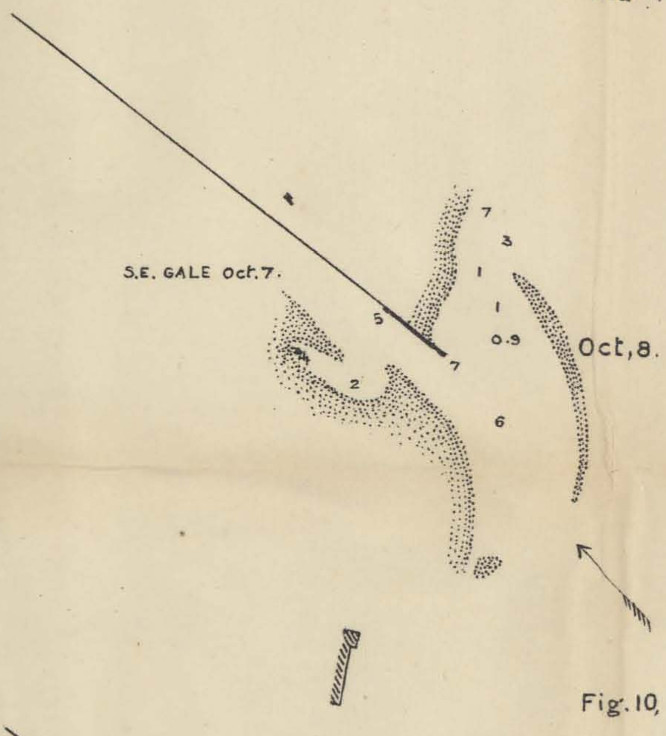
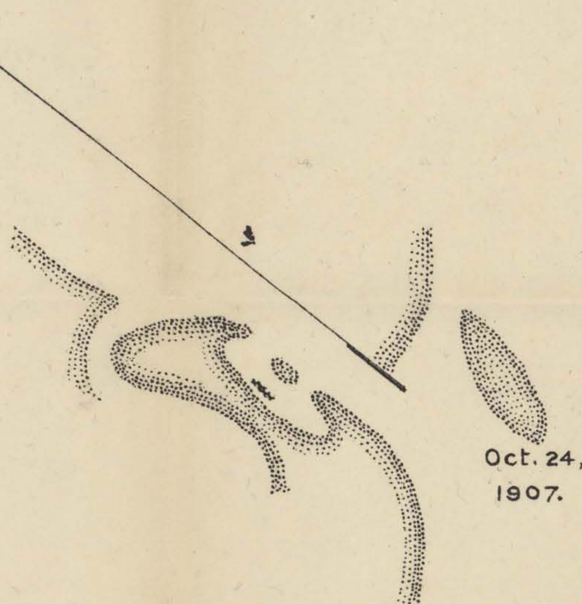


Fig. 10,



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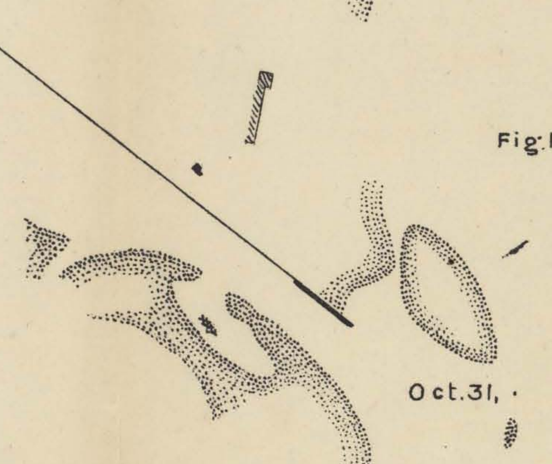


Fig. 12

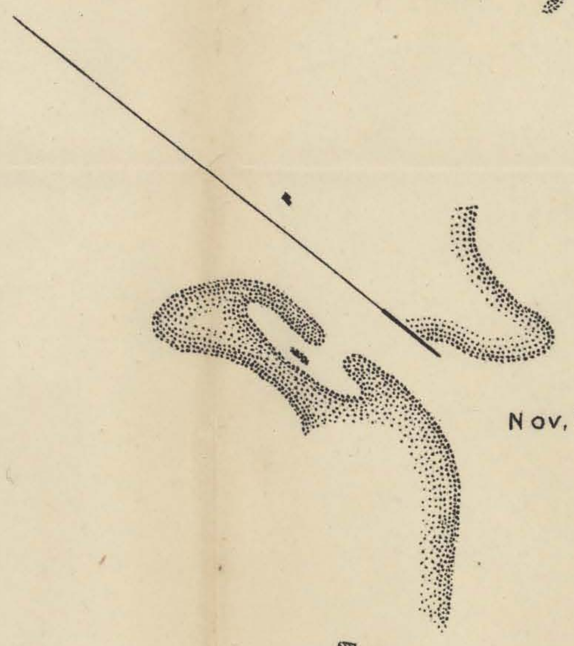
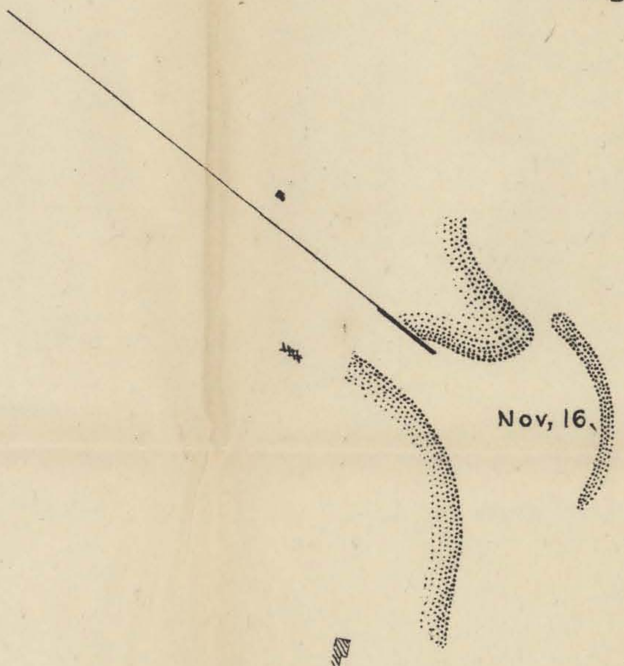


Fig. 13,



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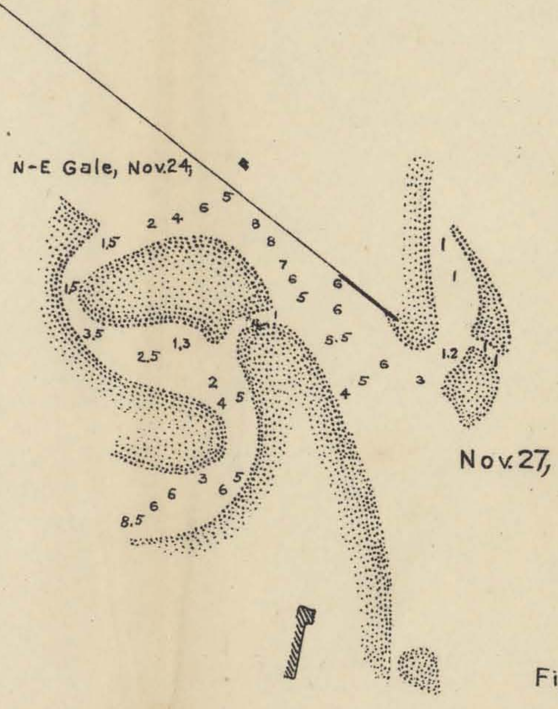

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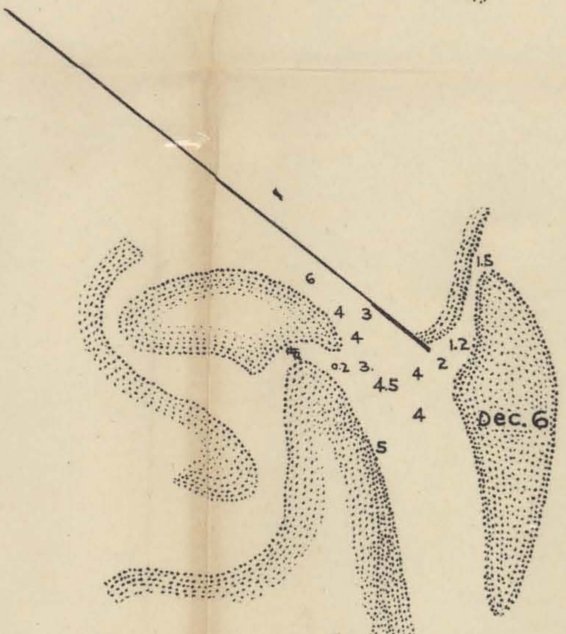

Fig. 16,

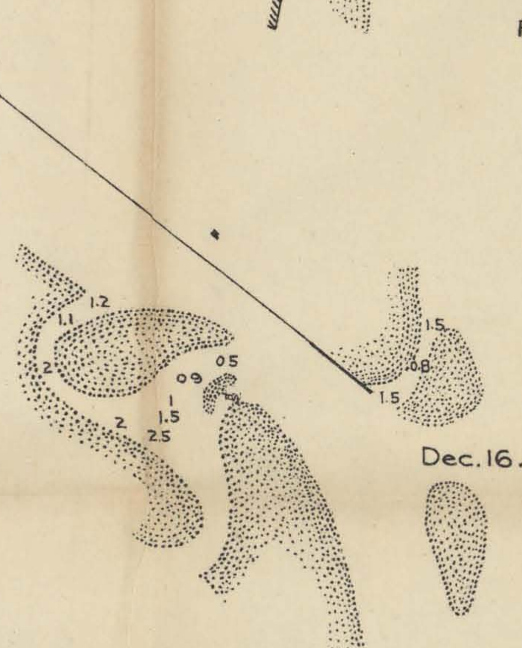

Fig. 17,

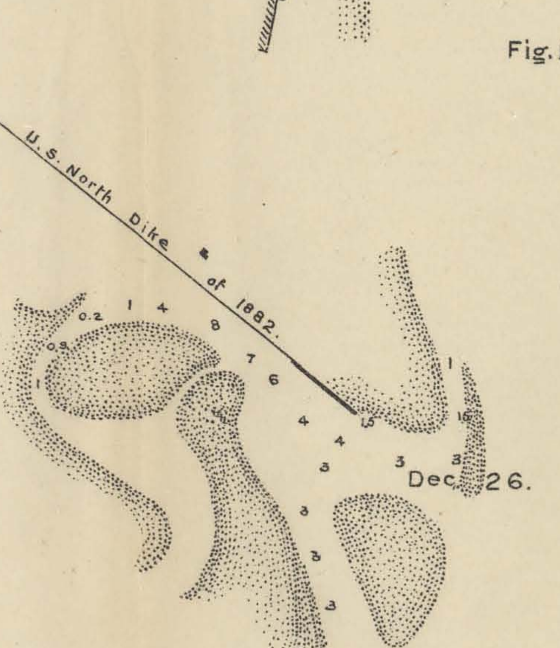

Fig. 18,

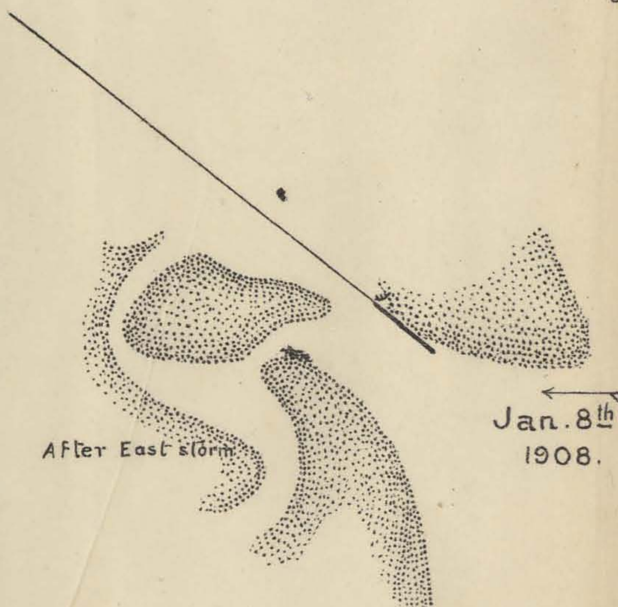

Fig. 19,

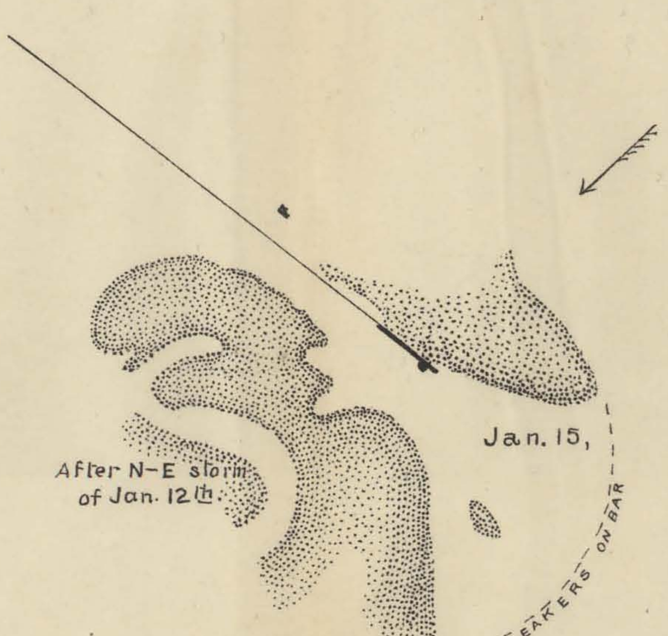

Fig. 20,