GEOLOGICAL SURVEY OF NEW JERSEY

ANNUAL REPORT

OF THE

STATE GEOLOGIST

For the Year 1908

TRENTON, N. J.
MacCrellish & Quigley, State Printers.
1909.

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The Geological Survey of New Jersey.

BOARD OF MANAGERS.

His Excellency J. Franklin Fort, Governor and *ex-officio* President of the Board, ... Trenton.

Members at Large.

Thomas W. Synnott,	Wenonah,	1909
Alfred A. Woodhull,	Princeton,	1909
David E. Titsworth,	Plainfield,	1911
George G. Tennant,	Jersey City,	1911
Harrison Van Duyne,	Newark,	1912
Charles L. Pack,	Lakewood,	1913
John C. Smock,	Trenton,	1913

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,	1913
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,	1913
X. Aaron S. Baldwin,	Hoboken,	1910

State Geologist.

HENRY B. KÜMMEL.

TRENTON, N. J., December 2, 1908.

To His Excellency, John Franklin Fort, Governor of the State of New Jersey, and ex-officio President of the Board of Managers of the Geological Survey:

SIR—I have the honor to submit my Administrative Report summarizing the work of the Geological Survey of New Jersey for the year 1908. In accordance with the custom of previous years, several papers of scientific and economic value will accompany this report. It has been impossible to complete these in the short time elapsing since the close of the field season. Furthermore, the statistics of the mineral production for 1908 cannot be compiled until after January 1st.

I, therefore, recommend that advance copies of the Administrative Report be printed for the use of the Legislature, and that the printing of the whole report be deferred until the other papers can be completed.

Yours respectfully,

HENRY B. KÜMMEL,

State Geologist.

Administrative Report.

Administration, Organization, Publications, Distribution, Library, Collections, Editorial Work.—Topography.—Hydrography.—Geology, Building Stones, Iron Ores, Paleobotany.—Chemistry.—Co-operation with the U. S. Geological Survey.

Administrative Report.

HENRY B. KÜMMEL, STATE GEOLOGIST.

The work of the Geological Survey for the year ending October 31st, 1908, is briefly summarized in the following pages of the Administrative Report. Reports giving the results of special investigations will follow.

ADMINISTRATION.

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

Washington A. Roebling, Trenton; Fourth Congressional District.

Joseph D. Bedle, Jersey City; Ninth Congressional District.

John C. Smock, Trenton; Member-at-Large.

A vacancy in the Board was also filled by the appointment of Charles L. Pack, Lakewood, as Member-at-Large.

During the year the Board lost by death one of its oldest members. Mr. Emmor Roberts, of Moorestown, died April 7th, 1908, after a brief illness. He was elected to membership in the Board December 18th, 1888, and for nearly twenty years was a regular attendant upon its meetings. For much of this time he represented the Survey at the meetings of the State Board of Agriculture.

During the year the following persons were engaged upon work for the Survey, most of them upon a per diem basis:

Henry B. Kümmel, State Geologist.
R. B. Gage, Chemist.
Laura Lee, Clerk and Stenographer.
Howard M. Poland, General Assistant.
J. Clifford Wilkes, General Assistant.
William S. Valiant, Indexer.

Rollin D. Salisbury, Geologist.
Stuart Weller, Paleontologist.
W. S. Bayley, Geologist.
J. Volney Lewis, Geologist.
E. W. Berry, Paleobotanist.

C. C. Vermeule, Topographer and Consulting Engineer.
Lewis M. Haupt, Engineer.
P. D. Staats, Assistant Topographer.
C. V. Coriell, Assistant Topographer.
D. C. Stagg, Draughtsman.

John Baumann, Janitor at Laboratory.

Publications.—The Adminstrative Report of the State Geologist for 1907, the Report on an Inland Waterway from Cape May to Bay Head, by H. B. Kümmel, C. C. Vermeule and L. M. Haupt, ordered by act of Legislature approved June 10th, 1907, and the Report on the Improvement of Manasquan Inlet, by L. M. Haupt, ordered by act of Legislature approved June 10th, 1907, were published in January and laid before the Legislature early in the session. The complete Annual Report for 1907, which included the following papers, was issued in July:

Administrative Report.

Report on an Inland Waterway from Cape May to Bay Head, by Henry B. Kümmel, C. C. Vermeule and Lewis M. Haupt.

Report on the Improvement of Manasquan Inlet by Lewis M. Haupt.

Supplementary Reports: Inland Waterway by C. C. Vermeule; Manasquan Inlet by Lewis M. Haupt.

Petrography of the Newark Igneous Rocks of New Jersey by J. Volney Lewis.

Notes on the Mineral Industry, with Mineral Statistics, by Henry B. Kümmel.

New and revised editions of Atlas Sheets Nos. 25, 35 and 36 were published in February, and of No. 26 in November, 1908, just after the close of the year. Before publication, Sheets Nos. 25, 35 and 36 were carefully resurveyed to bring them up to date, and in the case of No. 25 new copper plates were engraved, since the revision was so extensive that it was impracticable to correct the old stones. The changes on Nos. 35 and 36 not being so extensive were made upon the engraved stones. Sheet 26 had been resurveyed in 1903, but it was revised as carefully as possible without making a resurvey in order to embody the more important changes.

The first of the geologic folios, which are being prepared in co-operation with the U. S. Geological Survey, was published in July. It is known as the Passaic folio, and includes the region between latitude 40° 30′ and 41° N. and longitude 74° 00′ and 74° 30′; that is it covers the country from Perth Amboy and New Brunswick on the south to Westwood, Hohokus and Pompton on the north; from Jersey City and New York Bay on the east to Hibernia, Denville, Morristown and Dunellen on the west. It comprises a topographic map on a scale of 2 miles to an inch, a geologic map on the same scale showing the rock geology, a geologic map showing the surface formations—which are principally of glacial origin, a geological structure map showing by cross sections the underground position of the various geological formations, half-tone illustrations of the scenery and geology, and 27 pages of descriptive text. The whole is bound in heavy manilla covers and measures 18½ inches by 21½ inches. The text includes a full description of the geography and geology of the region grouped under the following heads:

- Geography.
  - Location.
  - Topography.
  - Drainage.
- Descriptive Geology.
  - General Relations.
  - Pre-Cambrian Rocks.
    - Introductory Statement.
    - Relations to Adjoining Pre-Cambrian Areas.
    - Character and Age.
    - Franklin Limestone.
    - Gneisses.
    - Garnetiferous graphite schist.
    - Magnetite.
    - Pegmatite.
    - Diabase.
  - Ordovician System.
    - Hudson schist.
  - Silurian System.
    - Green Pond Conglomerate.
  - Post-Hudson Ingeous Rocks.
    - Serpentine.
    - Granite.
  - Triassic System.
    - Newark Group in General.
    - Newark Group in Passaic Quadrangle.
      - Sedimentary rocks.
      - Watchung Basalt.
      - Palisade Diabase.
  - Cretaceous System.
    - Raritan formation.
  - Quaternary System.
    - Pensauken formation.
    - Glacial deposits.
      - General description of glacial phenomena.
      - Glacial phenomena in Passaic quadrangle.
        - Terminal moraine.
        - Ground moraine.
        - Stratified deposits.
        - Glacial changes in topography.
        - Glacial changes in drainage.
      - Submergence since last glacial stage.
      - Post-Glacial changes.

- Geologic structure.
  - General statement.
  - Structure of Highlands Area.
  - Structure of the Newark Area.
- Geologic History.
  - Pre-Cambrian events.
  - Paleozoic conditions.
  - Post-Carboniferous uplift.
  - Triassic conditions.
  - Post-Newark uplift.
  - Cretaceous conditions.
  - Tertiary conditions.
  - Quaternary conditions.
- Economic Geology.
  - Iron ore.
    - Character and composition.
    - Shape and occurrence of ore bodies.
    - Hibernia mines.
    - Origin of ore.
  - Graphite.
  - Copper ore.
  - Building stone.
  - Road metal.
  - Lime and flux.
  - Clay.
  - Sand and gravel.
  - Peat.
  - Underground water.

The authors of the folio are N. H. Darton, W. S. Bayley, R. D. Salisbury and H. B. Kümmel. The field work and preparation of the text was done partly by the U. S. Geological Survey and partly by the State Survey; the engraving and printing was done by the U. S. Survey. The edition of the State Survey is a small one and the folios are distributed only by sale at 25 cents per copy, postage 15 cents extra.

Three other folios, the Franklin Furnace, the Trenton and the Philadelphia, are in the hands of the engravers and will be issued during the current fiscal year, the first mentioned before the end of December, 1908.

Distribution.—The distribution of the Survey publications is through the office of the State Geologist. The maps are sold at a uniform price of 25 cents per sheet, while the reports are distributed free, except that the payment of postage in the case of some volumes is required. When the supply of any report is reduced to 200 copies it is withdrawn from free distribution, and, by order of the Board of Managers, the remaining copies are sold at cost.

The sale of maps by the Survey during the past three years is as follows:

	Sheets sold.		
	1906	*1907*	*1908*
Maps on scale of 1 inch per mile, ...	1974	1127	1637
Maps on scale of 2½ inches per mile, ...	2607	2160	1718
Geologic folios, ...	....	....	41
	4581	3287	3396

In addition to these maps there were sent out in response to requests 350 copies of a special map showing the proposed inland waterway from Cape May to Bay Head. These were in addition to the copies of the same map distributed with the report of the engineers.

The reports of the Survey have been distributed as follows:

SURVEY REPORTS DISTRIBUTED IN 1907 AND 1908.

	1907.		*1908.*	
Annual Report for 1907, ...			3,044	copies.
" " " 1906, ...	2,926	copies.	122	"
" " " 1905, ...	404	"	92	"
" " " 1904, ...	66	"	34	"
" " " 1903, ...	44	"	33	"
" " " 1902, ...	38	"	32	"
" " " 1901, ...	32	"	27	"
" Reports between 1883-1900, ...	438	"	419	"
Final Reports, Vol. II, ...	56	"	50	"
" " Vol. III, ...	58	"	55	"
" " Vol. IV, ...	42	"	44	"
" " Vol. V, ...	67	"	78	"
" " Vol. VI, ...	119	"	72	"
Other Reports, ...	138	"	1,423	"
Total Reports, ...	4,428	"	5,525	"
Map sheets –				
Scale 1 inch per mile – 19 sheets, ...	1,127		1,637	
Scale 2,000 feet per inch– 24 sheets, ...	2,160		1,718	
Total map sheets, ...	3,287		3,355	
Geologic folis, ...			41	

It is apparent that there is a constant demand for the reports of the Survey, not only for those of the present year but for previous issues. This, of course, is to be expected, in view of the permanent scientific and economic value of their contents.

Library.—The accessions to the library were 40 bound volumes, 101 unbound volumes, 87 pamphlets, 104 maps and 9 atlases. Most of these were received by exchange.

Collections.—Two requests from schools were received for the last of the thirty sets of minerals and rock specimens prepared several years ago. The collections were shipped, and the funds received ($50.00) were turned over to the State Treasurer.

The collection of samples from well borings has been arranged in small glass vials and properly labeled, so that now upwards of 6,000 samples can be conveniently stored in a cabinet 2 by 2½ by 5 feet, outside measurement.

Editorial Work.—Revision of manuscript, correction of proof and preparation of indices demands a portion of my time as well as that of my assistants. A complete index of all the reports of the Survey is being prepared, including also the reports of the Roger's Survey in 1835–1840 and the Kitchell Survey of 1854–1857. In the preparation of this index, Mr. W. S. Valiant of New Brunswick has rendered considerable assistance. Reading of proof of all maps is performed under the supervision of Mr. Vermeule.

TOPOGRAPHIC WORK.

Mr. C. C. Vermeule has continued in charge of all topographic work done by the Survey, and in this work he has employed several of his assistants for various periods.

Field Work.—Most of Monmouth County and portions of Ocean and Middlesex counties have been carefully resurveyed, preparatory to issuing a new edition of the one-inch per mile map (No. 29) covering this region. The changes were so extensive that it was found necessary to prepare entirely new drawings of the entire region, and new copper plates will have to be engraved, as it will be impossible to make such extensive alterations on the old engraved stones and get good results.

During the latter part of the year some field work was done in connection with the revision of Sheet 26—the region from Paterson to Perth Amboy, and the Newark sheet, the earlier editions of both being out of print.

Office Work.—The office work included drawing of Sheet 29, which was not completed at the close of the year, making corrections and preparing for the engraver copy of No. 26 and the Newark sheet, and reading proof of Sheets 35, 36 and 26.

HYDROGRAPHIC WORK.

The Legislature in 1907 ordered a survey from Bay Head to Cape May, and estimates of the cost of dredging a channel 50 feet wide with alternative depths of 8 and 10 feet. After the report was prepared and printed, the Survey was requested by the Governor to make estimates on a channel 100 feet wide and 6 feet deep. This entailed no additional field work, but it necessitated the revision of all estimates and the entire recalculation of all the data to determine the cubic yards of dredging necessary for the new dimensions. These new estimates were published as a supplementary report, and were completed in season to be published with my Annual Report for 1907.

The last Legislature adopted the report of the State Geologist regarding this waterway, and directed that "the said inland waterway from Cape May to Bay Head shall be constructed in accordance with such route as shown upon the official map now on file in the office of the State Geologist of the State of New Jersey, with a minimum depth at low water of six feet and a bottom width of one hundred feet." The construction of this waterway was placed in the newly created Department of Inland Waterways, and $300,000 was appropriated for the work, of which $75,000 was made available during 1908 and 1909. It is of interest to note that, when the contracts for a section at Bay Head and a section at Cape May were let, the unit prices per cubic yard for dredging were slightly under those in the estimates—an indication that the Survey figures of cost were not under estimates.

The constant shifting of the sand at the inlets along the coast makes the question of their betterment an exceedingly difficult one. Last year, in response to Legislative enactment, the Survey presented a plan for the improvement of Manasquan Inlet. Early in the present year Prof. Haupt prepared a series of drawings showing successive changes at the inlet at short intervals. This was accompanied by a supplementary report on the inlet, and printed with my Annual Report for 1907. Later in the year Prof. Haupt prepared a further set of comparative drawings showing the condition of the inlet, at intervals of about a fortnight, from the end of January to August. These with a brief description accompany the present report.

GEOLOGIC WORK.

Building Stones.—During the summer Prof. J. V. Lewis was in the field continuing the collection of data regarding the building stones of the State, in preparation of a report upon this subject. In connection with this work many chemical analyses have been made by Mr. Gage.

Iron-ore Report.—The report on the iron-ores of the State, by Dr. W. S. Bayley, will be completed soon and will at once be printed. It will contain numerous mine maps and a complete compilation of data regarding these mines, as well as much new information regarding them, a valuable discussion regarding the origin of the ore; and a careful estimate of the available ore reserves.

Paleobotanic Work by E. W. Berry.—A small allotment was made to E. W. Berry to permit him to continue his studies of the fossil plants in the Cretaceous sands and clays. Mr. Berry has submitted the following statement regarding the progress of this work:

"A careful study of the Raritan flora has been in progress during the current year. The available materials comprise collections by the writer from various localities within the Raritan terrane and large collections made in years past for the U. S. National Museum but never identified. These were kindly loaned by the latter institution. A considerable number of Professor Newberry's types, preserved in the Museum of the New York Botanical Garden, were also examined.

"Professor Newberry's active work ended nearly twenty years ago. In the interval which has passed since 1890 much new material, both stratigraphical and biological, has come to light, conceptions of species and genera have changed, nomenclature has undergone a revision, and most important explorations have unearthed allied floras eastward to Martha's Vineyard, southward to Alabama, and in the far West. For this and other reasons which could be mentioned it seemed eminently desirable to revise the Raritan flora and bring it up to date, more especially that it might serve for a standard of comparison in the study of the geology of the Coastal Plain to the southward, since related floras are largely preserved in Delaware, the Carolinas, Georgia and Alabama.

"The greater part of this work has been completed. It remains to write the detailed descriptions of species and prepare the discussion of the flora in its general relations, a task which it is hoped may be finished within the next few months."

Work of the State Geologist.—So much of my time as has been available for research work has been spent chiefly upon a report on the artesian waters of the State, and the preparation of material for the geologic folios now being published in coöperation with the U. S. Geological Survey. A little time was spent in the field in northern New Jersey on stratigraphic studies.

CHEMICAL WORK.

Mr. R. B. Gage has continued in charge of the chemical laboratory. During the year the following analyses were made:

Trap rocks (complete analyses),	22
Iron ores—Limonite and Magnetite (complete analyses),	28
Cement rocks,	4
Water,	2
Rocks, ores, minerals (partial),	20

Since each complete analysis of the trap rock and iron ores will average 20 determinations or more, while the other analyses will average about 10 each, there was a total of over 1,200 determinations made.

The permanent equipment of the laboratory has been increased by the addition of over 500 grains of platinum ware, four new carbon generators, a hot water bath, and a hardened steel mortar for crushing ores and rocks. The supply of chemicals and smaller apparatus has also been much increased with a corresponding saving in time for analyses.

CO-OPERATION WITH THE UNITED STATES GEOLOGICAL SURVEY.

Coöperative work with the U. S. Geological Survey in the publication of geologic folios has continued. The Passaic folio was published in July, the Franklin Furnace folio was almost ready for delivery at the close of the year, and the Philadelphia and Trenton folios are well advanced. In this coöperative work the field work and preparation of the manuscript has been done by workers of both Surveys according to a prearranged plan which may vary for each folio. The entire cost of engraving the plates and setting the type is borne by the U. S. Geological Survey. A special edition is printed for the State Survey, at a rate which covers the cost of press work and paper.

Plans for coöperative work in two additional lines have been made with the National Survey during the year. The first of these relates to the collection of well data and the second to the collection of mineral statistics.

In the collection of well records the U. S. Geological Survey has furnished the necessary blanks, bags, etc., all of which are sent under frank. The details of the work, the classification of the material and the preservation of the records are the work of the State Survey. The records themselves are open to examination by members of both organizations.

The agreement regarding the collection of statistical matter is as follows:

"*Agreement:* For coöperation in statistical work between the United States Geological Survey and the Geological Survey of New Jersey:

"In order to avoid a multiplicity of requests for statistical informaton from mine and quarry operations, and also in order that the State Geologist may keep in touch with the mineral producers and the economic development of the mineral resources of the State, the following agreement between the State Geologist and the Director of the United States Geological Survey is made:

"Early in the fall of each year (by October first if possible) a list of the mineral producers, as the United States Geological Survey has them, in the State of New Jersey, is to be sent to the State Geologist, who will check with the lists in the possession of the State Survey and make such corrections as he may be able from the State Survey records. These lists will then be returned to the Division of Mineral Resources of the United States Geological Survey. Blanks for the collection of the statistics will be printed each year at the expense of the United States Geological Survey. Franked envelopes for the transmission of the statistical blanks will be addressed in the office of the Federal Survey and the blanks, either numbered or having the names and addresses of the operators written thereon, will be enclosed in the envelope with a circular letter. A franked envelope addressed to the State Geologist will be inclosed in the envelope with the circular letter and blanks, and all will then be sent to the State Geologist in order that he may inclose such additional circular to the operators as he may desire, *provided* such circular letter has been approved by the Director of the United States Geological Survey. By rubber stamp the State Geologist will indicate on the blank that the work is done by coöperation of the two surveys. On the return of the blanks to the State Geologist he will have each report carefully scrutinized and see that it is in proper form for tabulation. He will make such transcript for his own use as he may desire and then forward the reports to the United States Geological Survey.

"The second and third requests for information will be prepared in the office of the Feedral Survey and transmitted to the State Survey in the same manner as the first requests. The fourth requests, which are sent by registered mail, will have to be sent from Washington. After all attempts to secure returns by mail have been exhausted, the State Geological Survey will undertake to secure the reports from the delinquent operators by personal visits of himself or assistants.

"In the publication of the statistical reports of the State Survey and of the United States Geological Survey, credit for the coöperative plan will be given.

"Either party to this agreement may terminate it by giving notice to the other party previous to September 1st of any year."

It is believed that this plan of coöperation will be of advantage to all concerned. It will save mine and quarry operators the annoyance of receiving duplicate requests for information from the State and National Surveys; it will enable the National Survey to secure more complete data through the greater readiness by which the State Survey can secure returns from the few operators who are inclined to delay or disregard the written requests; it will enable the State Survey to keep in closer touch with the mineral development of the State, particularly in lines which heretofore the State Survey has made no attempt to obtain returns.

PART I.

Further Notes on the Changes at Manasquan Inlet.

By HENRY B. KÜMMEL.

Further Notes on the Changes at Manasquan Inlet.

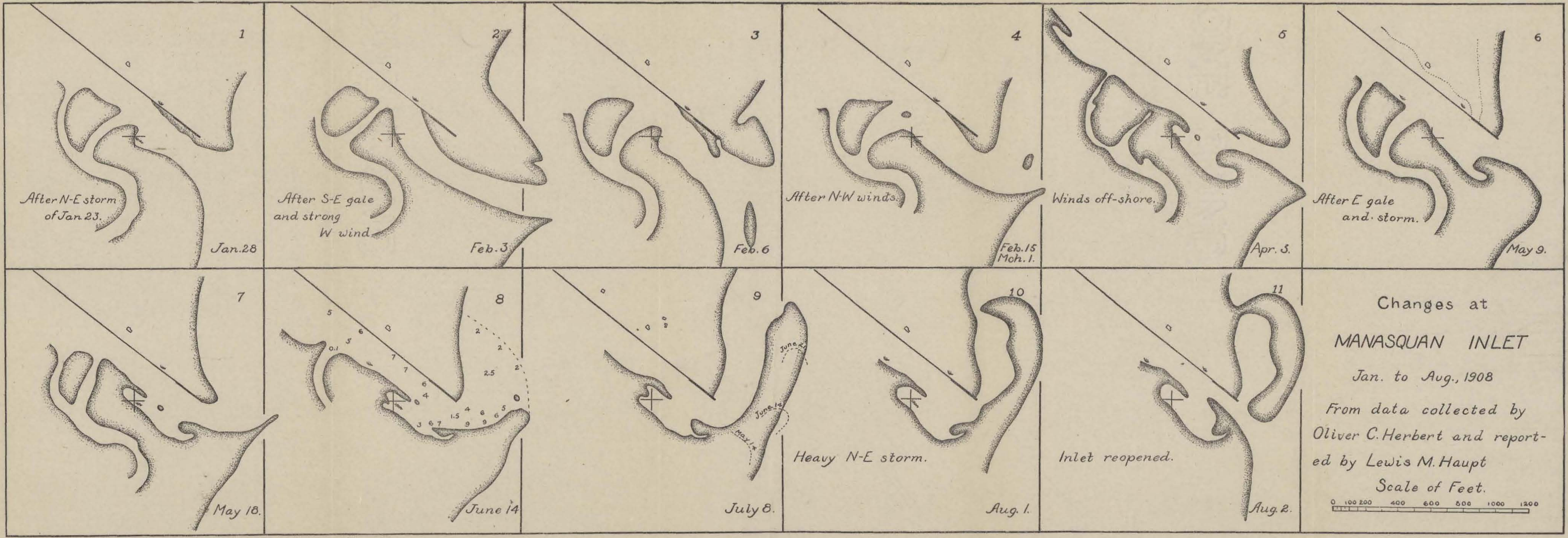
HENRY B. KÜMMEL.

In my Annual Report for 1907 there was published a series of sketches showing successive changes at Manasquan Inlet from July, 1907, to January 15th, 1908, due chiefly to the northward drift of the sand along the shore. These sketches, based upon observations of Oliver C. Herbert, of Point Pleasant, were compiled by Lewis M. Haupt. At my request, Mr. Haupt has supplemented these sketches by another series published herewith, which show the changes from January 28th to August 2d, 1908. Mr. Haupt also prepared for me some notes on the changes shown by these diagrams, the substance of which, in a somewhat condensed form, is given below. During the period in question, the inlet was almost or entirely closed by the northward growth of the spit,. and was reopened as a result of the northeast gale of August 1st and 2d. The series, therefore, possesses more than ordinary interest in that it represents a completed cyčle of change, beginning and closing with the inlet opposite the end of the bulkhead.

Only a few of the most typical sketches made by Mr. Herbert are here reproduced to illustrate the quantative movements of the shore sand. Thus, beginning on January 28th, with a nearly normal condition as shown in Figure 1 of Plate I, it appears that within a period of six days the shore line had been driven seaward some 600 feet and the area of the spits on both sides of the channel had been increased 8.51 acres (Fig. 2). This had been accomplished by a southeast gale followed by a strong west wind. Three days later, however, under a normal condition of forces, about 8 acres of this had been lost and the point on the south side had entirely disappeared (Fig. 3). By February 15th it had re-formed (Fig. 4) and it remained constant until March 8th, when it was broken up into islands covering the entrance. These finally merged into the south spit as shown in Figure 5. The effects of an easterly gale are shown in the recession of the shore on the north side and the flattening of the southern spit (Fig. 6). Nine days later, however (May 18th), the point of the south spit had become sharply marked (Fig. 7) and had flanked the inlet. Once started in this direction the spit rapidly increased at its northern end as shown in figure 9, until on August 2d its recurving end made connection with the shore at a point 600 feet north of the old bulk-head, or about 900 feet north of its position on May 14th. This growth was at a rate of 350 feet per month or *between 11 and 12 feet a day*. The same storm which drove the hook ashore and made a lagoon of the outer channel, also cut down the sand barrier in front of the bulk-head to such an extent that the impounded waters inside were able to reopen the old channel on the line of the Government jetty as shown in figure 11.

It will be noticed that as the south spit overlapped the entrance and grew northward (Figs. 8, 9, 10) the shore north of the jetty was eroded and undercut. The deposition of the wave-driven sand from the southward tended to divert the channel and drive it against the leeward bank, which was in turn cut away. If the drifting sand can be arrested by suitable works on the south side of the inlet this encroachment by it upon the channel will be avoided. The old Government bulk-head of 1882, which is now rapidly falling into decay, was placed on the wrong side of the inlet to be effective in arresting this shoreward drift, as is abundantly demonstrated by these sketches. That it has some value, however, in preventing the migration of the channel to the north, as the south spit grows northward, is beyond question, and steps should be taken to repair the damage which it has sustained during the last year.

It is believed that the construction of the curved jetty on the south side of the inlet, according to the plans proposed in the


1
After N-E storm of Jan. 23.
Jan. 28
2
After S-E gale and strong W wind
Feb. 3
3
Feb. 6
4
After N-W winds.
Feb. 15 Mch. 1.
5
Winds off-shore.
Apr. 5.
6
After E gale and storm.
May 9.
7
May 18.
8
June 14
9
June 2
June 14
May 14
July 8.
10
Heavy N-E storm.
Aug. 1.
11
Inlet reopened.
Aug. 2.
Changes at
MANASQUAN INLET
Jan. to Aug., 1908
From data collected by Oliver C. Herbert and reported by Lewis M. Haupt
Scale of Feet.
0 100 200 400 600 800 1000 1200

annual report of last year, will be effective in arresting the shore drift from the south, and will result in giving a permanency to this inlet which it has never possessed. I wish, however, to reiterate what was pointed out in that report, namely that any plan must be adapted to the conditions prevailing when the work is executed, not to those which may have prevailed several years before when the plans were first proposed.

PART II.

The Mine Hill and Sterling Hill Zinc Deposits of Sussex County, New Jersey.

By ARTHUR C. SPENCER.

The Mine Hill and Sterling Hill Zinc Deposits, Sussex County, New Jersey[1].

BY ARTHUR C. SPENCER.

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GENERAL DESCRIPTION.

The zinc mines of Sussex County, New Jersey, are situated about 50 miles northwest of Jersey City, at Mine Hill, near Franklin Furnace, and 2½ miles south of that place at Sterling Hill, near Ogdensburg.

The district lies upon the northwestern side of the New Jersey Highlands within a zone where the crystalline pre-Cambrian rocks of the plateau give place to the unmetamorphosed Paleozoic formations of that broad depression known as Kittatinny Valley.

[1] Published through coöperation with the United States Geological Survey. For a full discussion of the geology of this region the reader is referred to the Geologic Atlas of New Jersey, Franklin Furnace Folio, which may be obtained from the State Geologist. Price, 25c.; postage, 15c. additional.

which forms a part of the great intermountain valley of the Appalachian geographic province. From the northwest the Paleozoic rocks extend without interruption to the southeast side of the main Kittatinny Valley where the basal Cambrian sandstone rests upon ancient gneisses. These gneisses form a series of southwest-northeast trending hills or low mountains separated from the Highlands proper by a secondary depression, parallel with the Kittatinny Valley, which is underlaid in part by white crystalline limestone imbedded in the pre-Cambrian gneisses, and in part by blue metamorphosed Paleozoic limestone (Cambrian), faulted down into the ancient rocks.

The zinc deposits are in the white limestone. They are situated about one mile and 3½ miles, respectively, from the southwest end of a band of this rock from one-half a mile to 2 miles wide and 22 miles long, which extends northeastward into Orange County, New York. Southwestward from Franklin Furnace on the northwest side of the band, the crystalline limestone is found in contact with gneisses composed of dark and light layers, while toward the northeast this contact is overlapped by a thin sandstone formation of Cambrian age with the blue limestone resting on it. Opposite both mines the southeastern side of the valley is underlaid by the blue limestone (Fig. 1).

The blue limestone here present is part of a strip about 10 miles long, of which the northeast end is situated due east of the Parker shaft on Mine Hill. Between the two sorts of limestone there is a profound fault which continues to the southwest beyond the termination of the white limestone band. Opposite the mines the blue limestone is thought to be underlaid by the white limestone, since near the northerly end of the strip there is a narow wedge of the white rock between the exposures of blue limestone and those of gneiss upon the mountain slope southeast of the valley. The displacement by which this long block of the younger rocks was set down into the crystalline formations is tentatively referred to the well-known post-Paleozoic revolution during which the rocks of the Appalachian mountains were generally folded and faulted.

The Mine Hill deposit near Franklin Furnace lies within the white limestone adjacent to the contact with the gneiss which occurs to the northwest. The ore body has the shape of a trough with unequal sides. The outcrop of the northwestern or higher side ("west vein"), which is 2800 feet long, runs parallel with, and from 15 to 30 feet distant from the boundary between the limestone and the gneiss, excepting near the elbow where it is joined by the outcrop of the southeast side of the trough. From this elbow the "east vein" outcrop (600 feet in length) runs diagonally out into the limestone. Underground, the west vein closely follows the southeastward dip of the limestone-gneiss contact, diverging only as the keel of the trough is approached; while from the keel, the east vein rises into the limestone (cross-sections A-A to E-E, Fig. 1). The east vein is capped by limestone throughout the greater part of its length, and the top or crest plunges in a northerly course. Borings have shown that the limestone-gneiss contact holds its dip beneath the keel of the ore trough, and the fact that the gneiss does not rise conformably with the east vein is also apparent from the nearly straight trend of the contact as observed at the surface. The keel of the trough plunges at an angle of about 20 degrees in a north-northeast course.

Layers of magnetite outcrop locally along the limestone-gneiss contact, both adjacent to the body of the zinc ore, and for a distance of more than one-half mile toward the southwest. Magnetite in corresponding position has been found by foot-wall borings from the lower mine levels.

The Sterling Hill deposit lies well out in the white limestone. It also has a hook-like outcrop, but here the "west vein" appears at the surface for about 600 feet, while the curving outcrop of this "east vein" is 1500 feet long. Both sides of the trough dip toward the southeast, and the keel plunges toward the east with an angle estimated to be about 45 degrees. The lowest part of the outcrop is about 700 feet distant (toward the northwest) from the trace of the great fault which brings the blue limestone into contact with the country rock of the vein. The ore layers dip toward this fault, but, since the deposit is only partially developed it is not known whether it extends far enough on the dip to have been cut off by the displacement.

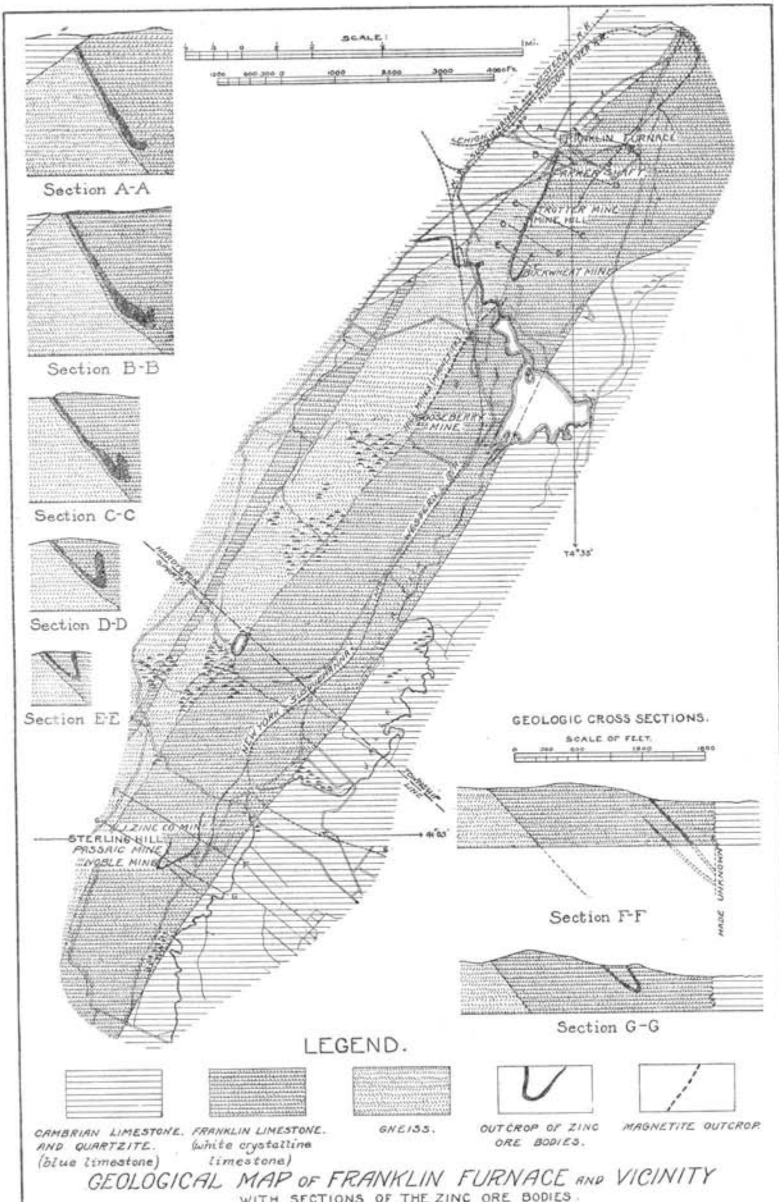
SCALE
Section A-A
Section B-B
Section C-C
Section D-D
Section E-E
FRANKLIN FURNACE
TROTTER MINE
BUCKWHEAT MINE
GOOSEBERRY MINE
NEW YORK & SUSQUEHANNA
TOWNSHIP LINE
STERLING HILL
PASSAIC MINE
NOBLE MINE
GEOLOGIC CROSS SECTIONS.
SCALE OF FEET.
Section F-F
Section G-G
LEGEND.
CAMBRIAN LIMESTONE. AND QUARTZITE. (blue limestone)
FRANKLIN LIMESTONE. (white crystalline limestone)
GNEISS.
OUTCROP OF ZINC ORE BODIES.
MAGNETITE OUTCROP.
GEOLOGICAL MAP OF FRANKLIN FURNACE AND VICINITY
WITH SECTIONS OF THE ZINC ORE BODIES.

Fig. 1.

DEVELOPMENT OF THE MINES.

Some evidence exists that the ores of Mine Hill and Sterling Hill had been discovered and prospected prior to 1650, but the earliest authentic record concerning them shows that about 1774 several tons of "red ore" (zincite) were sent to England by a landed proprietor of that period, Lord Stirling.

About 1817 the lands on which the present mines are situated came into the possession of Dr. Samuel Fowler, and in 1822 the first description of the deposit were published by Nuttall and by Vanuxem and Keating. Previously the minerals zincite and franklinite had been analyzed and described by Bruce in 1810 and Berthier in 1819.

About 1838, at the United States Arsenal in Washington, the first metallic zinc made in the United States was reduced from zincite ore furnished by Dr. Fowler to Dr. Hasler, then Superintendent of the Coast and Geodetic Survey. This metal was used in preparing brass for the first set of standard weights and measures ordered by Congress. The ore from which the metal was made came from a pit on Mine Hill which was afterward known as the Weights and Measures opening. The process of reduction employed was too expensive to permit its adoption on a commercial scale, and it was not until about 1860 that the production of spelter from New Jersey ores was placed on a practicable basis.

Experiments made for Dr. Fowler had resulted in the production of a bluish oxide of zinc, which about 1830 he had used as a substitute for white lead in painting his house. Between 1848 and 1860 there was considerable activity in the zinc mines, the ore being then used mainly for the manufacture of white oxide of zinc for use as a paint. During the same period several serious though commerically unsuccessful attempts were made to manufacture a special grade of iron from the franklinite.

At Sterling Hill two superficial basin-like deposits of calamine and smithsonite were mined out about 1875, and underground mining of zincite and franklinite continued until 1900. At Mine Hill extensive operations have been in progress since about 1850.

The treatment of New Jersey zinc ores has presented many difficult problems, the practical solution of which has given the mines their present value. Metallurgical methods now in use were developed mainly before 1860, but in ore dressing the greatest advance came in 1896, with the perfection of the Wetherell system of magnetic concentration.

THE ORE MINERALS AND THEIR OCCURENCE.

The ore minerals are principally franklinite, containing oxides of iron, manganese, and zinc; willemite (silicate of zinc), much of it containing some manganese; and zincite (oxide of zinc), with manganese as a minor constituent. In the Sterling Hill ore the minerals above named, with the addition of tephroite, a silicate of manganese, are practically the only metallic minerals, but in the Mine Hill deposit several other zinc and manganese-bearing minerals, mainly silicates, are found in considerable amounts, though still not present in the bulk of the ore. Valueless minerals which contaminate the ores are calcite, rhodonite (variety fowlerite), garnet, pyroxene, and hornblende.

Minor amounts of sphalerite are found at both mines, but the occurrence of this mineral is such as to indicate that it has originated since the main body of the ore was formed, probably in connection with the invasion of the pegmatite masses.

In parts of the deposits franklinite is the only metallic mineral; elsewhere it is accompanied by both willemite and zincite, or by one of these alone; and in still other places there are layers composed mainly of rounded grains or bunches of zincite set in a matrix of coarsely crystalline calcite. In the great bulk of the ores as mined the minerals occur in the form of dull rounded grains which appear to be corroded crystals. Perfect crystals of willemite and franklinite are found, however, protruding into or inclosed by masses of calcite. Crystal faces of zincite are only rarely to be observed.

The texture of the ore is highly granular, and in much of it foliation is strongly marked. The size of the grains varies greatly, but in a given mass the grains of the different components are ordinarily all about the same size.

The ore bodies may be called veins, in conformity with local usage, though like the bodies of magnetic iron ore occurring in the Highlands they are not really veins in the sense of being distinct fillings of definite fractures in the inclosing rocks. They are layers or stratiform masses consisting of varying mixtures of the three ore minerals and calcite, inclosed or cased by coarsely crystalline white limestone.

The veins of both mines have curved or hook-shaped outcrops, and mining has shown that they are warped bodies of rather simple and somewhat similar form. They are more particularly described under subsequent headings.

The ore and country rock are in general not sharply separated by definite walls, but the calcite of the rock is intergrown with that of the gangue, and in many places there is a gradual passage from workable ore through lean material into barren rock without the slightest suggestion of a physical break or parting. Both the inclosing rock and the ore show a rather well marked and persistent lamination that corresponds in appearance and attitude with the platy structure of the gneisses occurring throughout the general region outside of the white-limestone areas. In the ore this foliation is more strongly marked than in the limestone, because of the contrasting colors of the component minerals, but wherever foreign minerals are present in the limestone the laminated effect is obvious. Completeness of foliation depends on variations in the proportions of several constituent minerals segregated in different parts of the vein. The mineral grains on the borders of adjacent layers or plates interlock so that the entire mass is closely knit into a solid whole.

In places in both deposits the entire vein consists of franklinite and calcite, and is comparatively low in zinc content. Elsewhere brilliant-green or dull-brown willemite is added to these minerals, and certain layers show a sprinkling of blood-red zincite, contrasting with the black franklinite, white calcite, and tinted willemite, and making an ore of strikingly beautiful appearance. At Sterling Hill portions of the ore bed, as opened in the old mines, consisted of two distinct layers which were called the zinc and the franklinite veins. The zinc vein was composed mainly of zincite mixed with calcite, though locally carrying considerable willemite or tephroite and in some places franklinite also. The other layer was composed of franklinite and calcite, with willemite or sporadic tephroite. At the bend or elbow of the deposit the zinc vein is missing, but along the hanging wall of the eastern leg several shoots of the rich ore were encountered and one of them was mined for more than 700 feet on the dip of the vein. On the western or back leg, to judge from what may be seen in the abandoned workings, a similar layer, here on the foot wall, was followed for 200 feet or more along the strike and 100 feet down the dip. These are the only instances exhibited in the mines of so definite and persistent a separation of the ore minerals.

Less marked examples were noted in the Mine Hill deposit, in the shallow northeast openings on the western leg of the vein, where a layer carrying zincite in addition to franklinite occurred on one side of the vein, though the other side carried practically none of the richer zinc mineral. Toward the elbow of this deposit the western leg is said to have contained two streaks rich in zincite, but these seemed to have had no constant position in the vein. In the present deep workings no regularity in the distribution of the different ore minerals can be made out, though the ores of varying value are always disposed in the form of plates, which taken together bring out a gneissic structure almost everywhere. The early supposition that there was a persistent division of the Mine Hill deposit led to the separate conveyance of mining rights for zinc ore and franklinite ore, and eventually to troublesome litigation continuing from 1857 to 1896.

CONSTITUTION OF THE ORE.

At Mine Hill the ore (run of mine) has been estimated to contain from 19 to 22½ per cent. of iron, 6 to 12 per cent. of manganese, and 23 to 29 per cent. of zinc. The average of four estimates by different persons is iron 21 per cent., manganese 10 per cent., zinc 27 per cent. Figures giving the metallic content of the Sterling Hill ore have not been published, but it is known to average considerably lower in zinc than the ore from Mine Hill.

The proportions of the various minerals in the Mine Hill ore have been given as follows:

Mineral Composition of Zinc Ore from Mine Hill.

	1. (Ulke.)	2. (Ricketts.)	3. (Ricketts.)
Franklinite,	51.92	48.20	51.50
Willemite,	31.58	28.10	20.23
Zincite,	.52	2.70	6.40
Carbonates,	12.67	11.32	10.00
Silicates,	3.31	9.50	11.13
	100.00	99.82	99.26

The franklinite $(Fe, Mn, Zn)O(FeMn)_2O_3$, has been found to contain from 39 to 47 per cent. of iron, 10 to 19 per cent. of manganese, and 6 to 18 per cent. of zinc. Pure willemite ($2ZnO.SiO_2$) carries about 58 per cent. of zinc, but in the ore the mineral has been found to contain iron and manganese to the extent of 1½ to 3 per cent. each. The zincite (ZnO) contains about 77 per cent. of zinc and, as impurities, about 5 per cent. of manganese and iron, principally the former.

PRODUCTS OF THE MILL.

The Sussex County ores are chiefly valuable as a source of zinc, but also on account of the manganese and iron which they contain. From them is made a high grade of spelter (crude commercial zinc, Horse Head brand); zinc oxide, used as white paint and in the arts; and spiegeleisen, an alloy of iron and manganese used in the production of Bessemer steel and as a constituent of steels for certain special uses.

As now operated, the Wetherell magnetic concentrators (working on crushed Mine Hill ore) yield three products, known as franklinite, half-and-half, and willemite. The first product, composed mainly of franklinite, is used for the preparation of zinc white, the residuum from this process going to the blast furnace to make spiegeleisen. The half-and-half contains franklinite, rhodonite, garnet, and other silicates, with attached particles of the richer zinc minerals. This product carries somewhat more zinc than the franklinite. It is used for zinc white, but its residuum is too high in silica for the spiegel furnaces. The willemite product consists of willemite and zincite, with calcite and silicate minerals as impurities. The calcite is removed by means of jigs and concentrating tables, leaving material suitable for the production of high-grade spelter free from lead and cadmium. A large part of the waste from the jigs finds use in concrete construction. The dust from the crushing and concentrating plant is collected and used with the other material for tne manufacture of zinc oxide. The following is an approximate summary of the products of the mill at Franklin Furnace.

Products of the Mill at Franklin Furnace.

	Percentage.	Percentage of Zinc.
Franklinite,	49	22
Half-and-half,	12	24
Dust,	4	27
Willemite,	25	48
Calcite,	10	5
	100	

MINE HILL DEPOSIT.

The courtesy of the officers of the New Jersey Zinc Company in allowing the use of the assembled plans of the extensive underground workings has made possible the construction of diagrams which exhibit in clear manner the essential form of the great ore body which lies beneath Mine Hill. (Figs. 2 and 3.)

The ore mass is a layer varying in thickness from about 12 feet up to 100 feet or more, bent upon itself to form a long trough with sides of unequal height and varying thickness. The trough lies with its keel plunging in a northerly direction at an average rate of 36 feet per 100 (or about 20 degrees) for a horizontal distance of about 2900 feet from the elbow of the hook-shaped outcrop at the south end of Mine Hill. Still farther toward the north it rises at the rate of 16 feet per 100 (or about 9 degrees) for 600 feet, to the north edge of the

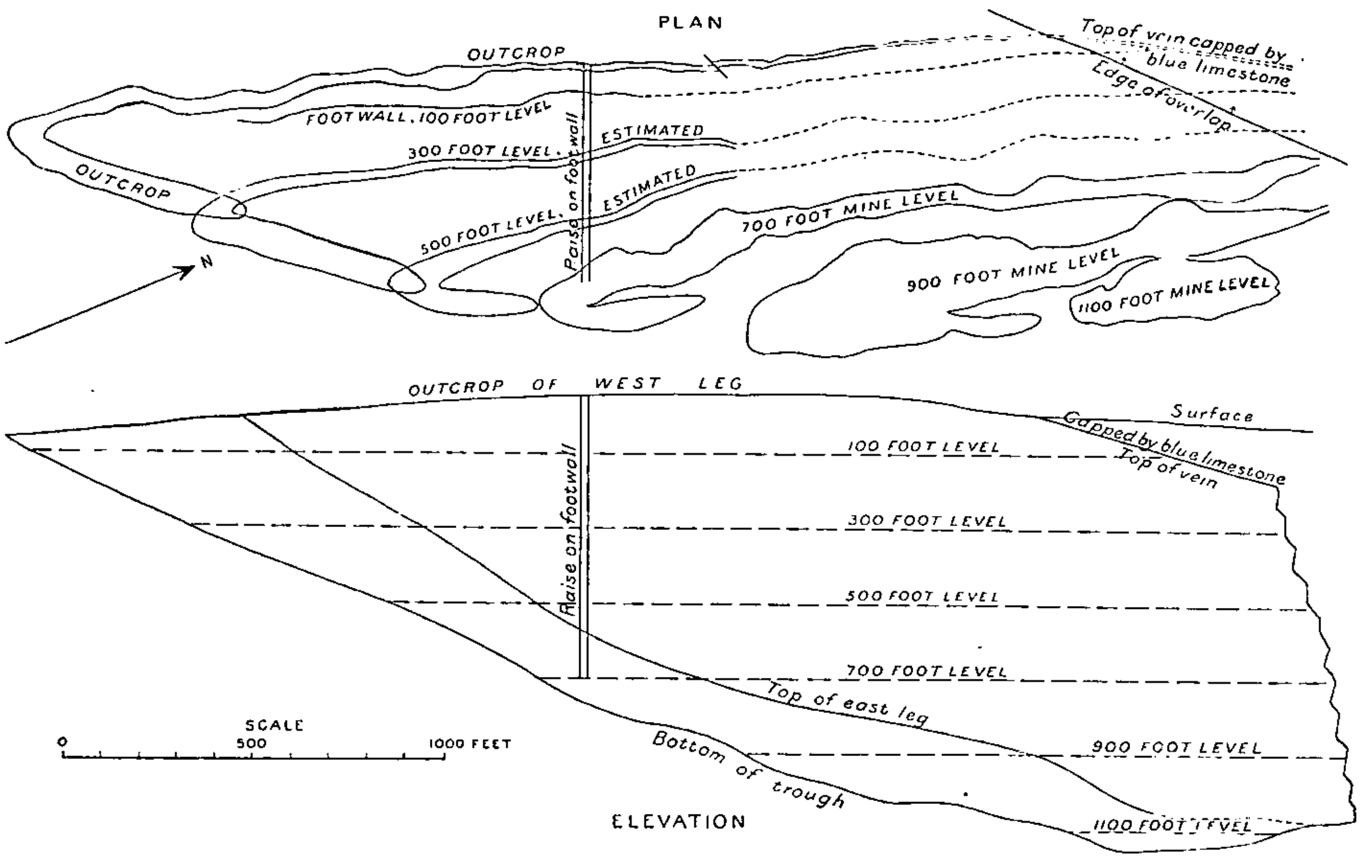

Fig. 2.
Plan of outcrop and levels and elevation of the Mine Hill ore body.

deposit. In addition to the plunge and rise of the bottom line of the trough, this keel is considerably curved in a horizontal sense, as is shown in the plan of the mine levels (Fig 2). The total length of the keel is somewhat more than 3,500 feet.

The west flank rises from the keel at an average angle of about 55° and comes to the surface along the northwest brow of the hill. Its outcrop is about 2,600 feet in length, but toward the north its full extent is not seen because the top of the vein is capped by Paleozoic formations. Though not yet explored in the upper mine levels the vein may be expected to extend for several hundred feet beyond the last surface exposure. On the 700-foot mine level the northward extension of the ore amounts to about 700 feet.

The greatest dip height of the west vein, measured from the surface to the bottom of the trough, about 1,350 feet, is on a section near the most northerly outcrop. On either side of this the height of the vein is less. Toward the south the dip height decreases through the gradual rising of the keel. Near the north edge of the deposit its full height, though not yet determined, is probably not more than 1,000 feet. The lowering of the vein top in this direction is a result of erosion which ensued before the Paleozoic strata which cap the ore body were deposited.

The east flank has not been fully developed in the underground workings, but enough is known to show that its attitude is somewhat variable. In the lower part of the mine it apparently stands nearly vertical. Farther south it dips strongly to the east and locally lies nearly parallel with the west leg; and still farther south, as its outcrop is approached, it either stands nearly vertical or dips steeply towards the east. This side of the trough appears at the surface for a distance of about 600 feet northward from the elbow where it is joined by the outcrop of the west leg. Its maximum height, about 300 feet, is beyond the north end of the outcrop. Between the elbow and this place its upper part has been eroded away. To the north it is sealed over by an arching cap of the white limestone, and the crest thus formed plunges in nearly the same azimuth as the keel of the trough, though somewhat more steeply, namely, about 60 feet per 100 (about 31 degrees). As a result of this steeper pitch the height of the ore gradually decreases toward the north. On the lowest level of the Parker mine the keel and crest appear to meet, and in the extreme northern part of the 1050-foot level only the west vein exists. The horizontal length of the buried portion of the east vein is about 2,700 feet, the outcrop being 600 feet long as stated above.

Vertical sections across the ore body show that the outer walls come together in a sweeping curve to form the keel of the deposit. Where exposed in the open pit near the elbow, the inner walls meet along a narrower but still an open curve, but underground the rock between the two flanks become narrower and narrower toward the north until below the 650-foot mine level it is a very thin wedge. In the deeper workings the deposit is much thicker along and near the bottom of the trough than on the limbs. Along the bottom of the trough the greatest mass of ore in the deposit is found, and for the most part this ore is of high grade because it contains much willemite and very little calcite.

Test holes from the lower levels prove that the ore body is entirely surrounded by barren rock. A vertical hole in the bottom of the mine gave the following section:

Section of Test Hole in Bottom of Parker Mine.

	Feet.
Limestone,	37
Magnetite ore,	5
Limestone,	24
Garnet and gray rock (gneiss),	5
	71

Wherever the foot wall of the west vein has been penetrated by the drill, the underlying gneiss has been encountered in about the same relative position as at the surface, but in no one of the several horizontal holes driven from the wall of the east vein into the hanging wall has this rock been found. In this direction there are no other rocks than limestone and injected dikes of pegmatite, from which it is apparent that the parting between the limestone which lies under the ore and the gneiss beneath

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does not rise parallel with the east leg of the vein, as was at one time supposed.

Interruptions of the ore are produced by some minor faults, by a few irregular injections of pegmatite, and by a diabase dike which crosses both sides of the trough about 600 feet north of the elbow in the outcrop. This dike stands nearly vertical, and is from 15 to 20 feet thick.

The masses of pegmatite were intruded into the ore body after its foliated structure had been acquired, and most of the uncommon minerals of this locality were formed under the metamorphosing influence of this invading rock. That the silicate minerals containing essential proportions of zinc and manganese were formed by metamorphism due to the pegmatite is shown by the fact that they do not occur throughout the ore mass, but only along or near the contacts with the pegmatite. It is believed that the metal-bearing silicates were formed by an interchange of materials between the previously existing ore body and the invading pegmatite, because the minerals which characterize the walls of the dikes where they penetrate the ore are not present where the dikes pass out of the ore mass into the country limestone. Franklinite and willemite, which are the principal minerals of the unaltered portion of the ore mass, occur also among the secondary minerals of the pegmatite contacts, and in this association both minerals are ordinarily well crystallized. It seems evident that they were formed by the rearrangement of materials derived from the original ore.

Cross-sections A-A to E-E, accompanying the map (Fig. 1), illustrate the present conception of the general structural relations of the Mine Hill ore body. Its shape is illustrated by a stereogram in Fig. 3. The plan in Fig. 2 represents the outcrop and horizontal plans of the ore bodies at 100, 300 and 500 feet below the top of the Parker shaft and on the 700, 900 and 1100-foot mine levels. The boundaries of the ore have been fairly well determined on all the mine levels, but above the 700-foot level the outlines have been intercalated except in the neighborhood of the Trotter mine. A longitudinal projection on a vertical plane (also shown in Fig. 2) exhibits the pitch of the keel and of the crest of the east vein and the vertical relations

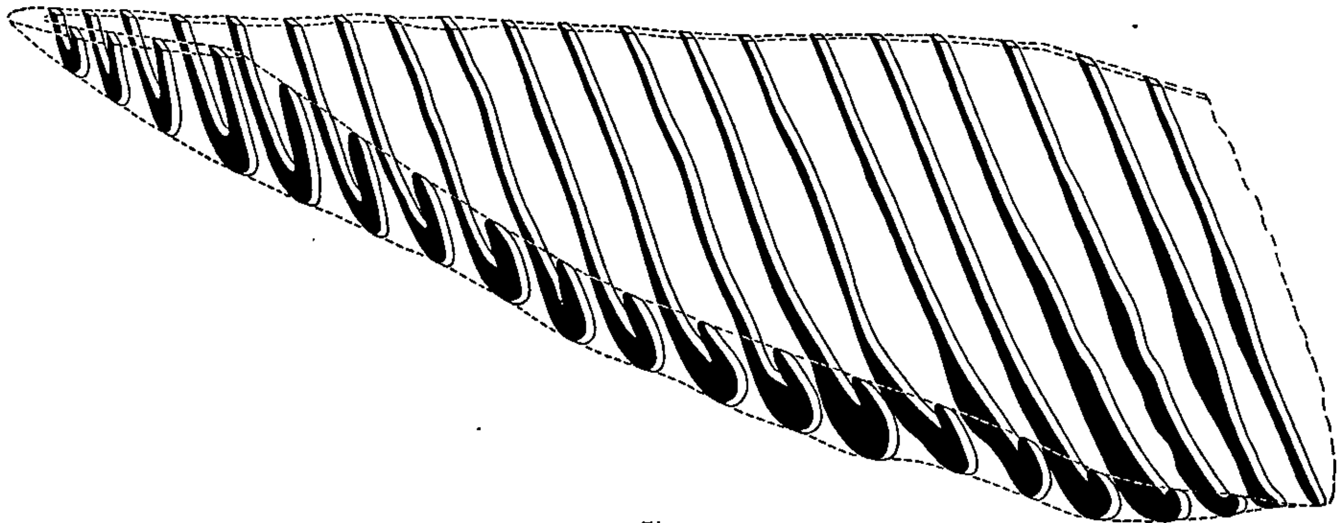


Fig. 3.
Stereogram of the Mine Hill ore body.

of these features to the outcrop of the west vein. The height of the east vein may vary more than has been indicated, as the data on this point are rather meager.

The principal underground workings are those of the Parker mine. The vertical shaft situated east of the deposit extends to the 950-foot mine level, the workings of which are reached by a tunnel about 300 feet long. In this mine the deposit has been almost completely outlined by foot-wall and hanging-wall drifts on levels 50 feet apart from 700 down to 1,100 feet. The lowest point in the mine, at the bottom of the ore body, is 1,126 feet below the top of the Parker shaft, which is taken for a datum for measures in depth.

The southern part of the 700-foot mine level was worked through the Taylor mine, which is reached from the open-pit workings on the south by a long slope nearly parallel with the pitch of the east vein. On the 650-foot level of this mine the bottom of the keel has been outlined and the west vein developed for several hundred feet. In 1905 connection had not been made with the Parker workings on this level, but a raise on the west vein connected with one of the old Trotter mine slopes at a depth of about 380 feet below the outcrop.

In the Parker mine, from the 850-foot down to the 1,050-foot mine level, the deposit has been found to pinch out along the strike between 500 and 600 feet north of the crosscut to the shaft, but on the higher levels the edge of the vein had not been reached in 1905.

STERLING HILL DEPOSIT.

The Sterling Hill deposit, like that of Mine Hill, is a layer in the form of a trough. (See Fig. 4.) The layer ranges in thickness from 10 to 30 feet, and in places it is composed of two parts, one rich in zincite and the other composed largely of franklinite. The sides of the trough, which are of unequal height, both strike in a northeasterly direction, the lower west flank outcropping for about 600 feet, and the higher east flank for about 1,500 feet from the sharp elbow at the southwest where they meet. Including the elbow the total length of the outcrop is about 2,200

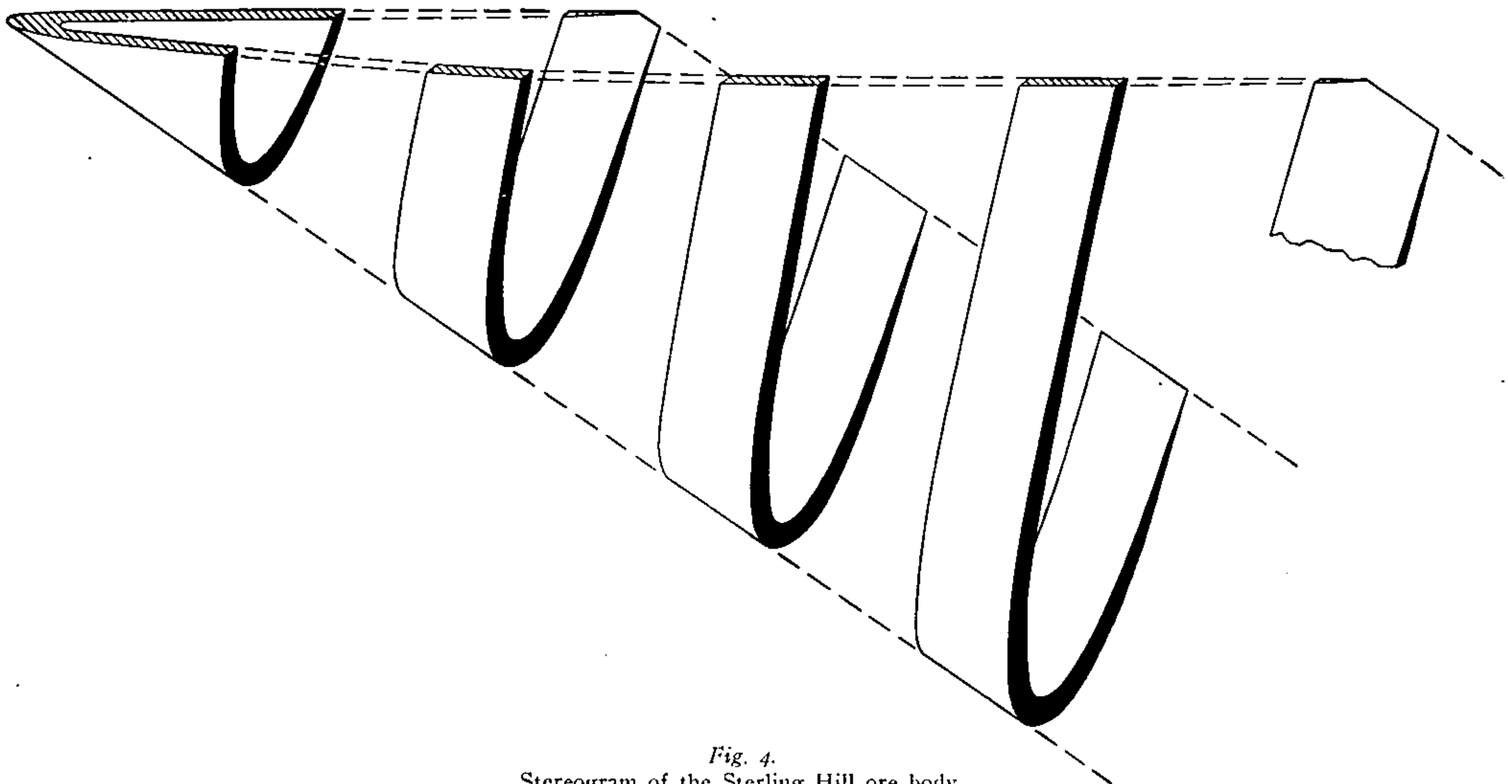


Fig. 4.
Stereogram of the Sterling Hill ore body.

feet. Both veins dip toward the southeast, and the keel of the trough plunges in an easterly direction. Near the surface the west vein dips about 45°. The east vein has been opened by shafts and slopes to a depth of about 600 feet measured along the dip. In different parts of the mine cross sections show dips averaging from 45° to 60°, and from the mine maps it is seen that on each level the inclination of the ore layer becomes gradually steeper as the keel is approached. This steepening may be readily seen in the open pit at the Noble Mine, which is situated in the elbow of the outcrop.

In the Noble pit the curving surface of the limestone from which the ore has been stripped slopes toward the northeast at an angle of about 50° from the horizontal. This, however, is not the direction of the plunge, the azimuth of which lies more to the east, as may be judged from the general dip of the east vein and from the position of the nearest drifts in the lower part of the Passaic mine. However, because the position of the keel has not been located in any of the underground workings, neither the bearing nor the angle of plunge can be determined with any degree of accuracy.

Each limb of the layer exhibits a feather edge at the northeast end of its outcrop, and it is supposed that these edges plunge into the ground along lines trending more to the east than the strike of the layers. If this supposition is correct, and if the pitch of the edges is about the same as that of the keel, the limbs of the trough may continue to have about the same length on successively lower layers as at the surface.

The foot wall of the eastern vein is said to be considerably corrugated, and the ore shoots resulting from this structure pitch toward the east. On the accompanying plan (Fig. 5) the outcrop and workings are shown, also the estimated position of a horizontal section about 400 feet below the lowest part of the outcrop, on the assumption that the plunge is 45° in the azimuth N. 85° E.

The two cross sections through Sterling Hill (F-F and G-G) which accompany the geology map (Fig. 1) and the three cross sections given in Fig. 6, though drawn from incomplete data, illustrate the structural relations of the ore bodies in so far as

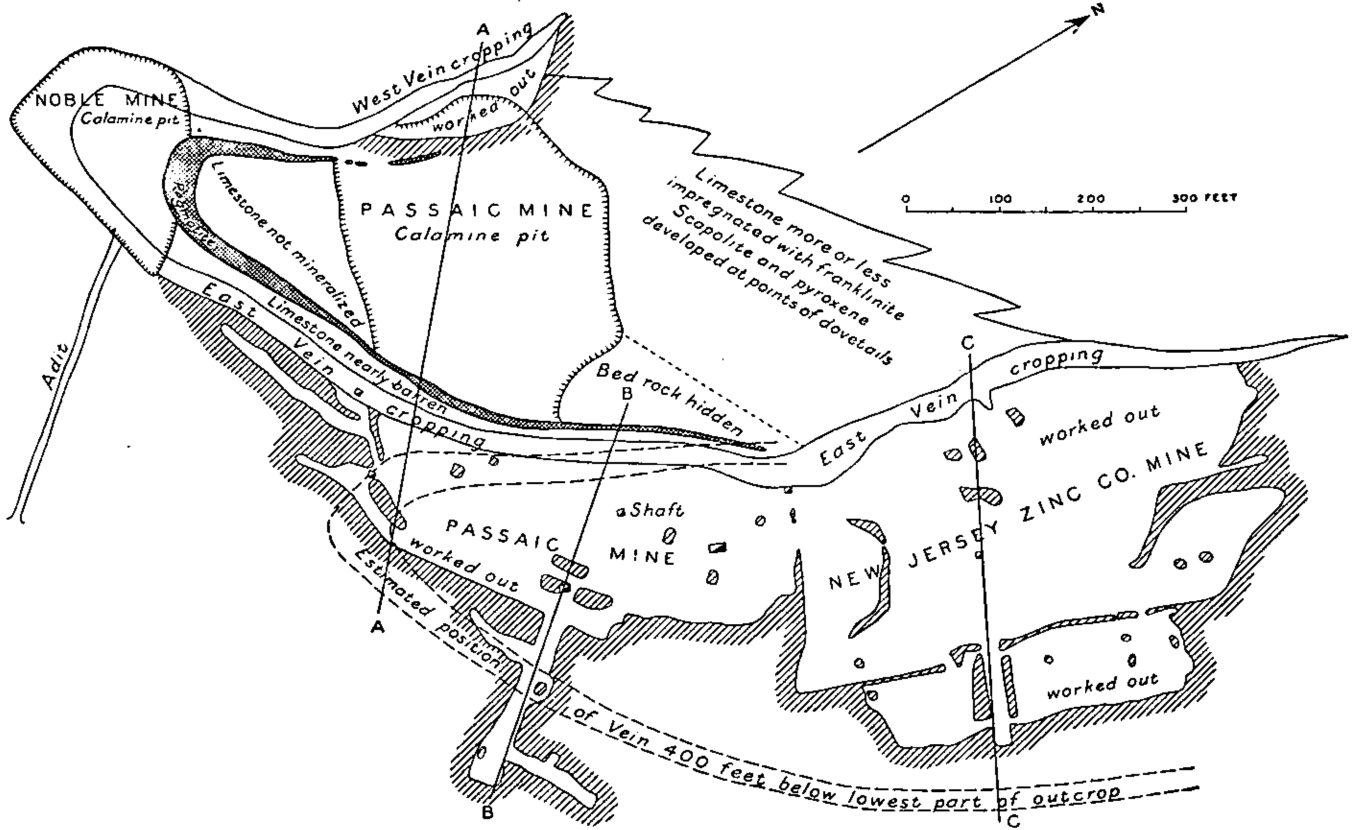


Fig. 5.
Plan of outcrop and workings of the Sterling Hill ore body.

they are understood. The presence of a great fault running northeast and southwest about 700 feet southeast of the nearest outcrop of the vein indicates that the veins must be cut off on their downward extension if they continue far enough in the direction of the dip. The depths at which they meet the fault can not be determined until all the variations in the dip of the veins are known, but an average inclination of 55° for the east vein would give a depth of about 1,000 feet at the fault, or a dip length of about 1,300 feet, if the plane of the fault stands nearly vertical. This estimate will be increased or diminished if the dip of the fault proves to be toward the southeast or toward the northwest.

From existing descriptions of the Sterling Hill mines it is known that locally the ore body is divided into layers, one of which, being rich in zincite, has been called the zinc vein, the other, which contains little or none of this rich mineral, being called the franklinite vein. A zinc vein forms the upper part of the east leg of the trough, and another is present on the lower side of the west leg. The zinc vein on the east leg is said to have been from 2 to 10 feet thick. It is not present along the portion of the outcrop near the elbow, and is said to be missing in the lowest levels of the underground workings. Rich masses of zincite, in the positions stated, may still be seen in pillars near the outcrop of both veins.

Between the two legs of the vein and opposite the termination of the western leg, the coarsely crystalline limestone is highly charged with franklinite and willemite. Much of the calcite from this part of the mine contains a considerable percentage of manganese oxide replacing part of the lime sides of the trough. Within the elbow these minerals are absent, but where the rocks have been exposed on the north side of the open workings of the Passaic mine, and also on the surface above, it may be seen that impregnation of the limestone with zinc-bearing minerals extends from a point near the end of the west vein all the way across to the east vein, giving a mass of lean ore about 250 feet wide though more or less interrupted by streaks of barren limestone. Toward the northeast the mineralized rock makes a series of dovetails into the country limestone, the line marking

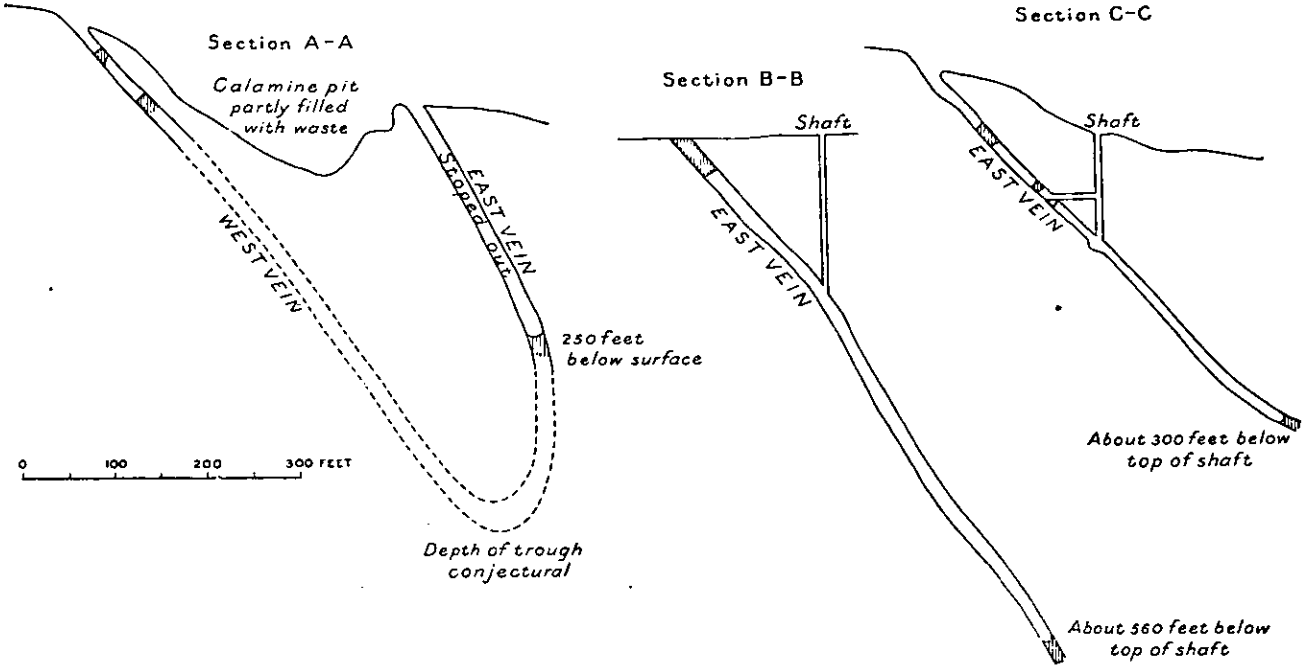


Fig. 6.
Cross sections of the Sterling Hill ore body.

its general limit running from a point near the end of the western leg diagonally across to the eastern leg, which it meets about 300 feet from its northeastern termination (Fig. 5). Near the points of the dovetails pyroxene and scapolite appear and the amount of franklinite diminishes greatly and the analysis of the latter mineral shows it to contain less than half the ordinary amount of zinc. The metallic impregnation between the legs of the vein dies out beneath the open excavation in ground not at present accessible for examination because covered by mine waste. South of the pit white and blue-tinged limestone fills all the space within the elbow of the vein. Here there are no metallic minerals and the limestone is in every way like the usual country rock, even carrying abundant graphite, which, though characteristic of the general run of the white limestone throughout the Franklin Furnace belt, is nowhere observed in any of the ore, however lean.

In the natural state of the ground at Sterling Hill, just where the large open pits of the Passaic mine are now, the ore veins were crossed by a broad swale 20 to 30 feet deep draining to the Wallkill Valley. Under this basin-like depression was found a deposit consisting in part of loose franklinite gravel, and in part of more or less decomposed franklinite and willemite crystals cemented by calamine and smithsonite. The manner of occurrence indicates that this material was derived from the breaking down of the surficial portion of the main ore body, the minerals of which were freed by solution of the calcite in which they were embedded, and at the same time were themselves partially dissolved to furnish solutions from which the secondary zinc minerals were precipitated. The maximum depth of this secondary product is said to have been about 75 feet. No deposits of the sort existed at Mine Hill, where calamine and smithsonite are found only in a few narrow veinlets in the upper portion of the ore body.

Lying inside the trough of the ore but separated from it by a few feet of barren marble or very lean ore, is a curving dike of hornblendic pegmatite with concentric walls, about 300 feet long on the western and 700 feet long on the eastern leg, and from 2 to 30 feet wide. Both the ore vein and the dike show a marked thickening at the bend. The wall of this dike on the side next the ore carries the unusual manganese and zinc-bearing silicates which the mine affords.

The dike of pegmatite inside the ore trough does not cross the lamination of the limestone but follows the curve of the ore layer, from which it is separated by 10 to 15 feet of limestone containing a minor amount of franklinite. The concave side of the dike which is in contact with the mass of barren limestone that fills the southeast end of the trough shows no development of contact minerals, but along the convex side, which faces the ore layer, garnet and zinc-bearing pyroxene and biotite occur in several places. This one-sided metamorphism suggests that the zinc which the contact minerals contain was contributed by the ore layer and, therefore, that the dike was injected after the ore body had been formed.

CHARACTERISTICS AND RELATIONSHIPS OF THE ZINC DEPOSITS.

The descriptions of the two zinc deposits given above show them to be distinct from all other known deposits of this metal. Not only is the triple association of iron, manganese and zinc in ore bodies of workable size unique, but the state of chemical combination in which these metals exist, though common enough in the case of iron and not unusual for manganese, is exceptional for zinc. Ordinarily zinc ores consist of sulphide (sphalerite), or of carbonate (smithsonite) and hydrous silicate (calamine) derived from sulphide in a secondary way by decomposition due to the action of atmospheric waters. Among the mines of the world only two others have been brought to the attention of mineralogists as having afforded any considerable amount of willemite. In one of these the mineral occurs with and is subordinate to sphalerite; in the other it is associated with calamine. Franklinite is reported from a few localities as an unusual mineral, and zincite is a rarity. In striking contrast to the paucity of these particular minerals in the ore deposits of the world at large is the fact that the New Jersey deposits contain each of them in amounts measurable by many thousands of tons.

The difference in the chemical state or combination of zinc in sphalerite and in the minerals franklinite, willemite, and zincite is most readily exhibited by the composition formulas of these minerals. Sphalerite in chemical notation is ZnS, zincite is ZnO, willemite is $2ZnO + SiO_2$, franklinite $(Fe, Mn, Zn)O.(FeMn)_2O_3$. In the New Jersey ore minerals the zinc is thus combined with oxygen and not with sulphur as in all other occurrences. From the chemical standpoint, therefore, these three ore minerals are closely related among themselves and are in no way allied to sphalerite. The association with the zinc in sphalerite ores elsewhere of sufficient amounts of iron, lead, cadmium, and in many places copper, to affect both the metallurgy of the ores and the purity of the metal derived from them, is to be compared with the presence in the New Jersey ores of these elements (except iron) in minute quantities only, which enables the production of a pure grade of commercial metal.

The association of the zinc with manganese and iron, the combination of these metals in the condition of oxide, and the mineralogic similarity between the franklinite and magnetite $(FeO.Fe_2O_3)$ suggest a close analogy between the zinc deposits and those of iron ore occurring throughout the area occupied by pre-Cambrian rocks in New Jersey and southeastern New York. Recorded analyses of the New Jersey magnetic iron ores show them to contain manganese in amounts ranging from a fraction of 1 per cent. up to several per cent., and small amounts of zinc have been found in several analyses where special tests have been made to determine its presence or absence. Not only are the zinc and iron deposits thus closely related in a chemical way, but they resemble each other in the form and structure of the ore bodies and in the manner of occurrence with respect to the inclosing rocks. Taken as a whole, these resemblances lead to the view that the ore bodies at Mine and Sterling hills are to be classified with the occurrences of magnetite and regarded as a variety of these ore deposits differing from the ordinary types mainly in the unusual amount of zinc and manganese which they contain.

ORIGIN OF THE ORES.

The crystalline rocks of the Highlands region are in part igneous intrusions and in part metamorphosed sediments, but in addition to the rocks which can be thus defined there are others which cannot be confidently assigned to one or the other of these general classes.

The magnetic iron ores which are distributed throughout the region, are believed to have been formed by igneous processes connected with the invasion of the ancient granitoid rocks, and the physical and chemical analogies existing between the iron deposits and those containing manganese and zinc afford fairly good reasons for including the latter in the same general scheme of origin. It is recognized, however, that the ore deposits of the Highlands do not offer in themselves adequate clews for a satisfactory determination of their origin, and the best that can be done in this direction is to assign them the most probable place in the history of the pre-Cambrian rocks.

The two deposits of zinc, iron and manganese and a few deposits of iron ore are enclosed by highly metamorphosed sedimentary limestone, whereas most of the magnetic iron ore deposits are associated with granitoid gneisses of igneous origin. Both in the limestone and in the gneisses the ore deposits are layers or tabular masses which conform with the structure of the country rocks The fact that there are usually no sharp physical breaks between the ore bodies and the wall rocks indicates that the present characters of the ore masses originated contemporaneously with the final crystallization of the associated rocks, so that the deposits must have been introduced either before or during deformation and metamorphism of the rocks which are recognized as originally sedimentary, and before or during the period in which the igneous rocks acquired their gneissic foliation. The greater number of magnetite deposits, including all of the large bodies of ore, occur in close association with igneous gneisses, and it seems necessary to admit that the ores thus associated are of igneous or magmatic derivation. Some of these ore bodies may be essentially iron-rich igneous rocks, which originated contemporaneously with the deep-seated magmas which give rise to the granitoid gneisses; while others may represent shreds of limestone or other extremely old rocks that were soaked and altered by solutions which emanated from the invading magmas. It seems almost certain that the ores at the Andover mines, situated about 11 miles southwest of Franklin Furnace, were deposited from migrating solutions as irregular replacements of limestone, shale and siliceous breccia. Elsewhere, as in the vicinity of Franklin Furnace, the masses of magnetite may have been introduced by iron-bearing solutions, or it may be that they represent bodily intrusions of an iron-rich magma. Possibly both of these processes were here involved.

The occurrence of large proportions of magnetite in certain pegmatites allied in composition to the granitoid gneisses, but younger than these rocks, gives definite evidence that a deep-seated source of iron existed and that actual concentration of this metal occurred through igneous or magmatic agencies.

No direct evidence can be cited to show how the Mine Hill ore body was formed, but it may be fairly assumed that the two similar deposits at Mine Hill and Sterling Hill originated in the same way, and the latter shows features which indicate that the materials of the ore could not have been deposited by sedimentation contemporaneously with the limestone, but must have been introduced after considerable deformation had taken place. The feature of the Sterling Hill deposit which leads to this conclusion is the great mass of lean ore which lies between the limbs of the synclinal trough of ore. The layer of massive ore could have received its present shape by simply folding if it had originally existed as an intercalated bed in the limestone, or if it had been formed by the previous replacement of a definite stratum, but it seems impossible to account for the great mass of lean ore which extends across the trough except on the theory that the metallic minerals in this portion of the deposit were segregated after the existing local structure had been produced. In other words, this mass of lean ore must have been deposited after the synclinal structure had been formed, whether the layer of rich ore had previously existed or not. This local folding must be regarded as a mere incident in the general deformation and not as marking in any way the end of metamorphism assignable to the period of igneous injection and deep-seated flow. The general similarity between the lean ore and the richer material of the definite layer makes it probable that they are closely related in origin, so that it seems reasonably certain that the whole deposit was formed out of invading materials. The lean ore was probably deposited by solutions which permeated and partly replaced the limestone. The richer ore occurring in the massive layer may have been formed in the same way, but this origin can not be affirmed and it may be that the main ore layer at Sterling Hill and the mass of ore at Mine Hill were injected bodily into the limestone after the manner of igneous rocks. If the layer of ore at Sterling Hill originated in this way it would seem that the lean ore of the deposit must have been formed by solutions which accompanied the igneous injection.

In so far as the evidence at hand shows, the material of the ore layer at Sterling Hill may have been introduced either before or after the local structure had been produced, but at Mine Hill there is ground for the suggestion that the ore layer was first formed; and afterwards shaped into the existing trough. The great body of ore is known to be entirely surrounded by barren limestone, and for this reason it appears to represent only a portion of a deposit that was originally of greater downward extent. In the open workings at the south end of the deposit the rock on both sides of the west leg is thinly charged with franklinite, but along the east leg this mineral is disseminated through the rock only on the inside of the trough. The absence of lean ore along the outer side of the east leg suggests that the original deposit has been sheared apart along a displacement which followed the outer wall of the east limb. If, during an important geologic movement, the rocks which lie east of the ore body had been thrust upward, under conditions of pressure demanding solid flowage instead of rupture, the thick mass of ore in the bottom of the trough, and the attitude of the east limb would be fully explained as the result of drag within the western block.

Several irregular masses of pegmatite were intruded into the ore body at Mine Hill after its foliated structure had been acquired, and most of the uncommon minerals of this locality were formed under the metamorphosing influence of this invading rock. That the silicate minerals containing essential proportions of zinc and manganese were formed by metamorphism due to the pegmatite is shown by the fact that they do not occur throughout the ore mass, but only along or near the contacts with the pegmatite. It is believed that these metal-bearing silicates were formed by an interchange of materials between the previously existing ore body and the invading pegmatite, because the minerals which characterize the walls of the dikes where they penetrate the ore are not present where the dikes pass out of the ore mass into the country limestone. Franklinite and willemite, which are the principal minerals of the unaltered portion of the ore mass, occur also among the secondary minerals of the pegmatite contacts, and in this association both minerals are ordinarily well crystallized. It seems evident that they were formed by the rearrangement of materials derived from the original ore.

The dike of pegmatite inside the ore trough at Sterling Hill does not cross the lamination of the limestone but follows the curve of the ore layer, from which it is separated by 10 to 15 feet of limestone containing a minor amount of franklinite. The concave side of the dike next to the mass of barren limestone that fills the southeast end of the trough shows no development of contact minerals, but along the convex side, which faces the ore layer, garnet and zinc-bearing pyroxene and biotite occur in several places. This one-sided metamorphism suggests that the zinc which the contact minerals contain was contributed by the ore layer and, therefore, that the dike was injected after the ore body had been formed. White sphalerite and galena occur in this dike.

PART III.

BUILDING STONES OF NEW JERSEY.

By J. VOLNEY LEWIS.

Building Stones of New Jersey.

CONTENTS.

INTRODUCTION.

Stone that may be used for building and engineering purposes occurs in all countries and in formations of all geologic ages. Indeed almost any kind of stone may be used locally for such purposes as foundations, monuments, paving, and even buildings. In practice, however, it has been found that many of these are, for one reason or another, unsuited to the best structures. The kinds of stone actually in general use in architectural and engineering construction may be classified under six heads, namely: (1) Granite, (2) Trap Rock, (3) Sandstone, (4) Slate, (5) Limestone, (6) Marble.

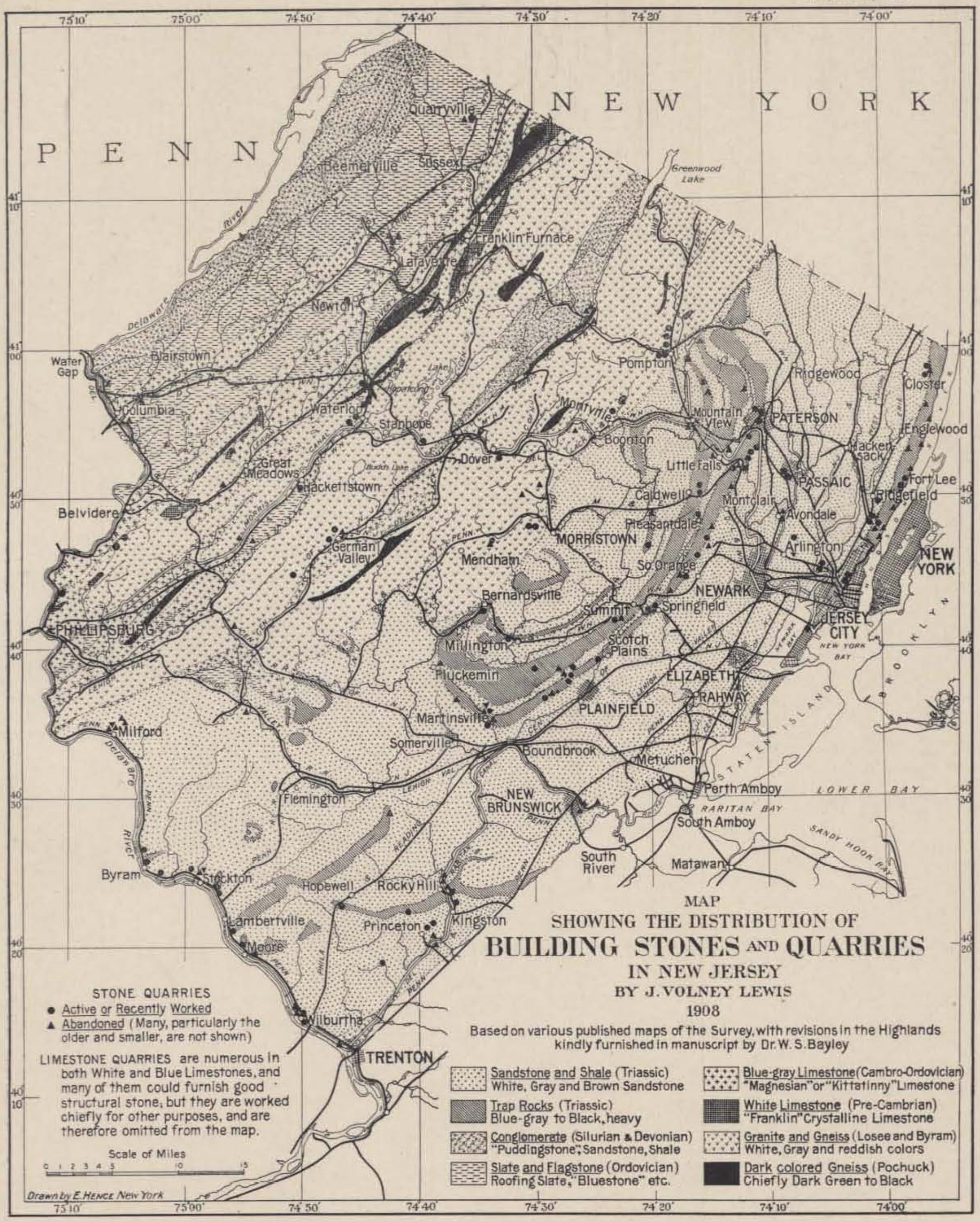
Trap is a name applied to a considerable class of rocks more or less similar in their dark colors and other characters. In common usage the other designations also are seldom restricted to exact or even very definite meanings. Thus, in the trade, granite includes, besides granite proper, a variety of stones that look more or less like granite and exhibit somewhat similar general characters in quarrying and cutting; such as syenite, gneiss, and often even the coarse-grained darker and heavier rocks, like gabbro and diorite, which are strictly very far from granite in both chemical and mineral composition. Marble also includes, besides crystalline limestone, a variety of ornamental stones that are capable of being polished and used for similar purposes, such as compact limestones, serpentine, and sometimes even slate.

Besides these a number of other terms are in use of very vague significance or with meanings that vary with the locality in which they are used. Thus freestone is applied indiscriminately to any kind of stone that may be split or broken readily in any direction, like the more massive limestones, sandstones, etc. Flagstone is any stone that may be separated readily into thin slabs suitable for curbing and pavements, such as thin-bedded sandstones, thinly foliated gneisses, schists, and slates. Bluestone is thus defined by Merrill:[1] "In Maryland a gray gneiss; in Ohio a gray sandstone; in the District of Columbia a mica schist; in New York a blue-gray sandstone. A popular term; not sufficiently definite to be of value." To this definition may be further added, in New Jersey and New York bluish-gray limestone; in New Jersey a dark-gray to brownish argillite (or mud-rock), and probably many other local meanings in the quarry districts of the various states. Brownstone, in New Jersey and neighboring states, is the name commonly applied to the reddish-brown to dark chocolate-colored sandstones of the Triassic or Newark formation. This stone was immensely popular two or three decades ago, and many buildings were constructed of it in most of the larger cities of the country.

STONE INDUSTRY OF NEW JERSEY.

Stone of all these various kinds occurs abundantly in New Jersey, and is actively quarried in the northern counties (see map, Plate II). Since early colonial days the glacial bowlders,

[1] Stones for Building and Decoration, 3d edition, New York, 1903, p. 531.


MAP
SHOWING THE DISTRIBUTION OF
BUILDING STONES AND QUARRIES
IN NEW JERSEY
BY J. VOLNEY LEWIS
1908
Based on various published maps of the Survey, with revisions in the Highlands kindly furnished in manuscript by Dr. W. S. Bayley
STONE QUARRIES
● Active or Recently Worked
▲ Abandoned (Many, particularly the older and smaller, are not shown)
LIMESTONE QUARRIES are numerous in both White and Blue Limestones, and many of them could furnish good structural stone; but they are worked chiefly for other purposes, and are therefore omitted from the map.
Scale of Miles
0 1 2 3 4 5 10 15
Sandstone and Shale (Triassic) White, Gray and Brown Sandstone
Trap Rocks (Triassic) Blue-gray to Black, heavy
Conglomerate (Silurian & Devonian) "Puddingstone", Sandstone, Shale
Slate and Flagstone (Ordovician) Roofing Slate, "Bluestone" etc.
Blue-gray Limestone (Cambro-Ordovician) "Magnesian" or "Kittatinny" Limestone
White Limestone (Pre-Cambrian) "Franklin" Crystalline Limestone
Granite and Gneiss (Losee and Byram) White, Gray and reddish colors
Dark colored Gneiss (Pochuck) Chiefly Dark Green to Black
Drawn by E. Hence New York
PENN
NEW YORK
Quarryville
Beemerville
Sussex
Greenwood Lake
Franklin Furnace
Lafayette
Newton
Water Gap
Blairstown
Columbia
Pompton
Ridgewood
Closter
Montville
Mountain View
PATERSON
Englewood
Waterloo
Stanhope
Boonton
Hackensack
Great Meadows
Hackettstown
Dover
Little Falls
PASSAIC
Fort Lee
Belvidere
Caldwell
Montclair
Ridgefield
Pleasantdale
Avondale
German Valley
MORRISTOWN
Arlington
NEW YORK
Mendham
So. Orange
NEWARK
Bernardsville
Summit
Springfield
JERSEY CITY
PHILLIPSBURG
Millington
Scotch Plains
NEW YORK BAY
Pluckemin
ELIZABETH
RAHWAY
BROOKLYN
STATEN ISLAND
PLAINFIELD
Milford
Martinsville
Somerville
Boundbrook
Metuchen
Perth Amboy
LOWER BAY
Flemington
NEW BRUNSWICK
RARITAN BAY
South Amboy
SANDY HOOK BAY
South River
Matawan
Byram
Stockton
Hopewell
Rocky Hill
Lambertville
Princeton
Kingston
Moore
Wilburtha
TRENTON
Delaware River
75°10′
75°00′
74°50′
74°40′
74°30′
74°20′
74°10′
74°00′
41° 10′
41° 00′
40° 50′
40° 40′
40° 30′
40° 20′
40° 10′

or "field-stones," that are found so abundantly over large areas in northern New Jersey, have been used locally for a great variety of structural purposes. Fences, chimneys, foundations, and often entire buildings were constructed of them, with little regard to kind, color, or any other quality. In such rubble work any stone is used that can be made to lie where it is placed, and of all sizes, within the limits set in earlier times by somewhat primitive methods of handling. In later structures bowlders of large size are used and often highly attractive results are achieved (Plate III).

In spite of the haphazard manner of construction, many of these old buildings have stood in good repair for two centuries and more; for, fortunately, the bowlders are themselves the product of a process of natural selection, and illustrate the law of the survival of the fittest in the realm of the inorganic, the more perishable stones having been ground to powder beneath the vast continental glacier.

In the early days, and long afterward, there was no stone industry, strictly speaking. In the northern counties each neighborhood, often each farm, even, supplied its own needs from the loose stones that could be gathered everywhere. Sometimes the surface material was supplemented by small local quarries, opened by the farmers between seasons and worked for a little while at a time in order to meet any special requirement. In several states large industries have developed from these early beginnings, as the growth of the cities gave rise to a greater and steadier demand for stone. New Jersey has shared in this development to only a limited extent, however, and much of the former activity, as, for instance, in the brownstone districts of Essex and Passaic counties, has fallen away in recent years.

Statistics of the U. S. Geological Survey show that, out of a total annual production of 60 to 70 million dollars worth of stone for the whole country in recent years, New Jersey furnishes only 1 to 1.5 million, or about 2 per cent., and two-thirds of this is crushed stone for macadam roads, concrete, and railroad ballast. In this particular class of stone New Jersey stands first, thanks to her abundance of excellent trap rock and her activity in the construction of good roads. A dozen states rank higher in total production, and many of these stand far higher in stone for building purposes. Less than half of these are neighboring states near the great eastern markets; but in the matter of location, as well as in the abundance and excellence of the material in several important classes, New Jersey must be ranked high. Thus it appears that the stone industry of the State is not enjoying the measure of prosperity that might reasonably be expected.

In many places stone is found possessing all the requirements of a high-grade building material—strong, durable, of good colors and working qualities, and often taking a beautiful polish. Hence it is not easy, at first thought, to find a satisfactory reason for the state of affairs described above. However, some of the more obvious conditions that have affected the industry unfavorably may be briefly stated.

In the brownstone regions, to which reference has been made, the larger quarries that once supplied the stone for numerous buildings in all the larger cities of the east are now closed and their machinery is rusting away. Some of these, as in the city of Newark, have become more valuable for building space and are now overrun by the growth of the city; but this is not the case with the great Belleville quarries, and there are many places in the surrounding country that could supply this stone in vast quantities. Public taste has changed. Brownstone houses and brownstone "fronts" are no longer fashionable. The colors are too somber to suit the popular taste for residences and are not adapted to the prevailing styles of architecture. Fewer large buildings of a public or a semipublic character are constructed of it, and even the churches are adopting the lighter tints. Hence the creamy-white Indiana limestone has now almost entirely displaced brownstone in general use. The rapidly increasing use of cement has also helped to crowd it out of the market, as it has all natural stone to a greater or less extent.

In the light of present tendencies it does not seem probable that this stone will regain its former prominence at any time in the near future. This statement does not apply, however, to the lighter-colored sandstones that occur abundantly in the same formation. These are of the popular white, creamy, and light-gray tints, and while they must meet the competition of cement

1. Old House at Comp Gaw.

2. Residence of C. W. Mc-Alpin, Glen McAlpin, near Morristown.

3. Residence of M. H. Behr, Far Hills.

RESIDENCES BUILT OF FIELD STONES.

and Indiana limestone, there seems to be no good reason why they should not find a larger market than they now enjoy, especially in view of their nearness to the large eastern markets.

The slate industry has also suffered to a certain extent from the change in architectural fashion. The Gothic and the mansard roof made a large demand for slate covering, but the low-pitched and flat roofs of prevailing styles require metal or other continuous, water-tight material. While there has been this decrease in the proportion of slate roofs on the better kinds of buildings, there has been such a great increase in population and wealth and in the total number of such buildings erected, that the actual demand for slate roofing has increased considerably and the industry still thrives. The use of slate for blackboards, billiard tables, grave vaults, laundry tubs, mantels, switch-boards, stair-treads, tiling, wainscoting, etc., has greatly increased, and some quarries devote a large part of their product to "mill stock" for such purposes.

What is further true concerning the desirable light-colored sandstones, and is equally applicable to the granites of the Highlands and the slates and "blue" limestones of Warren and Sussex counties, is that they simply await capital for their proper development, and the exercise of ordinary business prudence and sagacity in their management. In general the stone industry of the State suffers most from the lack of capital and the lack of initiative; but in exceptional cases capital seems to have been wasted, and failure naturally resulted.

DISTRIBUTION OF BUILDING STONE.

A line from Trenton northeastward across the narrowest part of the State separates the hilly and mountainous section, which abounds in rocks (Plate II), from the flatter Coastal Plain, in which rocks are either rare or absent altogether. North of this line, in the counties of Sussex, Warren, Passaic, Morris, Hunterdon, Bergen, Essex, Union, Somerset, and portions of Mercer and Middlesex, stone suitable for various construction purposes is very abundant. There is a wide range of materials, including trap rock, granite and gneiss, sandstone, limestone, slate, serpentine and marble, and an equally wide range of adaptability, from ballast, road metal, concrete, flagging, and rough foundation work, on the one hand, to general engineering purposes, architectural construction, and the finest polished ornamental work, on the other.

Even the southern part of the State, although consisting in general of only unconsolidated sand, gravel, and clay beds, is not entirely without stone that may be used in building. Locally certain beds have been hardened into quite firm sandstone and conglomerate, and occasional examples of their use in an important way may be found, as in the Episcopal church at Eatontown and the West Jersey Academy at Bridgeton. With the advantages of modern transportation, however, making the better and more abundant materials of the hills and the mountains available, both in the form of quarried stone and manufactured into cement, these sandstones of the southern counties cannot be seriously regarded as important resources. Occasional small local needs, such as foundations for frame buildings, may be supplied from this source, but no established stone industry is to be expected south of a line from Trenton to Bergen Point.

In the northern counties, as indicated above, the use of stone for building was begun in very early days, and many stone houses in this section are more than 200 years old. Some of these were built in the crudest manner of surface bowlders (or field stones) with only mud for mortar, while others were constructed either wholly or in part of stone quarried from the hills and carefully cut and surfaced. Old buildings of these types are scattered quite generally through the northern counties of the State from the Hudson to the Delaware.

In general, the chief stone areas of the northern section of the State may be divided into three belts, according to the prevailing characters of the stone.

1. *The belt of Gneisses and Granites.* This constitutes the Highland area of the State, which consists of a series of broad, massive mountain ridges of ancient crystalline rocks having a general northeast and southwest trend. The belt is from 10 to

20 miles wide and Jenny Jump Mountain, near Belvidere, and Pochuck Mountain, near Franklin Furnace, are its northwestern outposts. Several long narrow valleys in the western and southwestern parts of the Highlands are underlain by limestone and slate that belong to the third belt, as described below, but the higher mountains of the whole area are composed of hard crystalline granites and gneisses, except the narrow strip extending southwest from Greenwood Lake, and the rocks of the mountains in this strip are as hard as the granites of the Highlands.

2. *The belt of Limestones and Slates of the Kittatinny Valley.* This constitutes a large part of Warren and Sussex counties, extending northwestward from the crystalline Highlands to Kittatinny or Blue Mountain, thus including the broad lowlands of Kittatinny Valley which are underlain by limestone and slate. The broader valleys of the Highland belt are underlain by the same limestone and slate so that there is an interlocking of the two belts, particularly toward the southwest.

3. *The belt of Newark (Triassic) sandstone and trap rocks.* This belt is 32 miles wide along Delaware River above Trenton, extending into the great bend of the river above Milford, but it gradually narrows northeastward to half this width at the New York boundary, and extends back from the Palisades of the Hudson to Ramapo River at Suffern, N. Y. In this area are located most of the quarries of trap rock, in the production of which New Jersey excels, and a number of quarries producing brownstone and gray and white sandstone.

The high ridge of Kittatinny or Blue Mountain, which flanks the Kittatinny Valley to the northwest, and the narrow belt of country extending southwestward from Greenwood Lake (see map, Plate II) are composed largely of coarse sandstones and conglomerates which, in the latter region, are very hard and durable and often of attractive colors, but are scarcely available to any important extent for general building purposes..

The white crystalline limestone and the gneisses and granites of the Highlands are the oldest rocks of the State. The "blue" limestone and slate of Kittatinny Valley, with the overlying sandstone of Kittatinny Mountain, were deposited on a floor of these ancient crystallines in the seas which covered the interior of the continent through many consecutive periods of Paleozoic time. Many of the strata still bear well-preserved traces of shells and other remains of marine animals of these remote periods, imbedded in the muds and limy oozes which have since been hardened into compact rocks and lifted up through long periods of crumpling, folding and erosion into their present attitude. Their worn and weathered edges are crumbling again and furnishing muds and sands to the seas of to-day for the strata of rocks that are to be.

The wearing and wasting processes have removed the strata of limestone and slate from large areas of the old crystalline floor of granite and gneiss, and these are now laid bare, or are covered only by a thin veneer of soil and glacial drift, over large areas of the Highlands. On any one of the higher grounds of the region which was glaciated the bed rock may easily be found, and it is often hard and firm almost to the very surface.

Much of the sand and mud from the crystalline Highlands was washed down the southeastward slopes and spread over broad low flats in the next suceeeding geologic era, the Mesozoic. Molten lavas from the earth's interior were also spread repeatedly over these broad mud flats, and were in turn covered by other sands and muds, and similar lava worked its way between the layers deep below the surface, baking them into hard flinty hornfels. These muds and sands now form a belt of red shales and sandstones stretching northeastward across the State from the Delaware to the Hudson, and the interbedded and intrusive lavas are the trap rocks that are quarried so abundantly for crushed stone. The whole series is now tilted gently to the northwest, the strata in the quarries usually showing an inclination of 10 to 15 degrees.

GRANITE AND GNEISS.

The rocks of the Highlands are chiefly light-colored crystalline feldspar-quartz rocks similar in general character to granite, but usually possessing a visible foliated or linear structure. They are to be designated generally as gneisses, therefore, although the parallel structure is often indistinct and sometimes absent altogether. Occupying smaller areas in this region are much darker gneisses made up of feldspar and hornblende or other very dark-colored minerals (see Plate II).

These rocks usually possess a parallel foliated character which in general runs northeast and southwest and dips steeply toward the southeast. As stated above, however, the structure is often very slightly developed, and in such cases the rock becomes practically a massive granite. The darker and lighter-colored varieties are sometimes closely interlaminated, but areas may readily be found suitable for quarrying purposes in which one kind or the other greatly predominates, or even occurs entirely free from admixture.

In the detailed mapping of a part of this region these gneisses have been divided into three groups, which are thus described by Dr. Spencer:[1]

"All the dark gneisses, which owe their color to the hornblende, pyroxene or biotite which they contain, are grouped together under the name *Pochuck* gneiss. The second group, the most of which are brown, grey, bronzy pink and ocherous tones, is called the *Byram* gneiss. Here are included a great variety of granitoid or granite-like rocks related to one another and distinguished from the other gneisses by the presence of potash feldspar as an essential ingredient. The third group, the *Losee* gneiss, includes light-colored granitoid rocks, many of them nearly white, which contain lime-soda feldspar as an essential and characteristic mineral component.

"The varieties of gneiss are seldom found in large masses free from intermixture with other sorts, but the different facies or varieties occur in tabular masses which are interlayered both on a large and on a small scale. The mingling is so intimate and the proportions of the lithologic facies are so various that even after bringing the varieties together in groups it is impossible to give a really faithful representation of their distribution on a map of small scale. As a matter of necessity, therefore, the bands which are distinguished on the geologic map represent merely the presence of varieties of gneiss resembling the designated type as the most abundant rocks in the area * * * *

"Within the layers of the gneiss, besides a commonly well-marked foliation due to the arrangement of the more or less flattened mineral constituents in parallel planes, there is in many places a distinct streaking or graining which runs diagonal to the strike and dip * * * Locally the foliation may be observed to almost disappear and to give place to a pitching linear structure produced by the grouping of the mineral grains into pencils."

---

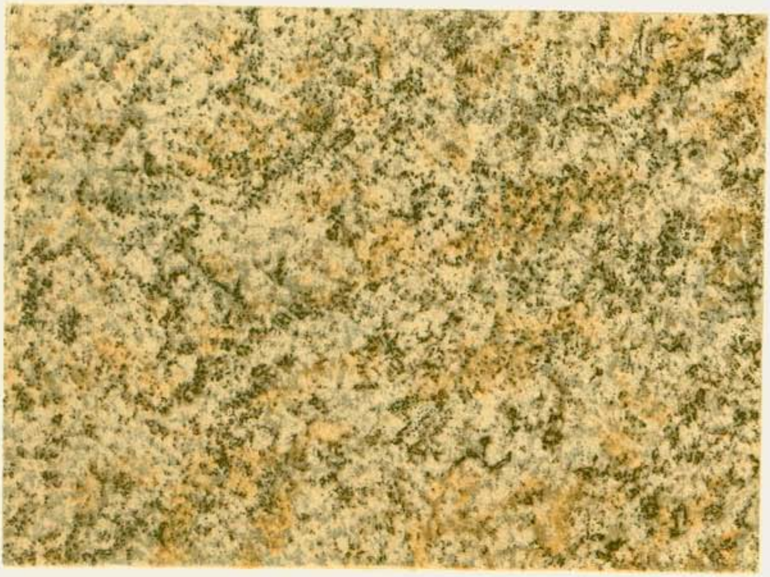
[1] Geologic Atlas of New Jersey, Franklin Furnace Folio, 1908, p. 2.

For purposes of description here the Losee and Byram gneisses are grouped together, since both furnish light-colored desirable building stones which have been quarried in many places. Occurring in dikes and larger irregular masses through the gneisses, a coarse-grained granite (pegmatite) is often found. It consists essentially of feldspar and quartz and is often of decided pinkish to reddish color. It has been quarried in a few places and constitutes a very attractive building stone. The dark Pochuck gneiss is quarried where crushed stone is desired and is produced in a number of places in this form to be used for concrete, railroad ballast, road metal, and other purposes for which the crushed trap rocks have become famous.

Beginning in the northeast and proceeding southwestward the more important quarries are described below. It should be born in mind, however, that the industry is but slightly developed in comparison with the possibilities, and a great number of places which have not been worked are just as promising as those here described. Intelligent search on the part of the prospective operator will reveal many favorable localities for the economic production and marketing of desirable stone. In some cases the smaller quarries have been opened by contractors to supply stone for some particular purpose and without any intention of establishing a permanent industry. Many such places have been worked intermittently to meet special contracts and their closing at any time means simply the completion of the particular work in hand.

Pompton Pink Granite (Pegmatite).—A very attractive coarse-grained pink granite with light yellowish-green mottlings (see Plate IV) is found in the eastern border of the Highlands about Pompton. It is intruded into the gneisses of the region and often contains inclusions of the latter in pieces ranging from fragments a few inches across to great slabs many feet in extent. These masses of the country rock sometimes become more and more numerous until the granite appears merely as thin sheets injected into the foliation planes of the gneisses, and all gradations can be found between the normal massive granite and the undisturbed gneiss.

1
POMPTON PINK GRANITE
(NATURAL SIZE AND COLOR)



A. HOEN & CO. BALTIMORE.

2
HASKELL GRAY GRANITE-GNEISS
(NATURAL SIZE AND COLOR)

The prominent hills along this steep front of the Highlands are advantageous to quarrying, especially as large areas of bare rock occur, and the chief consideration in selecting the quarry site is to avoid numerous inclusions of gneiss, which appear as dark streaks and layers in the rock and cause considerable waste in quarrying. If they are too near together they also make it impossible to get out large blocks of uniform color and free from imperfections. The texture of the rock also is often quite variable, ranging from medium fine to very coarse grained, and there is a corresponding variation in the proportions of pink, white and green colors.

Microscopic and chemical characters.—Under the microscope the rock is found to contain chiefly feldspar (microperthite and microline) and quartz. Occasional flakes of dark-brown mica also occur and scattering grains of magnetite and titanite. Small irregular areas of granular green epidote have been developed in some places between the feldspars.

A chemical analysis of the rock yielded the following results:

Analysis of Pink Granite (Pegmatite) from Quarry at Pompton Junction.

BY R. B. GAGE, CHEMIST OF THE SURVEY.

SiO_2	71.91	CO_2	0.22
Al_2O_3	15.71	TiO_2	0.03
Fe_2O_3	0.21	P_2O_5	0.11
FeO	0.13	SO_3	0.05
MgO	0.03	MnO	0.02
CaO	0.70	BaO	0.14
Na_2O	2.61		
K_2O	8.60	Total,	100.71
H_2O	0.27		

In the quantitative classification of igneous rocks, this is a dopotassic liparase, *omeose,* and its place is indicated by the symbol, I.4.1.2.

Contrasted with this in its higher silica, ferrous iron and magnesia, and its lower content of alumina and alkalis, is the following:

Analysis of Gneiss included in the Pompton Junction Pink Granite.

BY R. B. GAGE, CHEMIST OF THE SURVEY.

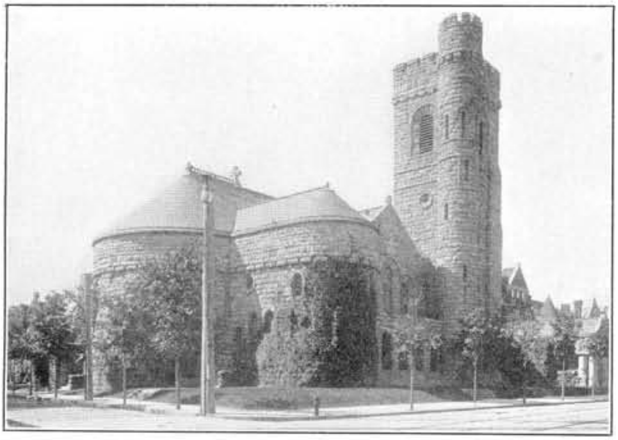
SiO_2	77.59	CO_2	0.13
Al_2O_3	10.53	TiO_2	0.60
Fe_2O_3	0.21	P_2O_5	0.05
FeO	1.74	SO_3	0.05
MgO	1.01	MnO	0.03
CaO	0.76	BaO	0.06
Na_2O	1.58		
K_2O	5.30	Total,	99.24
H_2O	0.60		

Considered as an igneous rock, the place of this gneiss in the quanitative classification is indicated by the symbol, I.3.2.2., and it would be designated as *mihalose,* a dopotassic alsbachase.

Two quarries are located in this stone, namely: that of the Jersey Pink Granite Company, at Pompton Junction, and that of the Herbert L. Brown Company, three-fourths of a mile southwest of Pompton. (See Plate IX.) The former, which is not now in operation, has a spur track from the railroad and is equipped with a steam power plant, derricks, drills, and a number of stone-working machines. Large blocks were obtained, but parts of the quarry suffered from an undue amount of gneiss included in the granite. In the other quarry, which is new and not yet fully developed, no trouble from this source seems to have been encountered, and there is little waste material. Blocks containing 40 to 50 cubic feet are readily obtained and much larger ones could doubtless be taken out if desired.

A good example of the architectural uses of the Pompton pink granite is found in St. Paul's Church at Paterson (Plate V). A considerable quantity of this stone is also being used in the approach to the new building of the National Museum in Washington, D. C.

HASKELL GRAY GRANITE-GNEISS.—A mile southwest of Haskell and about the same distance northwest of Pompton, a light-gray granite-gneiss (Plate IV) outcrops in a strong ledge. The stone is quite fine grained and contains very little dark-colored mineral. It has been quarried for several years in a

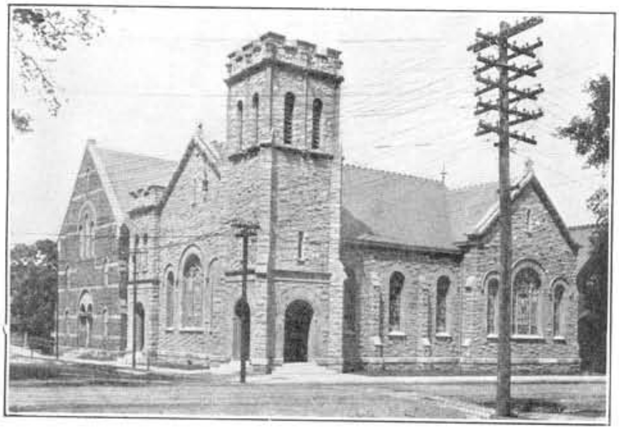


1. POMPTON PINK GRANITE.

St. Paul's Church, Paterson.

2. HASKELL GRAY GRANITE-GNEISS.

St. Anthony's Parochial School, Butler.



3. DOVER GRAY GRANITE-GNEISS.

First M. E. Church, Dover.

small way for buildings, paving stones, and general construction purposes by C. Di Laura. It is quite uniform and massive in character, and good examples of its use are be found in St. Anthony's Church and school buildings at Butler. (See Plate V.)

Microscopic and chemical characters.—Under the microscope the rock is seen to consist chiefly of microperthite and quartz with occasional dark-green augite and scattering crystals of magnetite. The texture in the section is granitic.

An analysis of this stone shows some points of resemblance to the gneiss inclusions in the pink granite at Pompton.

Analysis of Gray Granite-Gneiss, Di Laura's Quarry, near Haskell.

BY R. B. GAGE, CHEMIST OF THE SURVEY.

SiO_2	74.36	CO_2	0.02
Al_2O_3	12.75	TiO_2	0.45
Fe_2O_3	2.09	ZrO_2	0.04
FeO	1.35	P_2O_5	0.26
MgO	0.11	SO_3	0.09
CaO	0.82	MnO	0.04
Na_2O	3.44	BaO	0.09
K_2O	3.76		
H_2O	0.20	Total,	99.86

In the quantitative classification of igneous rocks this is a sodipotassic alaskase, *alaskose,* I.3.1.3.

A *dark-green gneiss* that occurs near by affords a stone of striking contrast in color to that described above. It is more distinctly laminated, so that broad slabs are readily obtained, and it has been used for curbing, steps, sills, etc.

Microscopic characters.—The feldspars include orthoclase, plagioclase, and microperthite; augite is abundant and considerably altered to green fibrous hornblende and chlorite in confused aggregates. Biotite occurs in large flakes and scattering magnetite grains. Quartz is entirely absent. The texture is strongly gneissic.

A coarse-grained pinkish granite (pegmatite) of similar character to that about Pompton is also found in the vicinity, where it is intruded into the gneisses. No quarry has yet been developed in this stone but small amounts of it have been taken out for monuments, fountains, etc.

CHARLOTTEBURG PINK GRANITE-GNEISS.—A medium coarse-grained pinkish-gray granite (Plate VI), which varies from massive to slightly gneissic in structure, was once quarried about half a mile east of Charlotteburg, on the steep mountain slope just opposite the railroad junction. It is of finer grain and more uniform in texture and color than the Pompton granite and has a grayish tint, owing to the admixture of small dark grains of hornblende with a pink and white feldspar. The green mottlings in the Pompton granite, due to the presence of epidote, are altogether lacking in the Charlotteburg stone.

The outcrop forms a bold steep exposure favorable to economic quarrying, and the jointing permits the removal of as large blocks as are usually desired in building. A spur track could be easily and cheaply laid from the railroad.

Microscopic and chemical characters.—In thin section the rock is found to be granitic in texture and composed chiefly of feldspar and quartz, the two being sometimes intergrown in the form of micropegmatite. There are several varieties of the feldspar, including microperthite, microline, orthoclase and plagioclase. Some green and brown hornblende occurs, secondary after augite, of which small remnants still remain unaltered. Occasional grains of magnetite also occur.

Chemically this stone is much like the gray granite-gneiss at Haskell, as shown by the following analysis.

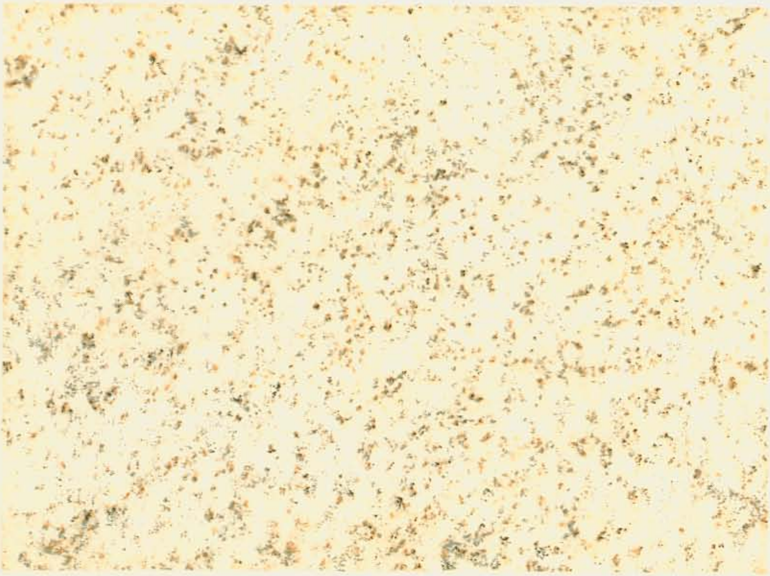
Analysis of the Pinkish Granite-Gneiss at Charlotteburg.

BY R. B. GAGE, CHEMIST OF THE SURVEY.

SiO_2	75.56	CO_2	0.19
Al_2O_3	12.61	TiO_2	0.22
Fe_2O_3	0.64	P_2O_5	0.05
FeO	1.16	SO_3	0.11
MgO	0.05	MnO	0.03
CaO	0.84	BaO	0.12
Na_2O	2.35		
K_2O	5.93	Total	100.27
H_2O	0.42		

In the quantitative classification this rock is almost on the line between dopotassic and sodipotassic alaskase, and is designated *alaskose* (I. 3. 1. 2-3).

1
CHARLOTTEBURG PINK GRANITE-GNEISS
(NATURAL SIZE AND COLOR)



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2
CRANBERRY LAKE WHITE GRANITE-GNEISS
(NATURAL SIZE AND COLOR)

POWERVILLE GRAY GRANITE-GNEISS.—A mile and a half west of Boonton, near Powerville, a coarse-grained greenish-gray granite-gneiss forms heavy ledges of bare rock on the south slope of the Torne. It has a distinct foliated structure which dips 70 degrees to the southeast (Strike N 65° E.) but as a rule it is quite uniform in both color and texture. Feldspar, quartz, horneblende and scattering magnetite grains are the constituents visible to the eye. Occasionally a coarser-grained pegmatitic streak or spot is darkened by a larger proportion of magnetite.

Vertical joints are spaced from 2 to 20 feet apart, and the horizontal joints, parallel to the foliation planes, afford natural benches 3 to 10 feet thick. A quarry face 50 feet high can be obtained very readily, as the whole mountain appears to be composed of this stone, which outcrops in numerous places on the steep southerly slopes.

Some quarrying was done at one point several years ago by the owner, Clarence De Camp, and an excellent illustration of its architectural use is found in the residence of John Claflin at Morristown. (See Plate VII.)

Microscopic Characters.—The texture is granitic to gneissic and microperthite, which seems to be the only feldspar, is the chief constituent. Quartz is next in abundance, while scattering brown hornblende and occasional magnetite crystals also occur.

MORRIS PLAINS DARK-GRAY GRANITE.—Malley's quarry is a small opening on the top of the mountain, 1.5 miles northwest of Morris Plains and three-quarters of a mile west of the railroad. It is in a medium-grained massive dark-gray granite with an unusual yellowish-brown tint. It is remarkably uniform in both color and texture, is perfectly massive and notably free from joints or other structures. The quarry face is about 20 feet high and few joints are visible, so that quarrying was probably somewhat more difficult and expensive on that account. There is little or no stripping, however, as bare rock makes up much of the top of the mountain.

The stone would seem to be well adapted to monumental work and also desirable for contrast with lighter colors in buildings. It would doubtless polish well and afford a pleasing effect with carving or lettering.

Microscopic and chemical characters.—In thin section the rock is granitic in texture, the feldspar and quartz occurring both in distinct grains and in micropegmatitic intergrowth. The feldspars include both orthoclase and plagioclase. There is little augite and occasional grains of magnetite and biotite occur.

Chemical analysis shows relatively low silica and potash and high soda, lime, and ferrous iron, in comparison with the preceding ones.

Analysis of Dark-Gray Granite, Malley's Quarry, near Morris Plains.

BY R. B. GAGE, CHEMIST OF THE SURVEY.

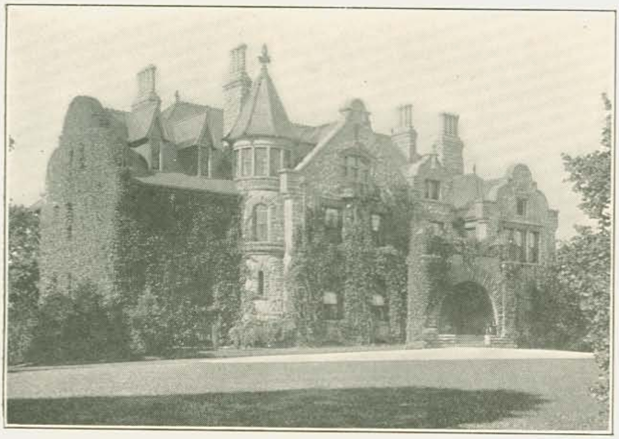
SiO_2	69.48	TiO_2	0.40
Al_2O_3	16.42	ZrO_2	0.02
Fe_2O_3	0.56	P_2O_5	0.11
FeO	2.60	SO_3	0.07
MgO	1.15	MnO	0.02
CaO	3.45	BaO	[1]0.05
Na_2O	4.59		
K_2O	1.18	Total	100.45
H_2O	0.34		

This rock is a dosodic coloradase with the specific name *yellowstonose*. Its position in the quantitative system is indicated by the symbol I. 4. 3. 4.

DOVER LIGHT-GRAY GRANITE-GNEISS.—Thomas Fanning's quarry is on the railroad, one-half mile east of the station at Dover. This stone is light gray to greenish gray in color and consists of medium-grained feldspar, quartz, and greenish-black hornblende in somewhat variable proportions. The gneissic structure is rendered distinct by the arrangement of the dark mineral in discontinuous parallel lines. In some places this foliation is more pronounced as the alternate dark and light bands of color become more continuous. At one end of the quarry veins of coarse pegmatite occur from three inches to a foot in thickness, consisting of large interlocking crystals of quartz and feldspar and masses of coarse black hornblende, magnetite, and black mica.

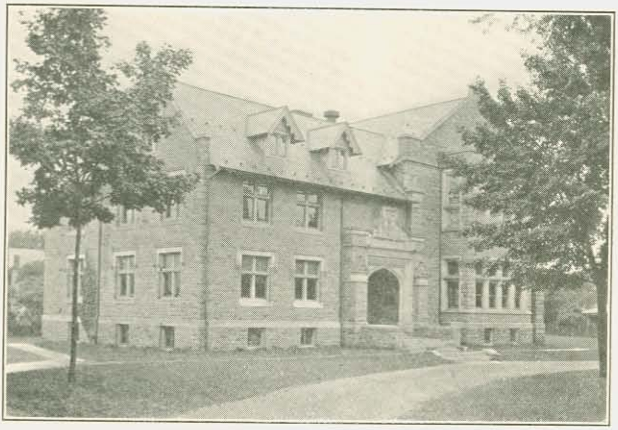
The folition dips 60 degrees to the southeast (strike N. 40° E.). The rock is jointed into layers 3 to 10 feet thick, with head-

[1] Tests were also made for Ni, Co, Cu, Zn, and Sr, but none was found.



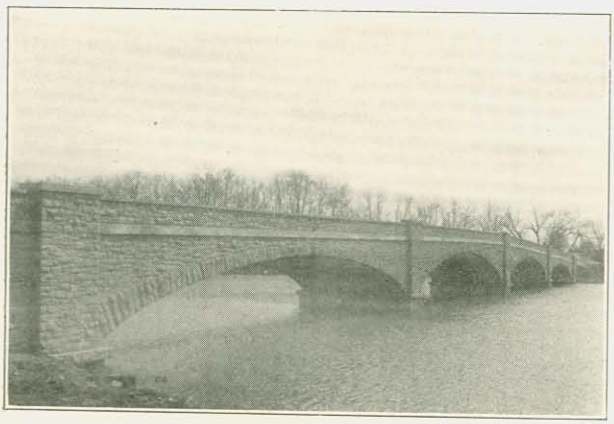
1. POWERVILLE GRAY GRANITE-GNEISS.

Residence of John Claflin, Morristown.



2. GERMAN VALLEY GRAY GRANITE.

Brainerd Hall, Lafayette College.



3. GERMAN VALLEY GRAY GNEISS.

Bridge at Princeton.

joints at right angles to these at intervals ranging to from 3 to 40 feet apart. The working face of the quarry is about 50 feet high (Plate XI).

This stone was used in the construction of the new First M. E. Church at Dover (Plate V), which presents a strong contrast with the dark-colored field stone of the old building beside it.

Microscopic characters.—In thin section under the microscope the texture is granitic to gneissic and the constituents are seen to be microperthite, orthoclase, quartz, a little dark-green hornblende, and black grains of magnetite. The feldspars are somewhat clouded by alteration to kaolin, and a little chlorite is developed from some of the hornblende. In the pegmatitic veins, quartz, orthoclase, microline, plagioclase occur, and the quartz and feldspar are in part intergrown as micropegmatite. The large grains are crushed somewhat about the borders and a little granular yellowish-green epidote has developed from the feldspar.

MOUNT ARLINGTON GRAY GRANITE-GNEISS.—The quarry of the North Jersey Stone Company is on the railroad a mile west of Mount Arlington station. The stone is a medium-grained light-gray gneiss, like that of Fanning's quarry at Dover, with similar occasional banded hornblendic portions, and veins of coarse pegmatite in places. The bed joints dip 70 degrees toward the northwest (strike N. 60° E.) and the layers are usually 10 feet or more in thickness. Certain dark colors also occur that are much like the dark-gray granite at Morris Plains, described above.

The quarry is favorably located in the steep slope of the mountain, with much bare rock exposed. The working face is about 100 feet high (Plate XI) and the equipment includes a steam power plant, derrick, drills, and crusher. Dimension stone, paving blocks and crushed rock are produced.

Microscopic characters.—The texture in thin section is fine-grained and gneissic, with quartz, orthoclase, and microperthite in great abundance. Dark-green hornblende and magnetite occur in scattering grains and minute crystals of apatite are occasionally seen. The minerals interlock on their borders to an unusual extent. The bands of darker-colored stone contain more hornblende and some plagioclase feldspar.

WATERLOO PINKISH-GRAY GRANITE-GNEISS.—The quarry of the Allen Granite and Construction Company, not now in operation, is three-quarters of a mile northeast of Waterloo, in the steep face of the mountain, on which much bare stone is exposed, with little surface covering anywhere. It is a medium coarse-grained stone, much like that at Charlotteburg, but of a somewhat deeper-reddish tinge. The color is slightly variable, however, ranging from pale pinkish-gray in the northeastern portion of the quarry to a deep brownish-pink in the southwestern part. There is but little dark mineral, and this is arranged in the parallel gneissic foliation, thus rendering it somewhat distinct. The texture is quite uniform and there are no unsightly streaks or patches of darker rock or of coarse pegmatite. (Plate X.)

The gneissic layers dip 60 degrees toward the northeast, and strike N. 50° W. with prominent jointing almost at right angles to the strike and dipping 75 degrees toward the southeast. The joints are spaced from a few inches to several feet apart. There is a spur track from the railroad and the quarry equipment includes steam-power derrick and drills.

Microscopic and chemical characters.—Like the Charlotteburg quarry, this stone is of granitic texture when seen in thin section, and is composed of quartz, orthoclase, microperthite, microline, with a little augite and magnetite. The pinkish color is seen to be due to minute flakes of hematite, which are disseminated chiefly through the albite portion of the microperthite.

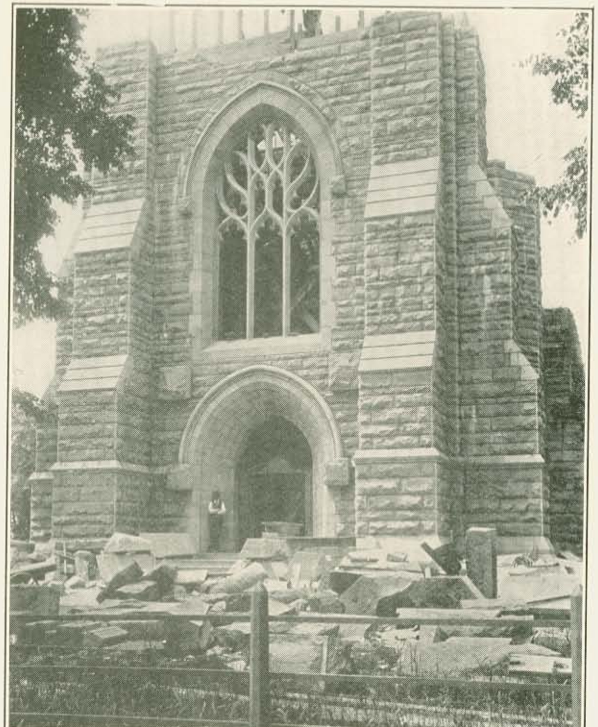
St. Peter's Church, at Morristown (Plate VIII), affords an excellent example of the use of this stone in building.

Analysis of Granite-Gneiss, Allen Quarry, Waterloo.

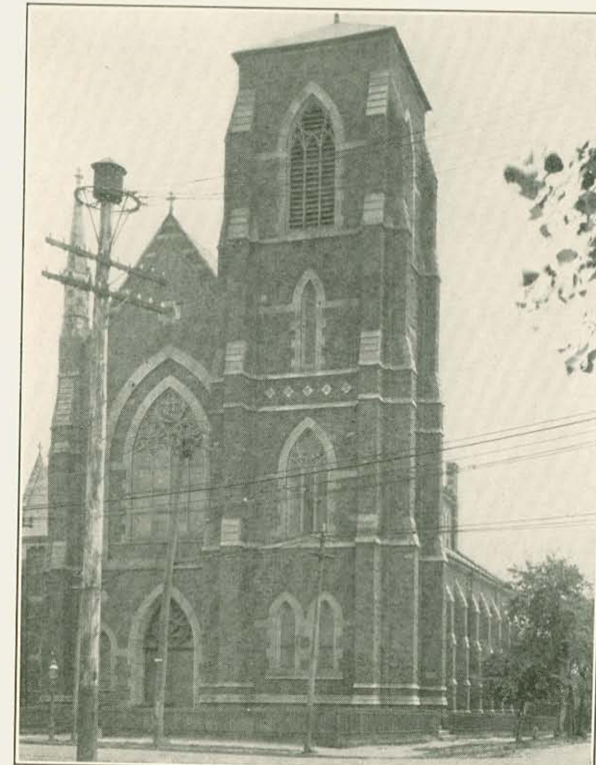
BY R. B. GAGE, CHEMIST OF THE SURVEY.

SiO_2	75.02	CO_2	0.11
Al_2O_3	13.73	TiO_2	0.10
Fe_2O_3	0.83	ZrO_2	0.05
FeO	0.99	P_2O_5	0.04
MgO	0.03	SO_3	0.08
CaO	0.88	MnO	0.04
Na_2O	3.36	BaO	0.06
K_2O	4.74		
H_2O	0.17	Total	100.23

PLATE VIII.



1. WATERLOO GRAY GRANITE-GNEISS
St. Peter's Church, Morristown.



2. PALISADE TRAP ROCK.
St. Patrick's Church, Jersey City.

The rock is to be classed as a sodipotassic toscanase, or *toscanose,* the position of which in the quantitative classification is shown by the symbol I.4.2.3.

WATERLOO LIGHT-GRAY GRANITE-GNEISS.—Another quarry of the North Jersey Stone Company is located on the railroad 2 miles north of Waterloo. The rock is a fine-grained granite, nearly white, with white and pale-pinkish feldspar and quartz as the prominent constituents, and a very little dark augite. The gneissic lamination is distinct. Occasional layers of darker rock contain more augite, and some of the light-colored rock is distinctly pinkish from the greater abundance of feldspar of this color. Some coarse pegmatite also occurs. The great bulk of the stone, however, is nearly white and uniform in texture and color, these varieties appearing in only minor amounts. The gneissic lamination strikes N. 20° W. and dips eastward 32 degrees.

Microscopic and chemical characters.—The microscope shows a fine-grained interlocking gneissic texture in the light-gray stone, comprising microperthite, orthoclase, quartz, and occasional grains of augite. The darker bands contain much augite, altered in part to blue-green hornblende, with a few large grains of titanite and minute crystals of apatite.

Chemically this rock is almost identical with that from the Allen quarry near Waterloo, described above, there being only a slight variation in the relative amounts of alumina and ferric iron.

Analysis of Granite-Gneiss from Quarry Two Miles North of Waterloo.

BY R. B. GAGE, CHEMIST OF THE SURVEY.

SiO_2	75.15	TiO_2	0.12
Al_2O_3	14.65	ZrO_2	0.01
Fe_2O_3	0.11	P_2O_5	0.02
FeO	0.90	SO_3	0.12
MgO	0.04	MnO	0.01
CaO	0.92	BaO	0.05
Na_2O	3.60		
K_2O	4.71	Total	100.64
H_2O	0.24		

The close resemblance of this stone to that from Waterloo (Allen quarry) is further shown by the fact that they both fall into the same place in the quanitative classification; that is, both are sodipotassic toscanase, or *toscanose,* and are represented by the symbol I.4.2.3.

CRANBERRY LAKE WHITE GRANITE-GNEISS.—The D. L. and W. Railroad quarry (Plates VI and IX), 1 mile south of the station at Cranberry Lake, is in a fine-grained white to very light-grayish granite, through which are sprinkled small pink-colored garnet crystals. The stone is somewhat gneissic, but the absence of colors renders this structure almost invisible, and it seems to be quite massive, except on close inspection. Joints parallel to the gneissic lamination gives rise to bed-like layers that dip 30 degrees toward the northeast (strike N. 30° W.). Occasional small flakes and clusters of black mica are seen. There is a little coarse pegmatite also in which feldspar greatly predominates, with a little quartz and larger, darker-colored garnets.

There is a spur track from the railroad and the quarry is equipped with a steam engine, derricks, etc.

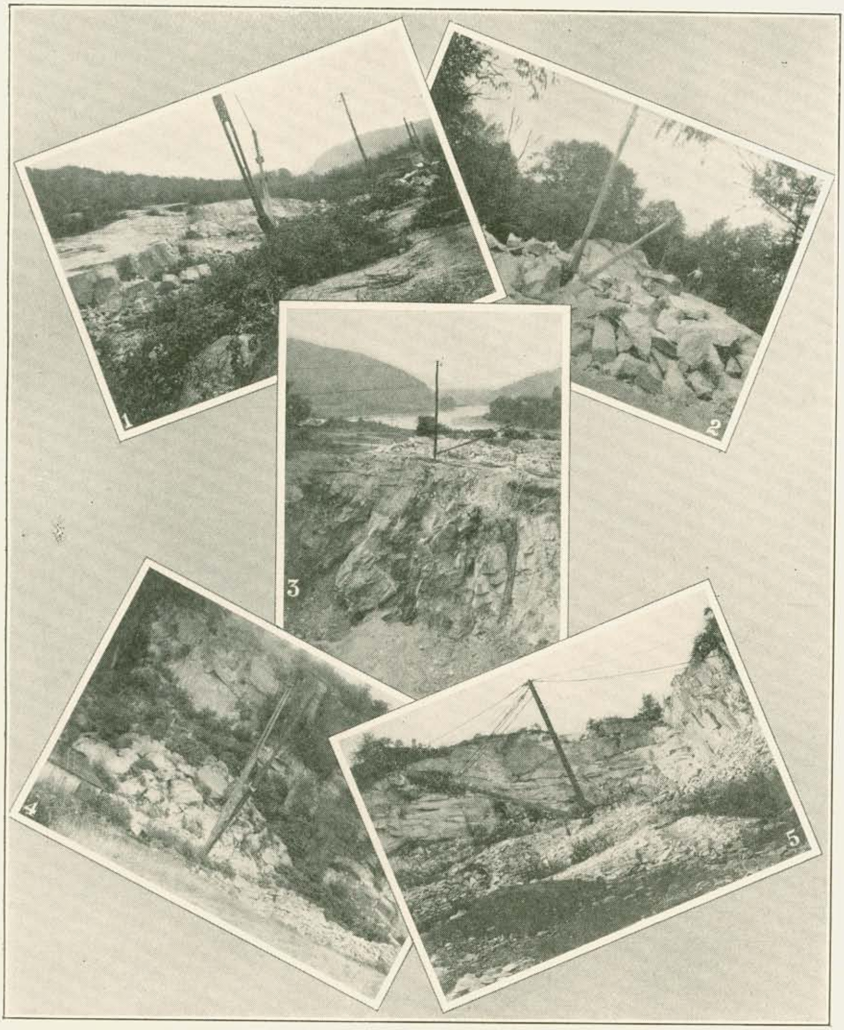
Microscopic and chemical characters.—The texture is fine-grained granitic. The constituent minerals are quartz, orthoclase, plagioclase, occasionally shreds of biotite and muscovite and scattering pinkish garnet crystals. The garnets are quite minute, being only about one-fourth the size of the other minerals.

Analysis of White Granite-Gneiss, D. L. & W. R. R. Quarry, One Mile South of Cranberry Lake.

BY R. B. GAGE, CHEMIST OF THE SURVEY.

SiO_2	74.70	TiO_2	0.07
Al_2O_3	15.45	ZrO_2	0.04
Fe_2O_3	0.08	P_2O_5	0.03
FeO	0.64	SO_3	0.05
MgO	0.06	MnO	0.05
CaO	1.70	BaO	0.07
Na_2O	4.00		
K_2O	2.62	Total	100.52
H_2O	0.10		

PLATE IX.



1. Jersey Pink Granite Co.'s Quarry, Pompton Junction.
2. H. L. Brown Co.'s Granite Quarry, Pompton.
3. Warne's Quarry—Serpentine and Ophicalcite, Phillipsburg.
4. Panther Hill Granite Co.'s Quarry, Cranberry Lake.
5. D., L. & W. R. R. Co.'s Quarry, Cranberry Lake.

Occasional coarse-grained streaks and spots are also encountered, but the waste from this cause is small.

Brainerd Hall at Lafayette College, Easton, Pa. (Plate VII) and residences in the vicinity of the college have been built of this stone and it would also seem to be well adapted to monumental work.

Microscopic and chemical characters.—Under the microscope thin sections of the stone show a typical granitic texture. The minerals found are quartz, with orthoclase and plagioclase feldspar, sometimes in micropegmatitic intergrowths, and scattering grains of dark-green hornblende. Occasional crystals of zircon, pyrite and apatite are also found.

Notwithstanding its uniform pearl-gray color, this rock resembles in chemical composition the white granite-gneiss of the D. L. & W. quarry south of Cranberry Lake, as shown by the following analysis. The lower silica and alumina and the higher iron and potash are notable differences, but both are quite high in soda as compared with potash.

Analysis of Gray Granite from Kice's Quarry, German Valley.

BY R. B. GAGE, CHEMIST OF THE SURVEY.

SiO_2	68.60	TiO_2	0.60
Al_2O_3	14.72	ZrO_2	0.01
Fe_2O_3	4.29	P_2O_5	0.16
FeO	1.41	SO_3	0.18
MgO	0.38	MnO	0.04
CaO	1.46	BaO	[1]0.18
Na_2O	4.82		
K_2O	3.52	Total,	100.33
H_2O	0.16		

The resemblance in the analyses above referred to is further emphasized by the fact that, in the quantitative system of classification, both rocks are *lassenose,* and their position is shown by the symbol I.4.2.4.

Another quarry was formerly worked in the same rock across the brook to the north. The outcrops here form prominent cliffs,

[1] Tests were also made for Ni, Co, Cu, and Zn, but none was found.

The rock is a dosodic toscanase, *lassenose,* and its position in the quantitative system of classification is shown by the symbol I. 4. 2. 4. Among the analyses given on the preceding pages, this most closely resembles that of the Waterloo stone but it is notably higher than the latter in soda, lime, and alumina, and lower in potash.

CRANBERRY LAKE GRAY GRANITE-GNEISS.—The quarry of the Panther Hill Granite Company is located just west of the station at Cranberry Lake in the high cliff overlooking the railroad. The rock is a coarse-grained gray gneiss, consisting of white and grayish feldspar and quartz, through which streaks and lines of black hornblende are evenly disseminated. There is no distinct lamination and the rock is very massive and solid. The working face of the quarry is at least 100 feet high and the cliffs rise steeply far above it (Plate IX). There is a spur track from the railroad and the quarry is equipped with steam derrick.

Microscopic characters.—The microscope shows a rock of massive gneissic texture in the main, consisting of quartz, orthoclase, microcline, microperthite, plagioclase, and dark yellowish-green hornblende.

GERMAN VALLEY GRAY GRANITE.—Lyman Kice's quarry (Plates VII and X) is three-quarters of a mile north of the railway station at German Valley, on the eastern crest of Schooley Mountain. The rock is a granite of medium-coarse texture and uniform gray color. The color is the natural tint of the feldspar and quartz, which constitute the bulk of the rock, and is not due to an admixture of black and white minerals, as is usually the case with gray granites. Only occasional grains of black hornblende and magnetite can be seen by the unaided eye. The system of jointing gives bed-like layers 3 to 15 feet thick, with cross-joints 1 to 10 feet apart, so that large blocks are readily obtained. A slight gneissic structure can sometimes be seen in the direction of the chief joints; that is N. 50° E., and dipping 60 degrees to the southeast.

The stone at the top of the quarry is discolored along the joints to a depth of 15 to 20 feet. The present working face shows 20 feet of fresh sound stone below this, with only occassional "sap" of 1 or 2 inches along some of the prominent joints.

1
GERMAN VALLEY GRAY GRANITE
(NATURAL SIZE AND COLOR)

A. HOEN & CO. BALTIMORE.

2
WATERLOO PINK GRANITE-GNEISS
(NATURAL SIZE AND COLOR)

and the quarry face is much higher; but the stone is more closely jointed, which interferes with the extraction of large blocks and has allowed the discoloring effects of surface waters and weathering to penetrate to greater depth. A heavy ledge which outcrops in the brook forms a waterfall of considerable height.

GERMAN VALLEY LIGHT-GRAY GRANITE-GNEISS.—Another of Lyman Kice's quarries, also on the eastern crest of Schooleys Mountain, is three-quarters of a mile west of the station at German Valley. It is in light-gray fine-grained gneiss with distinct but not prominent foliation. It is composed essentially of white feldspar and quartz, speckled with dark grains of hornblende. Sometimes darker hornblendic bands are developed, and there are occasional patches of coarser granite with large black hornblende. The foliation dips 60 degrees southeastward (strike N. 60° E) and the stone splits readily into sheets varying from a few inches to 2 feet thick. Horizontal joints are 3 to 10 feet apart and vertical cross-joints are at intervals of 10 feet or more. The quarry face is about 40 feet high, and there is practically no soil stripping or waste on account of "sap" or discolored surface rock. One of the bridges over Carnegie Lake at Princeton is faced with this stone (Plate VII).

Microscopic and chemical characters.—When examined in thin section under the microscope the rock shows a medium-grained gneissic texture, composed of quartz, orthoclase, microperthite, and dark-green hornblende, with scattering grains of magnetite and a few small crystals of apatite. The darker bands show a considerable increase in the proportions of hornblende and magnetite with occasional crystals of pyrite.

Analysis of Light-Gray Gneiss, Kice's Quarry, German Valley

BY R. B. GAGE, CHEMIST OF THE SURVEY.

SiO_2	75.17	TiO_2	0.31
Al_2O_3	12.55	ZrO_2	0.05
Fe_2O_3	1.54	P_2O_5	0.04
FeO	1.41	SO_3	0.02
MgO	0.21	MnO	0.04
CaO	1.15	BaO	0.10
Na_2O	3.07		
K_2O	4.62	Total,	100.50
H_2O	0.22		

Chemically this stone is much like those from the two quarries north of Waterloo, described above, differing only in somewhat lower alumina and alkalis and higher lime, magnesia and iron. In these respects it stands between the Waterloo stones and the gneiss inclusions in the pink granite at Pompton Junction. It is to be classified as *tehamose*, the sodipotassic alsbachase, I.3.2.3.

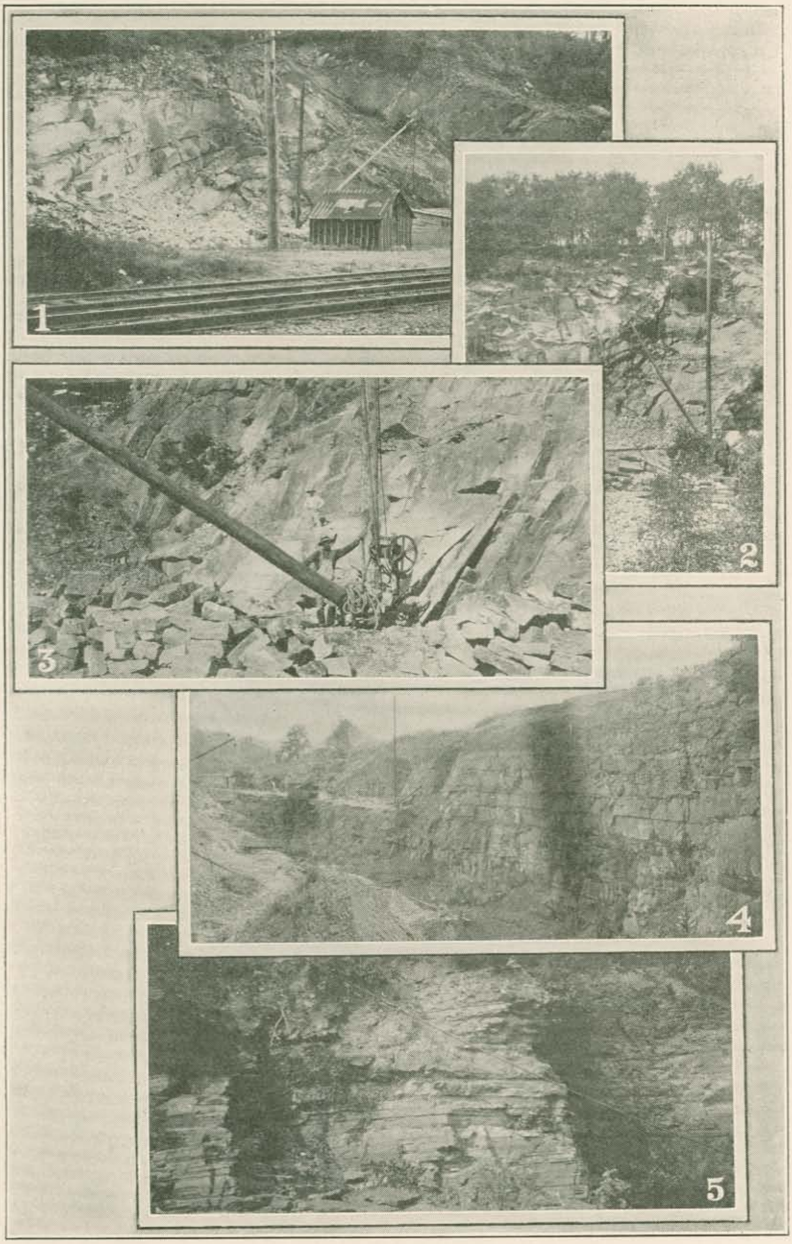
A larger quarry was formerly worked in a similar rock one-quarter of a mile north of the German Valley station at the mouth of the gorge of a small brook. The quarry face, 40 to 50 feet high, shows considerable jointing and rather heavy waste from discolored or "sap" rock.

PORT MURRAY COARSE GRAY GRANITE.—An old quarry on the hillside just north of the village was worked extensively for railroad construction a generation ago. The stone is a coarse-grained pegmatitic granite, gray to grayish-pink in color, with a slightly developed parallel structure and somewhat variable in texture. It has much quartz, pale-pinkish feldspar, and little dark-colored mineral.

Microscopic characters.—Under the microscope the feldspars are found to be orthoclase, microcline, and microperthite, with some micropegmatitic intergrowth with quartz, and a little augite altering to green hornblende.

TOWNSBURY GRAY GRANITE-GNEISS.—Marcus Garrison's quarry, which has been worked but little, is located one-half mile south of Townsbury (down the Pequest River) at the foot of the steep rocky slope of Mount Mohepinoke. The stone is a medium coarse-grained light-gray granitic hornblende-gneiss, much like that at the north end of Cranberry Lake and of quite uniform texture and color. Occasional coarser streaks are seen, but they do not appear to be common. Bare rock ledges and large loose blocks are common on the mountain slope, and a quarry could be opened at small expense.

Microscopic characters.—The microscope shows coarse and fine interlocking grains of quartz, orthoclase, microcline, and microperthite with smaller amounts of dark-green hornblende and black magnetite grains. Small crystals of apatite and zircon are occasionally seen.



1. Thos. Fanning's Quarry, Granite Gneiss, Dover.
2. North Jersey Stone Co.'s Quarry, Granite Gneiss, Mt. Arlington.
3. Lyman Kice's Granite Quarry, German Valley.
4. John VanDorn's Brownstone Quarry, Passaic.
5. Flagstone Quarry, near Milford.

BEEMERVILLE GRAY SYNEITE.—Although no quarrying has been done, a medium to coarse-grained granitic rock (a nephelite-syenite) of pleasing gray color and well suited to the purposes for which granite is generally used, occurs 1.5 miles north of Beemerville, on the eastern slope of Kittatinny or Blue Mountain 5 miles northwest of Sussex. It consists of coarse gray nephelite and feldspar in very variable proportions and speckled with black mica and pyroxene. It appears as a huge dike or intrusive mass between the slate and the conglomerate of the mountain, and forms an area 2 miles long and about one-quarter of a mile wide. Referring specially to the possible use of the stone for building and monumental purposes, Dr. J. E. Wolf[1] made the following report of its qualities:

The fact, however, that the nearest railroad is several miles distant makes the development of this rock practically impossible at present.

"There has been no attempt to quarry the rock, and it is difficult to form an adequate idea of its value from the surface. Judging from the specimens attainable with the hammer it would form a very handsome, massive building stone, of a gray or dark-gray color, which would dress well. The rock is composed of orthoclase feldspar, nephelite, pyroxene and some biotite as essentials, and differs from granite mainly by the absence of quartz and presence of nephelite (elaeolite). Studied in thin slices in the microscope the minerals are remarkably fresh, showing little change.

"The only similar rock used extensively as a building stone is that of Arkansas, especially from Fourche Mountain, near Little Rock. This elaeolite-syenite, which is gray or blue-gray, has been extensively quarried both for building stone, paving blocks, and road material, and has been used in a number of buildings in Little Rock and other cities. Its durability, hardness and toughness stand high in the scale. It is quite similar in appearance to the light-gray rock of Beemerville.

"Owing to the absence of any deep openings in the rock, and consequent inability to judge of other important qualities, such as structure of the rock, joints, rift, etc., which are so important in quarrying, we can only say that the rock promises well on the surface. One of the best places for development as at present exposed is in the middle of the mass where the old road crosses the mountain. There is a cliff here of the light-gray variety.

"The situation of the mass of the rock for quarry operations is excellent, since quarries opened at the east foot of the ridge will have a natural face to work into, with good drainage, room for the disposal of the waste rock, and a down-grade to the road."

[1] Ann. Rep. State Geologist of New Jersey for 1896, pp. 92, 93.

Microscopic and chemical characters.—The microscope shows it to consist chiefly of orthoclase and nephelite in about equal amounts, the latter mineral often enclosed in the former. The feldspars are often an inch or more in length. There are smaller amounts of deep reddish-brown biotite, bright-green pyroxene (aegirite) and scattering crystals of magnetite, pyrite and titanite. The minerals are usually quite fresh, but the nephelite is in part altered to cancrinite. Petrographic studies of this rock have been made by Prof. Kemp[1] and Dr. Wolff[2], from whose descriptions the following analyses are quoted.

Analyses of Nephelite-Syenite, 1.5 miles north of Beemerville.

	I.	II.	III.
SiO_2	53.56	50.36	41.37
Al_2O_3	24.43	19.34	16.25
Fe_2O_3	2.19	6.94	16.93
FeO	1.22	....	....
MgO	0.31	....	4.57
CaO	1.24	3.43	12.35
Na_2O	6.48	7.64	4.18
H_2O	0.93	3.51[3]	0.45[3]
K_2O	9.50	7.17	3.98
MnO	0.10	0.41	....
	99.96	98.80	100.08

I. Nephelite-syenite, Beemerville mass. (Franklin Furnace Folio, p. 13).

II. The same (Trans. N. Y. Acad. Sci., XI., p. 60), northern part.

III. Basic dike (ouachitite), in southern part.

Analyses I and II in the preceding table show variations in the main mass of the rock, which appear under the microscope in the varying proportions of orthoclase and nephelite, sometimes one and sometimes the other greatly preponderating. No. III is a basic intrusion in the form of a dike, which came into a fissure in the main mass at a later period. Using the first analysis as

[1] J. F. Kemp, Trans. N. Y. Acad. Sci, XI., 1891-2, pp. 60-71.
[2] J. E. Wolff, Geol. Atlas of New Jersey, Franklin Furnace Folio, 1908, p. 12.
[3] Loss.

the basis of classification the rock is *beemerose,* a sodipotassic miaskase named for this locality. No. II is distinctly more basic and goes over into Class II of the quantitative classification, probably representing a sodipotassic vulturase, although the analysis is incomplete and the classification to that extent uncertain.

GNEISS FOR CRUSHED STONE.—At a number of places in the Highlands, besides those described above, gneisses are quarried and crushed for concrete, railroad ballast, macadam, etc., only. The dark hornblendic variety is chiefly used, since it is tougher and more nearly resembles the trap rocks, which are so widely used for such purposes. The gneisses, however, consist of interlaminated light and dark-colored sheets in varying proportions, and in the quarries for crushed stone there is often great variation in both color and texture, with the darker hornblendic stone usually predominating. Such quarries are those of Colfax and Steele, one-half mile west of the railroad station at Pompton; J. P. Lange, at Haskell; the D. L. and W. Railroad quarry at Montville (Hog Mountain), 2 miles northeast of Boonton; those of P. Lubey and the city of Morristown, in the western border of Morristown. Crushed stone is also produced at some of the quarries described above, thus providing a use for much broken stone that would otherwise be wasted.

TRAP ROCKS (DIABASE AND BASALT).

Full descriptions of the trap rocks of the Triassic or Newark formation across the central part of the State have been published in Annual Reports of the State Geologist for 1906 and 1907.[1] These descriptions deal with the stone from the geologic and petrographic standpoints, and from the economic also so far as its use in road construction is concerned, and reference should be made to them for detailed information on these subjects.

Besides areas in the Triassic, dikes of trap rock also occur in the gneisses of the Highlands. One of these is worked at Trim-

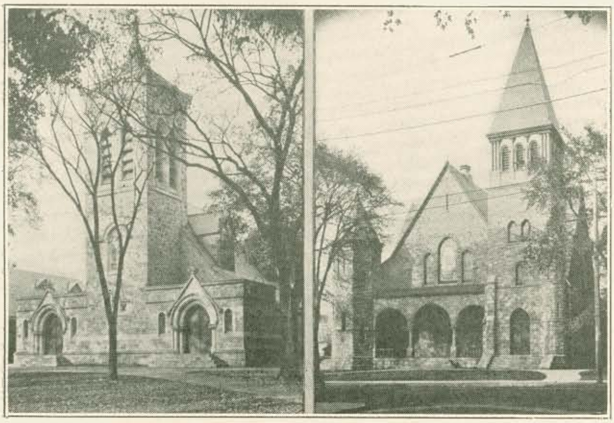
[1] J. Volney Lewis, Ann. Report State Geologist of New Jersey for 1906, pp. 97-172; Ann. Report for 1907, pp. 97-167.

mer's quarry, 4 miles southwest of German Valley, near Middle Valley, for crushed stone. Other localities are known but they have not been quarried yet.

Trap rock was formerly used for building purposes also, as many important buildings in Jersey City, Hoboken, West Hoboken, Paterson and other places testify. In many cases the trap alone was used, but often it was combined with trimmings of brownstone or granite, and some very satisfactory results were attained. (Plates VIII, XII and XIV.) In general, however, the color effects were somber, and this consideration, together with the difficulty and expense of working a stone of such great hardness, toughness and weight, has led to its practical abandonment for building purposes. It still continues to be employed locally, however, for foundations, and great quantities of it now enter into both engineering and architectural construction in the form of concrete.

While such purposes as those just enumerated will doubtless continue to be the chief uses of the trap rock, there would seem to be a legitimate field for the introduction of certain varieties in the form of dimension stone and even for faced and polished work in general building. This refers particularly to the gray coarse-grained granitic types which constitute a considerable proportion of the rock of the Palisades and the westward continuation of the same great sheet in Rocky Hill and Sourland Mountain. Much of this stone exhibits the colors and texture of the specimen shown in Plate XIV, and some of it is of even lighter shades. Useful combinations could doubtless be made with such trap rock and some of the gray granite or other stone of such colors as would afford a pleasing contrast.

The cost of working into shape, of cutting, and possibly of polishing will doubtless interfere to a certain extent with any general use of trap rock in building, but such objections apply with less force to its application to monumental purposes. For such uses it would seem to be particularly well suited. It polishes well, will doubtless give clear, distinct results for lettering or ornamental work on polished faces, and is a very hard and durable stone. Great surface bowlders of it have been quarried for this purpose, as well as for general building, at Rock Church,

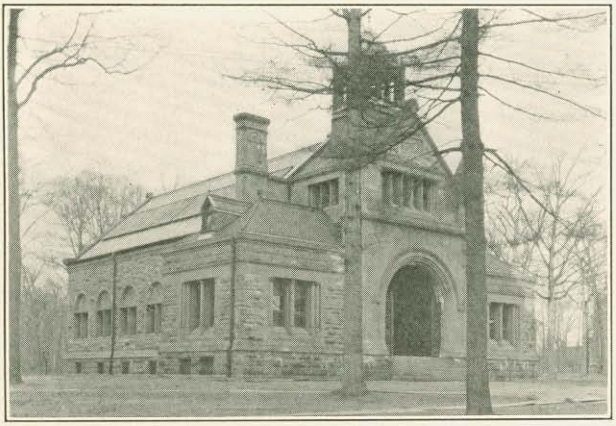


1. MARTINSVILLE GRAY SANDSTONE.

Reformed Churches, Somerville.

2. CONGLOMERATE.

Cornell Library. Drew Theological Seminary, Madison.



3. PALISADE TRAP.

St. Michael's Monastery, West Hoboken.

4 miles east of Lambertville, and similar stone is available at many places in the trap areas.

Large quantities of this stone have also been used in the manufacture of Belgian blocks for paving purposes.

SANDSTONE AND CONGLOMERATE.

Sandstones occur in many parts of the State and in a great variety of formations. (1) Brown sandstone, or brownstone, and also gray and white sandstones occur abundantly in the Triassic belt across the central part of the State (Plate II). (2) Conglomerates and sandstones are plentiful in the Kittatinny Mountain region and in the belt southwestward from Greenwood Lake. (3) White to gray sandstone or quartzite (Hardyston) is less abundant beneath the Kittatinny limestone of the northwestern counties. (4) Even the sands and gravels of the Tertiary formations in the southern portion of the State are sometimes consolidated into stone that has been used for building. (5) The hard reddish, purplish and bluish-gray argillites that are quarried at Princeton, Lawrenceville, and Byram, are described under this heading, although strictly speaking they are dense siliceous mud-stones. (6) Thin-bedded sandstones that are suitable for flagging, curbing, etc., and are known as flagstone, have been quarried in parts of Hunterdon, Warren, and Sussex counties.

The chief commercial sources of sandstone have very naturally been the Triassic belt of red shale, sandstone and trap rock. This area is in the smoother middle section of the State and also near the great centers of population where the stone finds its chief market. Of the former widespread uses of brownstone and its later decline in popularity in favor of materials of lighter colors, nothing need be said beyond the statements made in the introduction to this paper.

WHITE AND GRAY SANDSTONE.

A further word of emphasis, however, deserves to be said concerning the *white* and *gray* sandstones that occur in many places from the Delaware to the Hudson. Various localities at which such stone has been quarried in recent years, most of them still actively worked, are described below. In all of them the lighter tones of color prevail, with shades varying from gray to almost snowy whiteness. In all cases the stone contains large proportions of white feldspar in addition to quartz, constituting the variety of sandstone known as arkose, and the light color is chiefly due to the snowy whiteness of the feldspar grains.

In many places, particularly where the stone is obtained below the water level, it is cut to dimensions, faced or carved with great facility when freshly quarried, and becomes much harder and whiter as the "quarry-water" dries out. This increase in hardness is permanent, and such stone should always be cut at the quarry when fresh, both on account of the lower cost and the greater durability of the structure. In general these gray and white sandstones are somewhat harder and more durable than the softer oolitic and fragmental limestones which they so much resemble, but the advantage of this should offset the slight additional difficulty in working, not to speak of their nearness to the markets of the eastern cities and the availability of both railroad and water transportation in many cases.

Closter Light-Gray Sandstone.—Six miles north of Englewood and 1.5 miles east of Closter, on the back slope of Palisade Mountain are several quarries in the white and light-gray, medium to coarse sandstone. These are operated by Julius Gambellee, Taverniere and Johnson, Cæsar Campanini, and William Tate, the stone being practically identical in all. The workable beds vary from 4 to 12 feet in thickness, and have a gentle westward dip, following the slope of the hill, with very little surface soil or other stripping to remove.

The stone has much white feldspar, as well as quartz sand, and is, therefore, a typical arkose. The texture is usually rather coarse, becoming pebbly at some places, but the stone is firm and hard and possesses a very desirable color.

Ridgefield Light-Gray Sandstone.—Heisenbuttle's quarry is one-half mile east of the railroad station on the west side of Montgomery street, Ridgefield. The stone is a medium coarse-grained, white to light-gray sandstone, in layers 3 to 6 feet thick, with interbedded shales from 1 to 3 feet in thickness. A stripping of bouldery drift 10 feet thick covers the surface. The beds dip westward 8 to 10 degrees (strike N. 25° E.)

Stephen V. R. Martling's quarry, a new one, adjoins Heisenbuttle's immediately to the south and is in the same beds, which are from 6 to 8 feet thick, with a drift covering from 3 to 6 feet. A 30-foot face has been developed, and steam power is used for drill and derrick.

In both of these quarries at Ridgefield, the joints are sufficiently close to make quarrying easy, but not too close to interfere with the production of desirable sizes for building. The joint cracks are usually stained red and there are spots and mottlings of the same color in some of the coarser portions of the stone.

WATCHUNG GRAY SANDSTONE.—W. E. Bartle's quarry, one-half mile northeast of Watchung, and 2 miles north of Plainfield, is in a medium-grained gray sandstone similar to that at Martinsville, which occurs in a heavy massive bed 15 to 20 feet thick. Red shale covers it to a depth of about 15 feet. The bed dips 12 degrees northwest and is broken by joints 3 to 10 feet apart (strike N. 50° E.). The quarry is operated by the aid of a steam derrick.

Very near the post-office an old quarry formerly produced both brown and gray sandstone, the beds being separated by more or less red shale. Small faults occasionally offset the beds, and there is an overburden of drift 5 to 10 feet thick.

Other small quarries here and at Springdale and Warrenville and other places in Washington Valley have been worked from time to time to meet local needs, both brown and gray stone being found in different beds.

MARTINSVILLE GRAY SANDSTONE.—W. E. Bartle's quarry of fine-grained gray sandstone at this place is also in Washington Valley, 3 miles northwest of Bound Brook, and one-half mile southwest of the village of Martinsville. The stone is sprinkled with scattering scales of white mica and is in part finely laminated on close inspection. Occasional small brown specks occur where minute crystals of pyrite have oxidized. In parts of the quarry a considerable covering of soil and shale has to be removed.

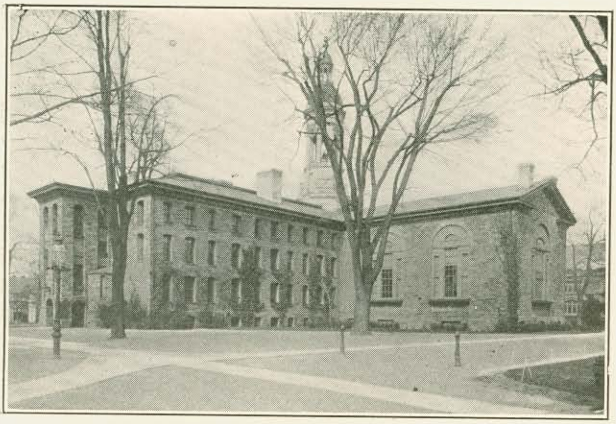
Microscopic characters.—The microscope shows the rock to be composed chiefly of quartz, but it also contains considerable amounts of feldspar (both orthoclase and plagioclase) with more or less iron-stained clay between the grains and occasional flakes of white mica. The feldspars are partly altered to opaque kaolin.

Several churches in Somerville have been built of this stone with very satisfactory results (Plate XII).

PLUCKEMIN GRAY AND BROWN SANDSTONE.—One mile east of the village of Pluckemin, a quarry has been considerably worked in alternating beds of gray and brown sandstone. There is a covering of 15–20 feet of shale and thin-bedded sandstone above, and some of the layers show small amounts of conglomerate.

PRINCETON YELLOWISH-WHITE SANDSTONE, creamy white and gray sandstone outcrops boldly in a line of steep slopes and bluffs overlooking Carnegie Lake at the foot of Broadmead near Princeton. At several other places in the vicinity, the stone has been quarried and also along the Delaware and Raritan Canal on the opposite side of Millstone River. The older buildings of both the University and the Theological Seminary at Princeton were built of this stone, and it has been used recently in a number of attractive residences in the same place (Plate XIII). This stone is not notably feldspathic nor so white as that at Closter, Stockton, or Raven Rock. The beds dip 16 degrees toward the northwest (strike N. 65° E.) and are sometimes separated by soft shale or sandstone that disintegrates too readily to be serviceable in building.

WILBURTHA LIGHT-GRAY SANDSTONE.—Quarries in light-gray sandstone are operated here by Peter De Flesco and by Charles De Grave & Bro. The beds range from less than a foot in thickness to 12 or 15 feet, with interbedded thin sheets of soft red shale. They dip about 15 degrees to the north (strike N. 80° W.). Some of the minor beds are brownstone, very fine grained and chocolate colored, but the chief product is light-gray and very feldspathic (arkose) similar in many respects to that quarried at Closter, Stockton, and Raven Rock. The

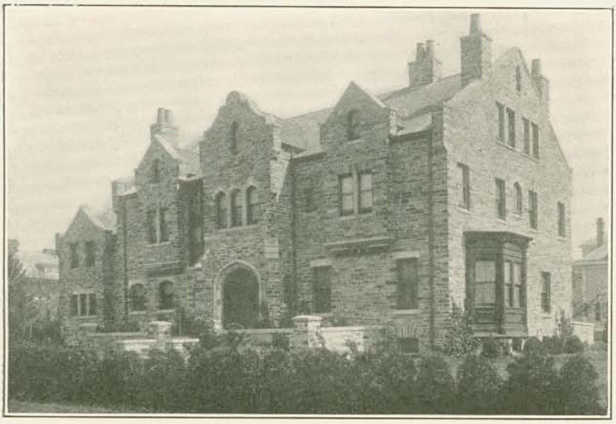


1. PRINCETON SANDSTONE.

Nassau Hall, Princeton University (1756).

2. PRINCETON SANDSTONE.

Residence of Wm. Libbey, Princeton.



3. PRINCETON ARGILLITE.

Residence at Princeton.

surface stripping of soil and shale varies from 5 to 20 feet in thickness. Massive sandstone beds 12 to 15 feet thick in one quarry and 30 to 40 feet in the other are quarried, with little interbedded shale or other waste rock.

Both of these quarries are equipped with steam-power drills, derricks, etc. These and a number of others in the vicinity have been worked extensively in the past, and are capable of producing much more than their present output.

Microscopic Characters.—In the gray stone the microscope shows a medium coarse-grained quartz and feldspar aggregate, the latter consisting of both orthoclase and plagioclase and occurring in considerable amounts. There is very little clay or iron stain, although the feldspars are considerably changed to kaolin. The brownstone is a fine-grained quartz rock with much calcite and red iron oxide between the grains, and frequent shreds of white mica.

STOCKTON LIGHT-GRAY SANDSTONE.—The S. B. Twining Company quarries at Stockton produce a medium-grained creamy-white to gray sandstone, the latter on close inspection often showing fine lamination with almost universal cross-bedding, and both are usually quite uniformly speckled with small brown dots. (See Plates XIV and XV.) Small crystals of pyrite are sometimes seen, both fresh and partly altered to brown hydroxide, which suggests a similar origin for the prevailing brown dots referred to above. There are occasional coarser streaks encountered, which sometimes run into conglomerate and breccia with large angular pieces of black argillite. The beds dip 13 degrees northwest (strike N. 50° E.). Joints are well developed at right angles to the stratification and coinciding approximately with the strike and the dip.

The quarries that are operated here are equipped with steam-power appliances. Many old quarries in the vicinity have been worked extensively.

Microscopic characters.—On examination with the microscope the light-gray varieties are found to contain chiefly quartz and feldspar, the latter sometimes composing as much as one-half of the rock and being always partly clouded with secondary kaolin.

There are frequent patches of granular calcite between the other minerals, and yellow spots from the rusting of small crystals of pyrite. The dark angular shale inclusions are found under the microscope to be of a fine-grained sandy variety.

Raven Rock Light-Gray Sandstone.—The quarries at this place produce a light-gray to almost white sandstone, similar to the lightest colors at Stockton, but more uniform in texture. There is no coarse conglomerate and lamination is very indistinctly seen. The gray sandstone forms beds about 10 to 15 feet thick, alternating with brownstone beds of similar dimensions. In a smaller quarry, near the principal one, a uniform light-gray stone forms a massive bed 20 feet in thickness. The quarries are provided with hoisting engines, derricks, etc.

The quarries at Wilburtha, Stockton and Raven Rock have adequate shipping facilities both by rail (Penna. R. R.) and water (Delaware & Raritan Canal feeder).

The Hardyston Sandstone or quartzite, which underlies the Kittatinny limestone, as explained above, ranges from a very fine-grained grayish and steel-blue to a coarse-grained and nearly white rock. In places it becomes pebbly, but this is exceptional. It is usually more or less feldspathic, and the coarser-grained varieties with their distinct quartz and feldspar constituents look much like granite. "It has been quarried at Oxford Furnace, near Danville (now Great Meadows), at Franklin Furnace, and in the Pohatcong Valley near Washington. It occurs in regular beds and is generally soft enough to dress readily, although at some localities it is very hard. The bedding and the joints serve to make it work out in rectangular blocks. A locality near Beattystown was observed * * * where it was to be had in heavy and very regular blocks on the surface. It has not been fully appreciated as a building stone because of the very narrow and limited extent of its outcrops, which are rarely near railroad or canal lines." [1]

Many old buildings constructed of this stone are to be found about the places named above, but no quarries have been worked in it for a great many years.

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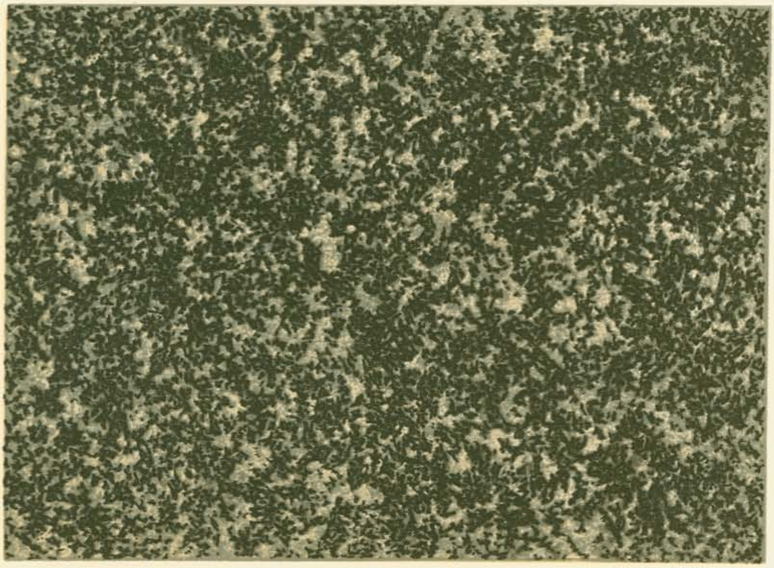
[1] Ann. Report State Geologist for 1881, p. 42.

1
STOCKTON SANDSTONE
(NATURAL SIZE AND COLOR)



A. HOEN & CO. BALTIMORE

2
LAMBERTVILLE TRAP-ROCK (DIABASE)
(NATURAL SIZE AND COLOR)

Light to dark-gray sandstone occurs associated with the conglomerates in the region about Newfoundland, and small quarries were operated in them several years ago. In general characters it is much like the Hardyston sandstone described above, except that it is not notably feldspathic in composition.

RED AND BROWN SANDSTONE (BROWNSTONE).

Brownstone, which is described next in order is too well known from its extensive use in the cities of the eastern and central States to require further special comment (Plates XV and XVI). In the early days this stone was used locally in many parts of Bergen, Passaic, and Essex counties, and a number of farmhouses and other buildings of it are still in good repair after two centuries or more. In later structures, which are found in such great numbers in the larger cities, the stone has often given trouble, either because inferior material has been used, or, as has more frequently happened, the blocks have been placed in the wall in the worst possible position; that is, they have been set edgwise, with their bedding planes vertical, so that serious scaling from frost action has often resulted. In most cases the same stone placed in its natural attitude, with the bedding planes horizontal, would have shown less disintegration in a century than they have actually suffered in a generation.

Where the stone has been properly selected and properly laid its lasting qualities are well established. It is still quarried at a number of places, chiefly in a small way, and used in foundations for buildings of all kinds, for window-sills, and other parts of brick buildings, and also in various combinations with other varieties of stone. Public and semi-public buildings are also still constructed of this stone, although not so frequently as formerly.

The red and brown-colored sandstones are usually of fine to medium-grained texture, although they also become pebbly and pass into conglomerates in places. On the whole, however, they are of finer texture than the lighter-colored stone. They contain more or less feldspar also, and a considerable amount of red oxide of iron, which gives the color to the stone. Often there is some clay in the finer-grained brownstones and every gradation may be found between the firm, durable stone and the worthless red shale. Sometimes the clay occurs in rounded lumps and irregular masses and strings through the more solid rock, causing considerable waste.

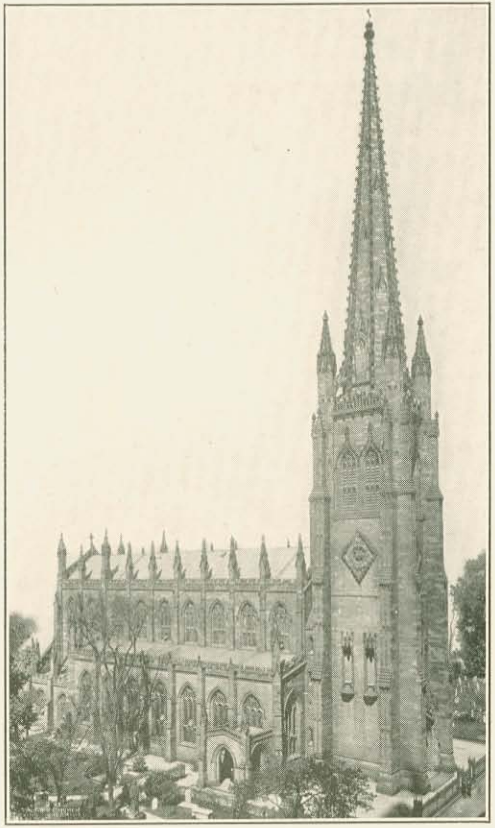
LITTLE FALLS BROWNSTONE.—Old quarries on both sides of Passaic River just below the falls at this place were formerly worked extensively. The limit of economic operation was apparently reached on the north side when the workings came under the thick overlying sheet of trap rock. On the south side the quarries extended far below the level of the river, involving the necessity of pumping. Further extension above this level would necessitate the removal of the street at the top of the bluff. Hence these quarries are not likely again to become producers of brownstone on a large scale.

A well-known example of the use of this stone in building is seen in Trinity Church, New York City (Plate XV).

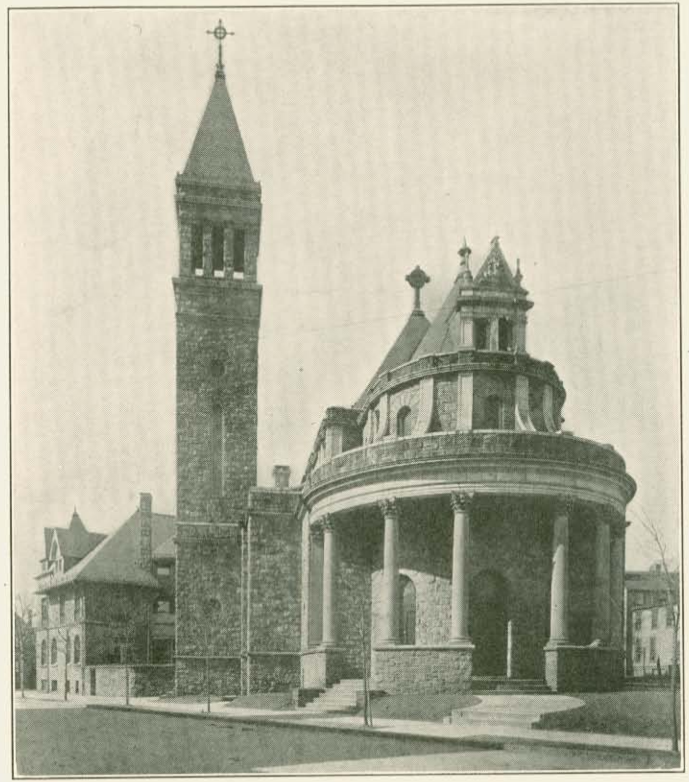
PATERSON BROWNSTONE.—A quarry is worked in the brownstone just below Great Falls on the east side of the Passaic River and beneath the floor of McKiernan and Bergin's trap quarry, which occupies the top of the high bluff. A face about 50 feet high has been developed in the brownstone beds, which vary from 1 to 8 feet in thickness, with a bed of shaly rock in the middle from 4 to 6 feet thick. In some of the strata the grain is variable, becoming pebbly in places, but most of the stone is of medium-fine texture. The trap rock overlying the brownstone has been largely removed, and there is no other stripping necessary in quarrying.

Old quarries at the foot of the cliff of Garrett Rock were once extensively worked until their operation began to undermine and bring down considerable quantities of the overlying trap rock. If it were desired to reopen these quarries they might still be worked for many years, however, in a direction parallel to the mountain (Plate XVI).

At Albion Place, 1.5 miles south of the court house in Paterson, and immediately underlying the steep trap cliffs of First Watchung Mountain, a quarry has been worked in brownstone



1. LITTLE FALLS BROWNSTONE.
Trinity Church, New York.



2. STOCKTON LIGHT SANDSTONE.
St. Columba's Church, Newark.

to a depth of about 80 feet. The stone is in massive beds up to 10 feet or more in thickness, and there is very little shale. The dip is 8 to 10 degrees northwest, and there is practically no overburden to be stripped away. Steam power is used.

PASSAIC BROWNSTONE.—One of the remaining active brownstone quarries is that of John Van Dorn, at the head of Oak Street, one-half a mile west of the railroad station at Passaic. It is a large quarry (Plate XI) with a working face 75 or 80 feet in height, made up of brown sandstone strata with little shale. The beds range up to about 10 feet in thickness. Steam power is used for drills and derricks, and a sawing plant has also been installed.

About a third of a mile southwest of Van Dorn's quarry a new one has been opened in line with Lafayette Avenue. At the time it was visited a working face about 20 feet high had been developed in good massive beds of sandstone of a dark-brown color. A covering of soil and drift 10 to 12 feet in thickness overlies the stone. Steam power is used.

UPPER MONTCLAIR BROWNSTONE.—Osborne and Marsellis's quarry in the face of First Watchung Mountain has produced both brownstone and trap rock, but only the latter has been worked in recent years. With the extensive removal of the overlying trap rock for crushing, the sandstone quarry might be easily extended, if desired. The character of the stone is similar to that at Paterson and Albion Place, described above.

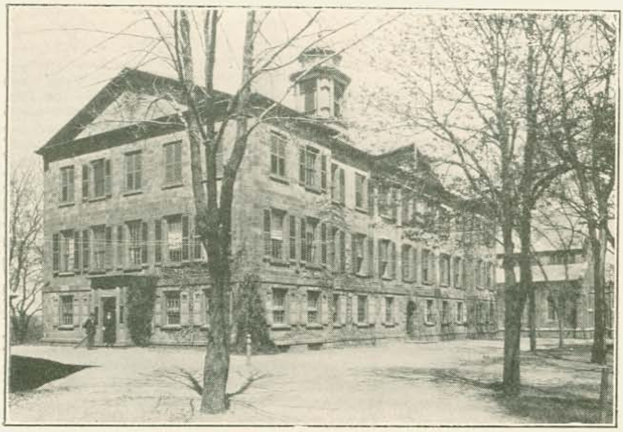
BELLEVILLE BROWNSTONE.—These famous old quarries are at Avondale, 5 miles north of Newark, on Passaic River. This has been the most widely used brownstone in the State (Plate XVI), although the quarries have now been idle for several years. It is a uniform light chocolate-brown sandstone in beds ranging in thickness from a few inches up to 6 feet or more, with occasional thin sheets of soft shale between. One such shaly layer in the old quarry is 6 feet thick, and there is an overburden of bowldery drift from 10 to 20 feet thick in the present stage of the workings. The beds dip 10 degrees toward the northwest. There are occasional gray streaks in the sandstone, with black fossil vegetable remains, and sometimes green copper stains; but these variations are insignificant in amount. As in most of the brownstone quarries, the upper layers are more broken and less solid for several feet from the surface, and most of these portions is fit only for rough foundation work, if used at all.

The quarries are provided with steam drills and a full complement of derricks, pumps, cable-ways, etc., and there is a mill fitted with sawing, planing, and rubbing machinery. When in operation, much of the stone was loaded directly into boats on the river and shipped to the various nearby cities.

PLEASANTDALE BROWNSTONE.—The quarry of F. W. Shrump and Sons is at Pleasantdale, 2 miles south of Caldwell and the same distance southwest of Montclair, on the easterly slope of Second Watchung Mountain (Plate XVII). A fine-grained light to medium-brown sandstone is quarried here in beds ranging from 4 to 15 feet in thickness. From the top downward there is a covering of drift and shale about 15 feet thick, followed by 20 feet of sandstone, 4 feet of shale, with the thickest and most massive stone at the bottom. Lamination and cross-bedding are visible in some portions of the quarry, but the best stone is quite uniform and massive. The shaly layers show ripple-marks and reptilian foot-prints.

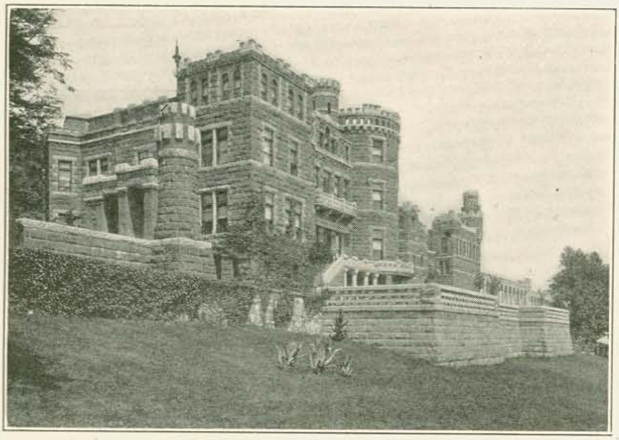
NORTH ARLINGTON BROWNSTONE.—F. A. Koch's quarry is 1¾ miles northeast of Arlington and 5 miles northeast of Newark, on the bluff overlooking the Hackensack Meadows. A heavy bed of brown fine-grained sandstone about 10 feet thick is the principal one quarried. The beds dip 12 degrees in a northwesterly direction, and therefore run deeper as the quarry penetrates the bluff. Thin-bedded sandstone with alternating layers of shale overlie the main bed to a depth of 30 to 40 feet and give rise to considerable waste-rock. Occasional green copper stains and grayish bleached streaks occur in the bedding planes and joints.

A mile south of Koch's quarry and the same distance northeast of Arlington, at the Schuyler copper mine, the "upper sandstone" of the mine, which has been quarried here at various times, is probably the same as the main bed at Koch's quarry, although here it is usually more grayish in color and shows more frequent copper stains.



1. BELLEVILLE BROWNSTONE.

Queen's Building, Rutgers College.



2. PATERSON BROWNSTONE.

Residence of C. Lambert, Paterson.

3. LITTLE FALLS BROWNSTONE.

Old Court House, Newark.

KINGSTON BROWNSTONE.—A quarry is operated beside the Delaware and Raritan Canal and the Rocky Hill branch of the Pennsylvania Railroad, 1.5 miles north of Kingston and 3 miles northeast of Princeton. The stone is a dense shaly sandstone which is quite hard and rings under the blow of the hammer. There are no coarse streaks, although some softer shale occurs and crystals of pyrite are thickly disseminated through some portions of it. This stone is somewhat intermediate between the dense brownstones, or brown sandstone proper, and the argillite of Princeton, Lawrenceville, and Byram.

From Rocky Hill northward for a mile or more small openings of quite a number of old quarries are found along the canal. The stone is chiefly a dense brown sandstone with layers of shale, and quarry sites might readily be found in favorable locations for shipment by the canal or by rail from Rocky Hill.

SOUTHERN BROWN SANDSTONE.—In many localities in the southern part of the State, where stone is generally absent altogether, certain beds of sand and gravel near the surface have been cemented by iron oxide into a stony mass of considerable hardness. Though never extensive, these indurated portions are generally distributed and have been much used for foundation walls and other rough work. It often has an attractive reddish-brown tint, is easily quarried and fairly durable, and important buildings have been constructed of it at several places with good effect. Instances of this kind, mentioned in the earlier reports of the Survey, are found about Bridgeton, Millville, Vineland, and Eatontown.

Mr. P. Kennedy Reeves, of Bridgeton, writes concerning the use of this stone in that locality: "The main building of the West Jersey Academy, at Bridgeton, is constructed of local sandstone. It was built in 1854 or 1855 and is in excellent condition. A peculiarity of this stone is that while it may be soft and liable to disintegrate when 'dug,' it hardens with age. It occurs in deposits rarely more than a few feet thick, and often only in large flakes. It is found in dozens of places within a mile or two of Bridgeton—in fact all through South Jersey * * * the foundations of practically all of our houses are composed of it. An addition to the West Jersey Academy was built about 15 years ago. When selected stones of good color and fineness are used and pointed with black cement, it makes quite a finished appearance. It is not popular for superstructure, however."

Rev. C. Graham Adams, of Eatontown, informs me that St. James' Episcopal Church of that place was erected in 1866 of local stone quarried from a hill about a mile south of the town. "The stones in the church are in as good condition as ever."

ARGILLITE.

Argillite is a massive mud-rock, which, in contrast to its usual condition, has been greatly indurated over considerable areas of Mercer and Hunterdon counties. It forms a stone of such hardness and durability that it has been long used as a building stone, particularly about Princeton and Lawrenceville, and considerable quantities of it are crushed for concrete. Old residences constructed of this stone appear to be in perfect condition, and its value has been further recognized by its recent adoption for the construction of a new dormitory—Sage Hall—to be erected at Princeton University.

New Jersey seems to be the only State in which argillite is used as a building stone, and the material is not yet known to architects, contractors, and dealers.

PRINCETON ARGILLITE.—The quarries of McCarthy Sons Company and Margerum Brothers, in the town of Princeton, produce a dense, hard, ringing argillite. It occurs in beds which split readily into flat slabs from 3 to 4 inches up to as much as 2 feet in thickness and as large as 2 by 4 feet or more in other dimensions. The joints are rather close, however, and most of the pieces are smaller than the dimensions given above.

Two distinct colors of stone occur in both quarries, the material being otherwise quite uniform in characters. One is a dark bluish-gray or slate-gray and the other is of a reddish-brown to purplish color. It is used locally both as a building stone (Plate XIII) and for foundations and rough work generally. It is also crushed at one of the quarries and used for concrete. The gray argillite has been adopted, as noted above, for the construction of the new Sage Hall, at Princeton University. Like the light-colored sandstones to the southeast of them, the beds here dip 10 to 12 degrees toward the northwest.

Microscopic characters.—Under the microscope thin sections of the rock show a dense aggregate of clay-like material sprinkled in places with minute crystale of calcite. Irregular spaces throughout the mass are filled with silica in the form of opal, and this seems to be the cementing substance that gives such hardness and durability to the stone, while the usual type of mud-stone (the red shale) in this central belt of the State is soft and quickly crumbles to mud on exposure to the weather.

LAWRENCEVILLE ARGILLITE.—At Scudder's quarry, 1.5 miles northeast of Lawrenceville, a stone similar to that at the Princeton argillite quarries is produced. The dark slate color preponderates here, although some of the reddish-brown stone also occurs. Some of the joints are filled with veins of calcite, and crystals and nodules of pyrite are found occasionally. The beds strike N. 45° E. and dip 11 degrees toward the northwest.

Several houses in the vicinity have been built of this stone and some that are quite old are still in a good state of preservation.

Similar stone is exposed in a small quarry along the line of the New Jersey and Philadelphia Traction Co. ("Johnson trolley"), about a mile north of Lawrenceville. Here the stone has been crushed and used for railroad ballast.

BYRAM ARGILLITE.—On Delaware River, 8 miles above Lambertville, the B. M. and J. F. Shanley Company operate a quarry in a dark slate-colored to brownish-black argillite, which is more massive that that at Princeton and Lawrenceville, and does not readily split into flat slabs or blocks suitable for building. Hence, it is crushed for concrete, railroad ballast, etc. Beds occur 10 to 40 feet thick, which are entirely massive, and the stone breaks with a conchoidal fracture like dense flint. The stratification is shown in some parts by a banding of slightly varying colors. The beds dip 8 degrees toward the north (strike N. 80° E.). Calcite veins occur and pyrite nodules are abundant in parts of the quarry. Many of the joints are lined with beautifully radial clusters of the mineral laumontite, which quickly loses its water of crystallization on exposure to the air and crumbles away.

Microscopic and chemical characters.—Under the microscope this rock is found to have entirely lost its original clay-like character and become crystallized into a dense aggregate of fine flakes of brown mica and granular scapolite, feldspar, and calcite—a typical hornfel. Occasional irregular patches of quartz occur, apparently corresponding to the opal silica in the Princeton argillite. In some bands the minerals are much more coarsely developed.

Analysis of black Argillite, Shanley's Quarry, Byram.

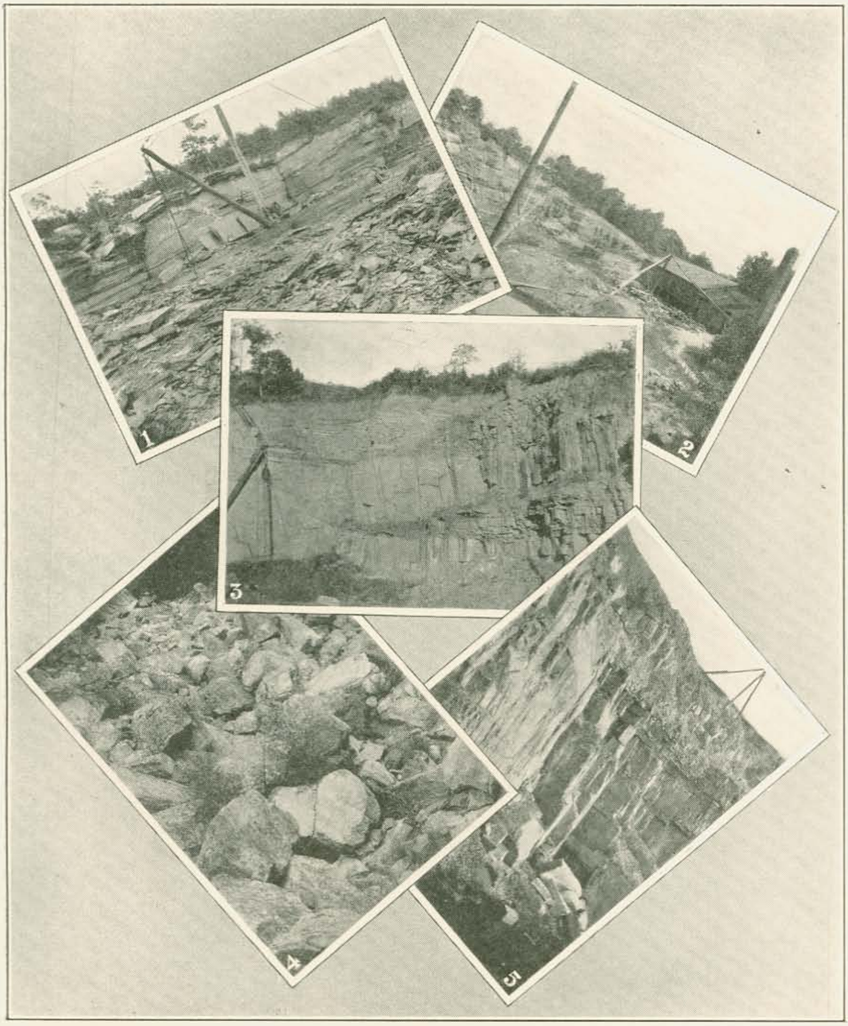
BY R. B. GAGE, CHEMIST OF THE SURVEY.

SiO_2	47.38	CO_2	2.31
Al_2O_3	20.35	TiO_2	0.55
Fe_2O_3	0.64	ZrO_2	0.02
FeO	7.27	P_2O_5	0.29
MgO	4.09	SO_3	0.06
CaO	3.10	MnO	0.03
Na_2O	7.99	BaO	0.11
K_2O	3.73		
H_2O+	1.38	Total,	99.43
H_2O-	0.11		

This analysis is notable for its low silica and its high alumina, ferrous iron, and alkalis, particularly the soda; in many respects it strongly suggests the nephelite-syenites, but it is difficult to imagine any relationship with such rocks. The composition shown above is equivalent to approximately 50 per cent. scapolite, 40 per cent. biotite, 5 per cent. calcite, with minor amounts of quartz, feldspar, apatite, pyrite, etc.

CONGLOMERATE (PUDDINGSTONE).

The *conglomerate* of Green Pond, Kanouse and Bearfort mountains, southwestward from Greenwood Lake, is a very attractive stone, consisting usually of white or light-colored pebbles imbedded in a dark-red to chocolate-brown ground mass. There is some variation in the size of the pebbles and in the color of both



1. Flagstone Quarry, Quarryville.
2. F. W. Shrimp & Son's Sandstone Quarry, Pleasantdale.
3. One of S. B. Twining Co.'s Sandstone Quarries, Stockton.
4. Conglomerate Bowlders, Echo Lake, Charlotteburg.
5. Another of S. B. Twining Co.'s Sandstone Quarries, Stockton.

parts of the stone from place to place, but it holds the same general characters with remarkable uniformity. The stone is so hard and durable that bowlders of it, often of large size, are found widely distributed over the country for many miles to the south and southeast in the glacial drift.

This conglomerate has been used in a number of buildings both alone and in combination with other stones. Most of the stone for this purpose has been gathered from the plentiful glacial bowlders, which are still perfectly fresh and hard. In the Cornell Library at Drew Theological Seminary, Madison (see Plate XII), it is combined with pleasing effect with brownstone trimmings. In the M. E. Church, Morristown, and in the residence of Mr. R. J. Cross, 2½ miles north of Newfoundland, are found contrasted the earlier and later uses of this stone.

While highly effective results can be achieved with this stone, its great hardness, coupled with its lack of any capacity for easy splitting in any direction, probably makes the expense of its use prohibitive in the majority of cases. In many places in this region, however, bowlders are found in great abundance, as at the east base of Kanouse Mountain (see Plate XVII). When these can be used without much breaking or shaping, and particularly when first cost is a secondary consideration, this is an admirable architectural stone, unexcelled by any for durability and possessing high artistic possibilities.

FLAGSTONE.

Flagstone, like so many other terms in the trade and in popular use concerning stone, has no very exact or definite meaning. It is applied indiscriminately to all kinds of stone that may be split readily into broad slabs suitable for floors, pavements, curbstones, etc. Generally the stone so used and designated is a thin-bedded sandstone, but sometimes slates, gneisses, and schists are included in various localities. The term "bluestone" is often used as a synonym of flagstone.

In New Jersey flagstone has been quarried from sandstone formations and from sandy portions of the slates in Hunterdon, Warren, and Sussex counties. The slates themselves have been used locally for sidewalks, steps, etc. The harder varieties of these are well adapted to such uses, and much that is now wasted at the quarries might be turned into marketable products of this class.

MILFORD FLAGSTONE.—In several places from Milford northward for 1.5 miles considerable quarries were formerly worked in the thin-bedded sandstones of Triassic age for flagstone. The sandstone beds are mostly from 2 to 4 inches thick, although some are as much as 1 and 2 feet (Plate XI). They are interleaved in some places with thin sheets of red shale, the whole series dipping regularly 18 to 20 degrees toward the northwest (strike N. 30° E.).

Several of these quarries are favorably situated for economic operation, with little soil cover or other stripping, small amounts of interbedded shale, and steep hillsides in which a good quarry face is readily obtained. The old quarries have not been worked for about 15 years, it is said.

DELAWARE FLAGSTONE.—Two miles and a half east of Delaware, a village 10 miles below Delaware Water Gap, flagstone has been quarried on the farm of Alpheus J. Swayze. The material is a thin-bedded shaly sandstone of the Martinsburg ("Hudson") slate formation, and has been chiefly taken out intermittently for local uses, although some is said to have been quarried also for shipment The stone lies in gently sloping beds (dip 7 degrees northwestward, strike N. 20° E.) and has been stripped off in successive sheets over an area about 40 by 100 feet. It is rather shaly in character and would not be suited to exposed positions where it would be placed on edge or would have to stand heavy wear. When laid flat for paving on walks subjected to only moderate traffic, it would probably give very good service. The colors are dark steel-blue to nearly black.

QUARRYVILLE FLAGSTONE.—Several flagstone quarries are situated on the high ridge (Flagstone Hill) three-fourths of a mile west of Quarryville station and 4 miles north of Sussex. The hill is composed of thin-bedded and fine-grained sandstone of the Martinsburg ("Hudson") slate formation. The beds range from less than 2 inches to 2.5 feet in thickness, although the thin beds predominate and some of the layers are too thin for use. As shown in the illustration (Plate XVI) the strata lie horizontal or nearly so, sometimes dipping as much as 5 degrees eastward. They usually split apart with perfectly smooth surfaces, although ripple-marks are sometimes seen. Thin layers of slate also lie between the beds of sandstone sometimes, and these invariably show slaty cleavage developed diagonally to the bedding planes. The beds are broken by joints at intervals of 6 to 30 feet, although they are seldom closer than 15 feet apart, so that slabs of any commercial size can be readily obtained.

The quarries are located on high sloping ground, with a down-grade haul all the way to the railroad at Quarryville. They are not now working continuously, but only as stone is required to fill special contracts.

SLATE.

Although the slate belt of Pennsylvania passes across Delaware River into New Jersey in its full width, its commercial development in this State has remained insignificant by contrast with the great and thriving industry in the regions immediately adjacent on the other side of the river. Years ago numerous attempts were made in a small way to open slate quarries north of the Delaware, particularly in the regions near the river and about Port Murray, Hackettstown, Newton, and Lafayette. Several of these early beginnings developed into quarries that were operated with apparent success for many years, but at present only one at Newton and one at Lafayette are active producers (Plate XVIII). In most cases the work was done on a small scale and with inadequate appliances, and the possibilities of the industry in the State have by no means been fully demonstrated. There is no reason for supposing that good material may not be found at many places.

The opening of a new quarry, however, or the rehabilitation of an old one is a matter involving considerable expense, and should not be undertaken without sufficient capital to properly equip and operate it. It should go without saying that no considerable sum should be invested until thorough investigation by competent authority has demonstrated a reasonable chance of success. In slate, as in the stone industry generally, the small poorly equipped quarry works at a low efficiency and often bears a disproportionately heavy burden of operating expenses.

A reduction in the enormous proportion of waste in slate quarrying deserves careful consideration, since it costs as much to remove the waste rock from the quarry as the marketable product. Some of this is good slate broken in quarrying; other portions not suitable for roofing slate might be converted in part into flagging and steps, in the hard slates, or into mill-stock for sawing and surfacing, in the soft slate quarries, as is done extensively in Pennsylvania. This would often more than redeem the cost of handling what would otherwise be waste rock.

"The visitor to these slate quarries is deeply impressed by the immense amount of waste slate piled up in the immediate vicinity of every opening, covering large tracts of valuable slate property, and naturally wonders why so much slate has been broken up and thrown away.

"These monuments of waste material mean not only the loss of the slate itself, but also an expenditure of about 40 cents per cubic yard to remove it from the quarry to the dump pile; so that, could the slate have been used for commercial purposes, there would have been a great saving to the operator.

"As an illustration of the loss due to this old method of working the quarries [by blasting alone], the following figures have been compiled upon an opening 100 feet by 100 feet, the bed of slate being ten feet thick. In loosening up this bed there would be 51,000 cubic feet of slate blasted out. Under the most favorable conditions four-fifths of this could be used, so that the damaged or ruined material was about 10,200 cubic feet. The value of slate varies from 7 cents to 14 cents per square foot one inch thick, or from 84 cents to $1.68 per cubic foot, so that the loss on 10,200 cubic feet would be $12,852, plus the cost of removal from the quarry to the dump, .40×10,200 equals $151, or a total of $13,003.00."[1]

The substitution of channelers for the old wasteful methods of blasting is said to have resulted in a great saving of slate in the Pennsylvania quarries. The following quotation from a letter from Mr. J. S. Morss, Vice-President of the Crown Slate Company, Pen Argyl, Pa., is typical of a number of similar

[1] Arthur E. Blackwood, M. E., *Mine and Quarry*, May, 1907.

replies that have been received in response to inquiries concerning these machines.

"The cutting of backs and sinking in general formerly was accomplished by the use of powder, which shattered the rock very often to a considerable degree and destroyed a great deal of good slate material. Furthermore, the backs and sides of the quarry where blasted were not left as secure as when channeled. In other words, channeling machines are used almost wholly now where possible in slate quarrying in the general opening up of rock drifts and for sinking operations, and are considered a matter of great economy in the saving of material over the old methods."

The quarries in New Jersey, with the exception of the one near Delaware Water Gap, and also most of the minor workings are in slate of a character that corresponds to the southeasterly or "hard-vein" slates of the region about Chapmans, Pa. In this stone both the slate and the ribbons are harder than those of the "soft-vein" or northwesterly areas, like the Lehigh, Pen Argyl, and Bangor regions. The ribbons in these hard slates are much less liable to disintegrate, and their presence is far less objectionable. The various quarries of the State have produced good durable slate, and many roofs that have stood the test for a generation or more show little or no deterioration, and in most cases but slight change of color.

The great hardness of most of this slate adapts it to a variety of uses to which the softer slate is unsuited, such as steps, flooring, railings, and flagging, in which resistance to wear and weathering are prime requisites. On account of these same qualities, however, it is not so easily sawed into slabs for switchboards, blackboards, table tops, mantels, etc., as the softer kinds. In New Jersey but little effort has been made, apparently, to produce anything but roofing slate, and it is quite possible that some of the great waste in quarrying might be prevented by converting a part of the stone into some of the other marketable forms, such as steps and flagging, particularly where this might be done without much expensive sawing.

Tests of roofing slates.—In order to determine the properties of these slates in New Jersey, as compared with well-known types of Pennsylvania slates, a series of physical and chemical tests was made in the laboratories of Rutgers College, with the results given in the table below. The methods pursued in these tests were, in the main, those devised by Prof. Mansfield Merriman,[1] and the results, with the exception of those for softness and corrodibility, are comparable with his.

Strength was determined by placing 12x24-inch slates on wooden knife-edge supports 22 inches apart, and applying weight on a similar knife-edge at the middle, by means of sand pouring at the uniform rate of 70 pounds per minute. The flow of sand was automatically shut off at the moment of rupture. The strength, or "modulus of rupture," is equal to three times the breaking load by the length divided by twice the width by the square of the thickness.

Toughness is shown by the amount of bending before rupture. This was carefully observed by means of a long pointer, which greatly magnified the small distances involved.

Density is simply the specific gravity of the slate, or its weight compared with the weight of an equal volume of water, determined by the usual method of weighing in air and then in water. For this purpose, broken pieces about 3x4 inches in size were used.

Softness is measured by the loss in weight suffered by the slate from 50 turns of a small grindstone, under a uniform pressure of 10 pounds. It is manifest that comparable results can be obtained only on the same grindstone, with the face in the same condition. Hence the values given in the table are comparable with each other, but not with Prof. Merriman's.

Porosity was determined by the amount of water absorbed by the slate in 24 hours. Pieces 3x4 inches in size were used.

Corrodibility is the amount of corrosion, or loss in weight, suffered by pieces approximately 3x4 inches in size from exposure for 65 hours to the action of an acid solution, composed of 98 parts water, 1 part hydrochloric acid, and 1 part sulphuric acid, by weight. Although pieces of about the same size were used, there was considerable variation in thickness, and hence in weight. The extent of corrosion in such cases seems to depend, not on the weight, but on the area of exposed surface. The solution undoubtedly penetrates the whole mass, but in rocks of such great compactness there is little circulation, and the material lost by solution is practically all taken from the surface. This is confirmed by the fact that the "fading," or discoloration due to the acid, is confined to a very thin surface film, which is sharply contrasted with the unchanged interior when the pieces are cut or broken.

For these reasons, the actual loss by weight, in specimens presenting approximately the same surface to corrosion, is believed to be a much better measure of corrodibility than percentage. For comparison with Prof. Merriman's results, however, the percentages are also given in the accompanying table.

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[1] Trans. Am. Soc. Civil Engineers, vol. XXVII, 1892, p. 331; vol. XXXII, 1894, p. 529; Bulletin U. S. Geol. Survey, No. 275, 1906, p. 122.

Tests of Roofing Slates from Newton and Lafayette, N. J., and from Chapmans and Slateford, Pa.

Locality and Number.		Strength (modulus of rupture) (Lbs. per square inch)	Toughness (bending, on supports 22 in. apart) (Inches)	Density (specific gravity)	Softness (loss by 50 turns of grindstone) (Grams)	Porosity (water absorbed in 24 hours) (Per cent.)	Corrodibility (65 hrs. in acid solution) (Grams)	(Per cent.)
Newton, ...	1	5,953	0.155	2.777	0.092	0.166	0.263	0.194
	1a	.....	.....	2.783	0.096	.....	0.265	0.205
	2	3,851	0.100	2.774	0.114	0.175	0.257	0.217
	2a	.....	.....	2.764	0.092	.....	0.274	0.424
	2b	.....	.....	.....	0.109	.....	0.238	0.423
	3	5,311	0.130	2.776	0.098	0.190	0.249	0.223
	3a	.....	.....	2.783	0.104	.....	0.234	0.222
	3b	.....	.....	2.777	0.121	.....	0.236	0.228
	4	5,286	.....	.....	.....	.....	.....	.....
	5	4,699	.....	.....	.....	.....	.....	.....
Averages, ...		5,020	0.128	2.776	0.103	0.177	0.253	0.267
Lafayette, ...	6	8,357	0.340	2.773	0.079	0.171	0.301	0.368
	6a	.....	.....	2.773	0.086	.....	0.328	0.439
	7	8,088	0.340	2.773	0.091	0.144	0.329	0.416
	7a	.....	.....	2.773	0.082	.....	0.318	0.400
	7b	.....	.....	2.775	0.102	.....	0.339	0.422
	8	8,164	0.330	2.773	0.091	0.189	0.364	0.401
	8a	.....	.....	2.774	0.111	.....	0.347	0.405
	8b	.....	.....	2.773	0.094	.....	0.369	0.395
Averages, ...		8,203	0.337	2.773	0.092	0.168	0.337	0.406
Chapmans, ...	9	10,953	0.290	2.770	0.128	0.125	0.255	0.246
	10	11,786	0.285	2.774	0.145	0.126	0.251	0.220
	11	11,542	0.400	2.790	0.155	0.110	0.273	0.273
	11a	......	.....	2.784	0.139	.....	0.308	0.331
Averages, ...		11,427	0.325	2.780	0.142	0.120	0.272	0.267
Slateford, ...	12	11,303	0.340	2.778	0.112	0.161	0.455	0.437
	12a	......	.....	2.777	0.122	.....	0.448	0.433
	13	9,445	0.305	2.779	0.133	0.200	0.435	0.491
	13a	......	.....	2.775	0.154	.....	0.456	0.505
	14	11,184	0.355	2.780	0.138	0.188	0.425	0.420
	14a	......	.....	2.779	0.120	.....	0.397	0.417
Averages, ...		10,644	0.333	2.778	0.130	0.183	0.436	0.450

Locality and Number.	*Strength* (modulus of rupture) (Lbs. per square inch)	*Toughness* (bending, on supports 22 in. apart) (Inches)	*Density* (specific gravity)	*Softness* (loss by 50 turns of grindstone) (Grams)	*Porosity* (water absorbed in 24 hours) (Per cent.)	*Corrodibility* (65 hrs. in acid solution) (Grams)	(Per cent.)
Slateford,							
"No. 1 Rib," 15	8,921	0.245	2.794	0.169	0.251	0.381	0.457
15a	.....	.....	2.794	0.152	.....	0.475	0.430
16	7,680	0.300	2.787	0.122	0.184	0.472	0.523
16a	.....	.....	2.806	0.120	0.219	0.482	0.569
17	8,554	0.305	2.789	0.126	0.246	0.462	0.467
17a	.....	.....	2.791	0.121	0.186	0.498	0.508
Averages, ...	8,452	0.283	2.793	0.135	0.217	0.462	0.492

MERRIMAN'S AVERAGES.

Albion (Pa.), ...	7,150	0.27	2.775	80*	0.238	.....	0.547
Old Bangor (Pa.),...	9,810	0.312	2.780	128*	0.145	.....	0.446
Peach Bottom (Md.),	11,260	0.293	2.894	90*	0.224	.....	0.226
Chapmans (Pa.), ...	9,460	0.212	2.764	0.208	0.231	.....	0.383
Arvonia (Va.), ...	9,040	0.227	2.781	0.060	0.143	.....	0.394
" "	9,850	0.225	2.791	0.108	0.216	.....	0.323
Brownville (Me.),...	9,880	0.200	2.798	0.265	0.148	.....	0.305
Monson (Me.), ...	9,130	0.205	2.794	0.256	0.188	.....	0.286
Fair Haven (Vt.),...	6,410	0.225	2.771	0.341	0.230	.....	0.295
W. Pawlet (Vt.),....	7,250	0.207	2.736	0.190	0.325	.....	0.768
New York (Green),.	8,050	0.190	2.783	0.226	0.374	.....	0.379
" " (Red),...	9,220	0.232	2.848	0.148	0.243	.....	0.373

DELAWARE WATER GAP SLATE.—The slate quarry near the eastern portal of the Water Gap, 2 miles northwest of Columbia and Portland, was opened about 85 years ago. For many years it was successfully operated and produced large quantities of roofing slate. It is a continuation of the "soft-vein" slates of the Bangor and Slateford areas across the river. The quarry is filled with water, which is probably 50 feet or more in depth, and the enormous waste heaps, the relics of old cars, derricks, etc., indicate the great activity that must have prevailed here for long periods. Descriptions of the quarry were published in the "Geology of New Jersey," 1868, and in the Annual Reports of

*Grains. These three values are not comparable with those that follow, having been obtained with a different grindstone. None of these tests for softness are comparable with those of the preceding parts of the table, of course.

the State Geologist for 1872 and 1881, and under the circumstances it scarcely seems desirable to add to these.

There are several old quarries and prospects in the hard slates in the region lying just east and southeast of Delaware Water Gap. Some of these, a mile southeast and 2 miles north of Columbia, are openings about 30 by 50 feet and less than 50 feet in depth. The largest is probably Hallett's quarry, 2 miles northeast of Columbia, which has not been worked for about 15 years. Prior to this it was operated more or less intermittently for 7 or 8 years for roofing slate only. The beds dip 28 degrees southeastward and the cleavage dips 40 degrees in the same direction. The joints, which are chiefly north and south and nearly vertical, are spaced irregularly from 5 to 20 feet apart.

PORT MURRAY SLATE.—Hard slate was formerly quarried for many years east of the railroad station at Port Murray, 6 miles southwest of Hackettstown. Roofs of this slate seen at Port Murray and at Washington (N. J.) still show a good, uniform dark color after about 25 years exposure. The beds dip 55 degrees and cleavage dips 35 degrees in the direction 20 degrees east of south. The color is dark grayish-black with ribbons of a little lighter tone. The surface is fine grained and dull. The last quarrying here is said to have been done in 1887.

Northeastward between Port Murray and Hackettstown several small openings have been made in prospecting for slate, and some of these near the latter place have produced roofing slate on a small scale for the market. Nothing has been done in this region for many years, however, and little is known of the qualities or possibilities of the slate of this region.

NEWTON SLATE.—The quarry of the Newton Slate Company at this place was opened in 1845 and has reached a depth of more than 150 feet (Plate XVIII). It is a hard bluish-black slate, with dip of the bedding 15 degrees in the direction north 30 degrees west, and dip of the cleavage from 45 degrees towards the southeast on top of the hill to nearly horizontal in the bottom of the quarry. The dump is on higher ground than the quarry, requiring both good slate and waste material to be hoisted to a considerable height. Only roofing slate is produced. A mill for sawing and surfacing has been installed here, but is not now in use.

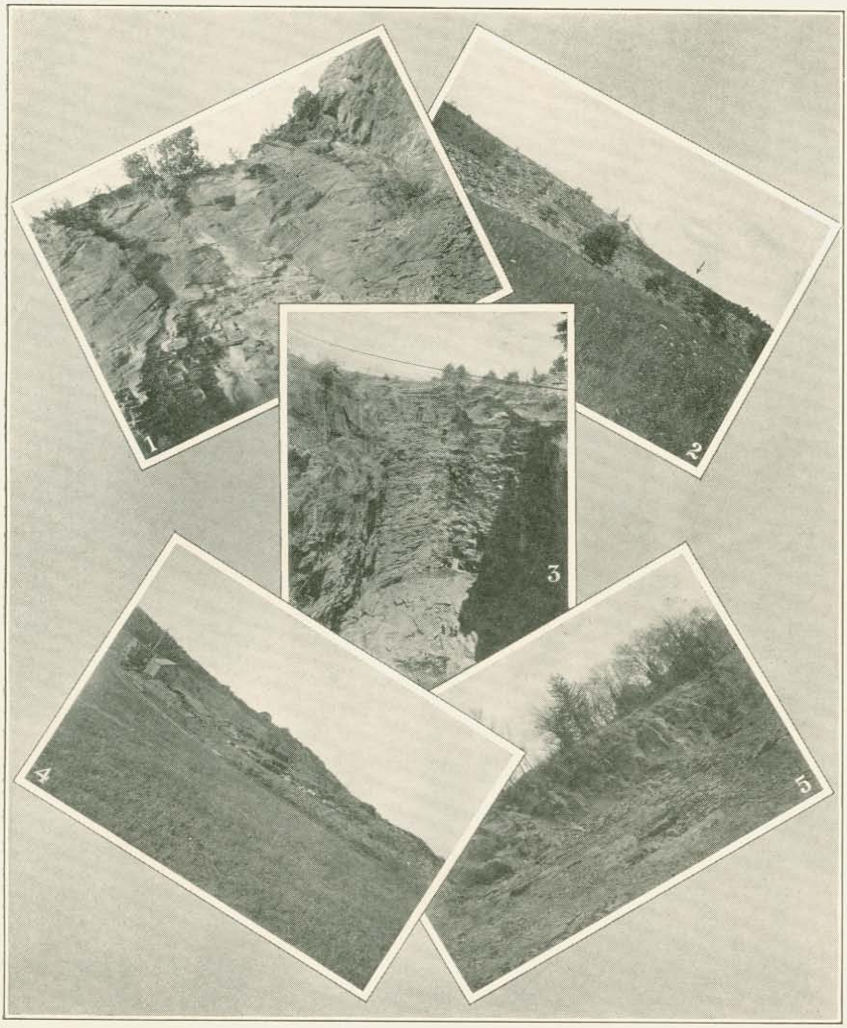
Results of tests.—The tests described on page 103 show that this slate is not very strong, although it does not fall much below some of the widely-used Pennsylvania and Vermont slates. It is also notably more brittle, or low in toughness; but, on the other hand, it is considerably less porous than the others that were tested with it, and is more resistant to the corrosive action of acids than any slates in the country that have thus far been tested. On account of these qualities it is particularly well adapted for use in cities and in manufacturing establishments, in fact wherever much coal is burned or corrosive fumes are produced by any means. This conclusion is further strengthened by the fact that in the acid tests "fading" or change of color was barely perceptible in a film less than one-hundredth of an inch (0.14—0.24 mm.) in thickness. In this respect it was equalled only by the slate from Chapmans, Pa.

The slate has an established reputation from its use on many buildings, particularly in New Jersey and New York.

Microscopic characters.—Thin sections of this slate when examined with the microscope show a medium to fine-grained, thoroughly crystalline aggregate of muscovite and chlorite flakes inclosing numerous grains of quartz and calcite and occasional magnetite crystals. When cut parallel to the grain of the rock these granular minerals show elongated, lenticular forms with the flaky micaceous minerals draws out in the direction of the cleavage and undulating about the grains of quartz and calcite, binding the whole into a tough elastic body of great strength. Sections parallel to the cleavage show broad flakes of muscovite and chlorite; at right angles to the rift and grain, the granular minerals appear in more angular forms.

Small quarries and prospects have been opened at several places to the southwest and also northeastward toward Lafayette.

LAFAYETTE SLATE.—The quarry of the Lafayette Slate Company, 2 miles north of Lafayette, is an old one that has been recently reopened and is being equipped for steady production. The opening is about 75 by 125 feet and over 50 feet deep (Plate XVIII). The plan of the present operators is to widen the



1. Couse's Slate Quarry, Lafayette.
2, 3. Newton Slate Co.'s Quarry, Newton.
4. Lafayette Slate Co.'s Quarry, Lafayette.
5. McCarthy Sons Co.'s Argillite Quarry, Princeton.

quarry in order to give a broader working area at the bottom and reduce the waste from blasting.

The bedding dips northwestward 20 degrees, while the cleavage dips 26 degrees toward the southeast. There are distinct joints in the direction of the dip and at right angles to it at intervals of 2 to 20 feet, so that there is little waste on this account.

Results of tests.—The tests described on page 103 show that this slate equals in strength many of the best slates of Pennsylvania and Vermont, while in toughness it exceeds all slates that have thus far been tested, although it is nearly equalled by the products of the Chapmans, Old Bangor, and Slateford quarries. It is also very low in porosity and near the average in corrodibility. The acid test gave a distinct brownish tinge to a surface film about one-two-hundredth of an inch (0.14 mm.) in thickness.

Microscopic characters.—Examined with the microscope, thin sections of this slate show coarse grains of quartz and calcite surrounded and bound together by muscovite and chlorite. The rock is thoroughly crystalline throughout, and no magnetite or pyrite appears in the sections. The texture in different directions is the same as that described above for the Newton slate.

Two other old quarries in the vicinity show similar conditions, the one half a mile to the southwest being larger and the other a quarter of a mile northeast, somewhat smaller. These have not been worked for 10 years or more. Some of the waste on the dump of the largest shows a slight brownish tint on the weathered surface when compared with the fresh fracture. Occasional veins of quartz, calcite, and pyrite are developed in the bedding-planes and sometimes in fractures making a small angle with the bedding. Very little curved or irregular twisted slate occurs at any of these places. The ribbons which are spaced at intervals of an inch or two to 2 feet, are narrow and of slightly lighter-gray color, although they become darker on exposure.

LIMESTONE.

Two well-known limestone formations occur in the State, chiefly in Sussex and Warren counties, which are known respectively as the Franklin or "white" limestone and the Kittatinny, "blue,'" or magnesian limestone. The former is a coarse-grained, crystalline rock that may properly be called a marble, and it is further described under that head. It is often too coarse-grained or variable in texture, and sometimes too irregularly sprinkled with dark-colored minerals to be used for polishing, but much of it is adapted to ordinary building purposes. The latter is a dense massive rock, usually of light-gray to bluish-gray color and is much the most abundant limestone in the State.

Other limestones occur in the extreme northwestern part of the State, west of Kittatinny Mountain, but apart from their inaccessible location so far as outside markets are concerned, they are generally thin-bedded and often shaly, sandy or cherty. The more massive beds are frequently banded with alternating layers of light and dark colors and sometimes thickly set with fossil shells. All things considered, these limestones and the sandstones that occur in the same general region, can scarcely assume more than a minor local importance as building stones.

THE KITTATINNY OR "BLUE" LIMESTONE is massive, fine-grained, and usually of a quite uniform bluish-gray color, although it varies in places to nearly white or to dark grayish-black. Many of the beds are minutely crystalline, so that the freshly broken surface has the texture of fine-grained lump sugar; but it is never coarsely crystalline like the Franklin white limestone. Its characters are thus described by Dr. Kümmel:[1]

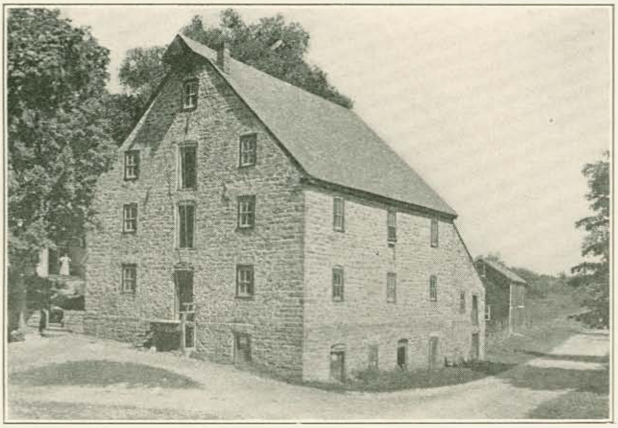
"This formation occurs in beds which vary greatly in thickness and regularity. In part it is made up of thin leaf-like layers of limestone alternating with thin sheets of greenish shale. * * * In great part, however, this formation is composed of regular beds one, two, three or even more feet in thickness. Locally they are so massive and the formation is so regularly jointed that it is extremely difficult to determine the true position of the beds. Some layers also are oolitic; that is, made up of minute round particles somewhat closely resembling fish-roe. The oolitic layers are apparently confined to the lower portion of the formation. Its thickness is apparently between 2,500 and 3,000 feet, but accurate measurements cannot be obtained. More than 99 per cent. of the limestone of Sussex, Warren and Hunterdon counties belong to this formation, the extent of which is shown on the geological map of the State. (See Plate II.)

"A marked feature of this formation is the chert, or black flint, which occurs either as seams, sometimes 8 or 10 inches thick, or as separate masses. The chert layers are usually, but not always, parallel to the bedding planes."

[1] Annual Report of State Geologist for 1900, pp. 32, 35.

1. BLUE LIMESTONE.

Residence of Dr. G. W. Cummings (1833), Belvidere.



2. BLUE LIMESTONE.

Old Moravian Mill (1768), Hope.

3. BLUE LIMESTONE.

Moravian Inn (1781), Hope. Formerly the Moravian Meeting-House.

Numerous chemical analyses of this limestone from various parts of the region have been made and published in the reports of the Geological Survey, of which the following are typical.[1]

Analyses of the Kittatinny ("blue" or "magnesian") Limestone.

	Calcium Carbonate ($CaCO_3$)	Magnesium Carbonate ($MgCO_3$)	Alumina & Iron Oxide (Al_2O_3. Fe_2O_3)	Silica and Insoluble (SiO_2)
1	54.38	40.11	0.8	3.6
2	42.14	34.0	6.0	15.7
3	52.9	40.3	1.4	2.9
4	50.4	42.4	1.3	5.5
5	57.9	32.6	8.4	2.0
6	47.0	36.5	5.3	8.0

1. Near Wm. Richey's, Vernon Township, Sussex County.
2. Railroad cut one-fourth mile west of Hamburg, on the N. Y. S. & W. R. R.
3. Quarry in the town of Belvidere.
4. Quarry at Oxford Furnace.
5. Pottersville, Somerset County.
6. Henry Hilliard's quarry, north of Peapack.

The blue limestone has long been used locally throughout the region in which it occurs for foundations, rough walls, bridge piers, etc. It has also been frequently employed in the construction of residences, schools, churches, and other buildings (Plates XIX and XX), and some of these have stood in good condition for considerably more than a century. Many attractive residences of both earlier and later periods of construction are found in all the larger towns and often in the country throughout the limestone regions.

While this stone has been generally used with good results for local purposes, there has been no attempt, apparently, to establish a permanent industry and find a broader market for it. In fact, the local demands have been met, as they arose from time to time, very largely by the establishment of temporary

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[1]Ann. Rep. State Geologist for 1900, p. 33.

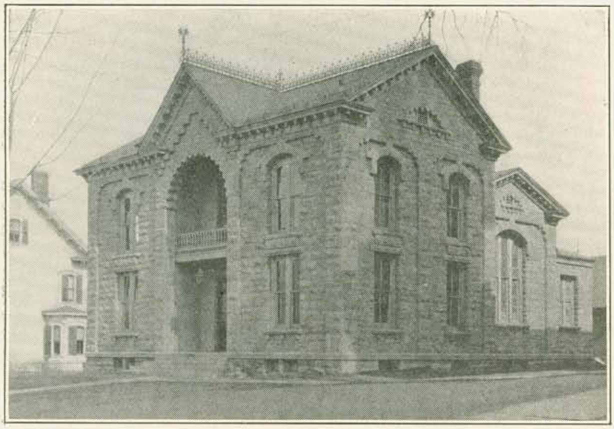
For present purposes the analyses quoted have been recast, the lime and magnesia being given as carbonates, the form in which they undoubtedly occur in the rock. It is to be borne in mind that in calcium carbonate a little more than half (0.56) is lime, while in magnesium carbonate a little less than half (0.476) is magnesia.

quarries in the most convenient ledges in the vicinity, and continuing their operation only so long as the special work in hand required. This primitive method has served the local needs fairly well, owing to the widespread occurrence and uniform qualities of the blue limestone, but it has not served to bring the stone to the attention of the larger markets nor to establish a profitable industry in these communities.

Where the limestone is not too closely broken by joints to permit the quarrying of desirable sizes for building, and where beds of sufficient thickness free from thick seams of shale and chert can be found, it should be a simple matter to quarry it and place it in the market at small expense. There are many ledges, often forming prominent cliffs in nearly every township, where these conditions can be met. Some of these were worked and the stone burned for lime in the early days, although no particular care was exercised as to joints, of course, in such work, and for this reason some of the old lime quarries would not furnish good building stone.

The stone could be cut with channeling machines and worked into shape with any of the usual types of marble-cutting machinery, if desired, or it might be broken and tool-dressed and made into dimension stone of any style of finish that might be desired. The chief single item of expense in marketing it would probably be the cost of transportation, but with both canals and railroads available over large parts of the limestone country, this should not prove an insuperable barrier. Much of the building stone that is used in the eastern cities is shipped far greater distances by railway alone.

In this, as in all such enterprises, sufficient capital should be available to equip properly a quarry for efficient and economic operation, although the first cost of opening a new quarry is not nearly so great in limestone as in slate. Some expense should be incurred, however, in prospecting and developing suitable beds before installing elaborate equipment. This is only a matter of ordinary business precaution, but it is sometimes overlooked with disastrous consequences.

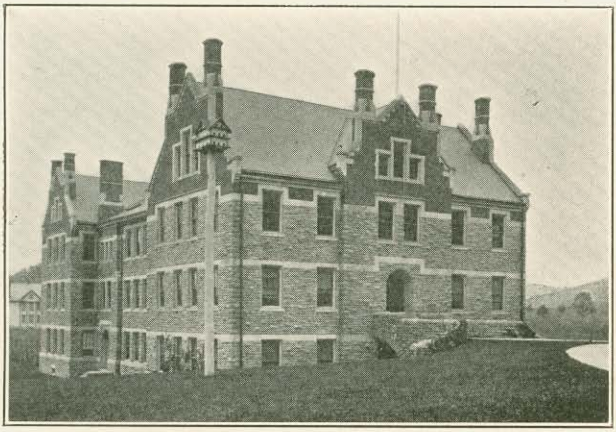


1. BLUE LIMESTONE.

Chapel of the Presbyterian Church, Newton.

2. BLUE LIMESTONE.

Locke Hall, Blair Academy, Blairstown.



3. BLUE LIMESTONE.

Clinton Hall, Blair Academy, Blairstown.

MARBLE AND SERPENTINE.

Marble is a term used in the stone industry in a somewhat indefinite way so as to include, besides crystalline limestone or marble proper (a calcium carbonate rock), also crystalline dolomite or dolomite marble (the double carbonate of calcium and magnesium), serpentine (a hydrous magnesium silicate rock), and ophicalcite, a marble more or less spotted and mottled with serpentine, and sometimes called verdantique.

Marble, serpentine, and ophicalcite are all found in New Jersey, but, with the exception of the white limestone, the localities are few and the areas small. The pink marble that occurs near Great Meadows on a spur of Jenny Jump Mountain is a variety of the Franklin white limestone, which, strictly speaking, is marble. The ophicalcite that is found near Phillipsburg, Mendham, and Montville is also a part of the same formation, and both of these stones occur in attractive colors, well adapted to polishing for interior decorative purposes.

Serpentine occurs in two entirely different conditions. About Phillipsburg and Montville it is, like the ophicalcite, a part of the white limestone formation. At Hoboken a mass of greenish-yellow serpentine forms the hill that projects into Hudson River at Stevens Point, and underlies the loose surface accumulations as far south as the Delaware, Lackawanna and Western Railroad terminal. This area has no relation to the crystalline white limestone, but the rock is of igneous origin; that is, it is an altered form of a rock that was produced by the cooling and consolidation in this position of a mass of molten rock.

GREAT MEADOWS MARBLE.—The quarry of this beautiful "Rose Crystal Marble," as it has been called, is on a southeasterly spur of Jenny Jump Mountain, 2 miles northwest of the village of Great Meadows (formerly Danville). It is situated at the junction of the Hope road with the road that runs along the north side of the meadows. The marble is composed of coarse-grained pink and white crystals of calcite (with some dolomite), sprinkled with brownish-black mica (phlogopite), green pyroxene (diopside), and occasional black crystals of tourmaline. The stone takes an excellent polish and the color mottlings produce a very rich effect (Plate XXI).

About a generation ago an effort was made to open a quarry here, but at that time the nearest shipping point was Hackettstown, 7 miles distant, and the route lay across Upper Pohatcong Mountain. Nevertheless a large number of blocks were shipped to Philadelphia where they were used for the interior decoration of public buildings. The character of the stone as exposed by these workings has been described by Prof. George H. Cook[1] as follows:

"There are two openings, but thus far nearly all of the stone has been taken from that on the south side of the Hope road. This is about 50 yards long, 50 feet wide, and at the deepest 25 feet down. The dip of the strata is 80° N. 75° W. The rose-colored beds, as exposed, measure 80 feet across the strike; on the west of these the stone is pearl-gray in color. The stone is mostly calcareous, the calcite being white, flesh-colored, and rose-colored. With this there occurs a greenish-black hornblende, black mica, and here and there crystals of black tourmaline; but the calcite largely predominates, so much so that it could be used for burning into lime. The stone polishes well, and these foreign minerals give it a beautiful variegated appearance.

"Many of the larger blocks on the bank will measure 8×3×2 feet. They are free from seams or jointage flaws. On the opposite side of the road a trench has been dug down to the rock, exposing the strata for 100 feet or more across the strike. Here it is the ordinary white limestone, and none of the colored varieties are seen."

Dr. George P. Merrill, in his well-known book on "Stones for Building and Decoration,"[2] says: "it is a great pity that so beautiful a stone should not be utilized." Now that a railroad is within easy reach, it should find a ready market for interior decoration.

Analysis of Great Meadows Pink Marble.

BY R. B. GAGE, CHEMIST OF THE SURVEY.

SiO_2	6.65	H_2O	0.48
Al_2O_3	0.90	CO_2	38.56
Fe_2O_3	0.02	TiO_2	0.04
FeO	0.84	P_2O_5	0.08
MgO	3.07	SO_3	0.06
CaO	49.20	MnO	0.06
Na_2O	0.03		
K_2O	trace	Total,	99.98

[1] Ann. Report State Geologist for 1872, p. 27.
[2] Third edition, 1903, p. 218.

1
GREAT MEADOWS PINK MARBLE
(NATURAL SIZE AND COLOR)

A. HOEN & CO. BALTIMORE.

2
PHILLIPSBURG SERPENTINE
(NATURAL SIZE AND COLOR)

This analysis corresponds approximately to a composition of calcite 85 per cent., dolomite 2, diopside 5, and phlogopite 8.

THE FRANKLIN WHITE LIMESTONE.—Although usually occurring only in small areas, thick masses of this stone are found in Sussex and Warren counties, and less extensive beds are widely scattered in many parts of the Highlands (see map Plate II). The character of this rock has been described by Dr. Kümmel[1] as follows:

"Typically the limestone is a coarsely crystalline rock, the calcite (or dolomite) crystals of which often measure an inch or more in diameter. It is commonly white in color, the lustrous cleavage faces of the large crystals giving it a bright and resplendent aspect, but it often has a slight bluish tinge, and in the Jenny Jump Mountain area much of it is mottled pink ["Rose Crystal Marble"]. Nearly everywhere the rock contains small brilliant scales of graphite, flakes of yellowish mica and grains of various silicates—diopside, chrondrodite, etc.

"It is not possible anywhere to recognize beyond all question definite planes of sedimentation, although in many localities there is a distinct structure or foliation due to the arrangement of the accessory minerals in certain planes, or where these are absent, to a lenticular arrangement of the crystals of calcite. In at least one quarry at McAfee there are definite belts along which the rock is found to differ in composition from that on either side. These differences are such as to suggest at least that they are the result of original sedimentation. * * *

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

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

Chemically the rock ranges from nearly pure limestone or calcium carbonate ($CaCO_3$) to typical dolomite ($CaCO_3.MgCO_3$),

[1] Ann. Report State Geologist for 1905, pp. 177, 178.

in which magnesium carbonate constitutes 45.65 per cent. of the rock. The latter constituent, however, seldom rises above 10 per cent. and frequently drops below 4 per cent. in the numerous analyses that have been published. The silica (SiO_2) ranges from less than 2 per cent. in the majority of the analyses, to as much as 20 per cent. in exceptional cases; and the oxides of iron and alumina (Fe_2O_3 and Al_2O_3) are generally below 1 per cent., though exceeding 5 per cent., in rare instances. The following analyses, selected from a great number,[1] represent the range of composition fairly well.

Analyses of the Franklin White Limestone.[2]

	Calcium Carbonate ($CaCO_3$)	Magnesium Carbonate ($MgCO_3$)	Alumina & Iron Oxide (Al_2O_3, Fe_2O_3)	Silica and Insoluble (SiO_2)
1	93.10	3.19	0.77	1.67
2	98.18	1.20	0.30	0.37
3	88.15	0.50	0.80	9.40
4	55.28	44.51	0.85	0.09
5	68.01	2.68	6.84	19.90

1. Average of shipments from Bethlehem Steel Co.'s quarry, McAfee, during the month of June, 1905.

2. Specimen 4 feet from a granite dike 700 yards east of the north end of Franklin Furnace pond.

3. Average of samples from an old quarry three-fourths of a mile north of Andover.

4. Sample 450 feet from the surface in the Parker shaft at Franklin Furnace.

5. Average of samples from an old quarry containing large amounts of intrusive rock, near Cranberry Reservoir.

Marble quarries were formerly operated in a somewhat variable mass of this stone at Lower Harmony, 5 miles northeast of Phillipsburg. The colors there are gray and white, with streaks of dark hornblendic rock.

The white limestone is now extensively quarried at many places for use as a flux in iron smelting, and where not too closely

[1] Ann. Report State Geologist for 1905, pp. 180–185.

[2] It should be borne in mind that the percentage of magnesia in the rock is somewhat less than half (0.476) that of the magnesium carbonate in every case, while the percentage of lime is more than half (0.56) that of calcium carbonate.

jointed it might well be used also for general building purposes. The almost snowy whiteness of the stone in many places would produce handsome effects either in rock-face or in rubbed or tool-dressed finish. In locating a quarry for such purposes the principal defects to guard against are too close jointing and intrusive dikes and masses of granites or dark-colored trap rocks.

PHILLIPSBURG SERPENTINE AND OPHICALCITE.—Warne's quarry, 2.5 miles north of Phillipsburg, on Delaware River, produces serpentine and ophicalcite for polishing as slabs, columns, etc., for decorative materials, and also a mixture of talc and serpentine that is ground into fine flour and known as "mineral pulp." It is one of the largest quarries of the region and the only one now in operation on the New Jersey side of the river. It is worked as an open cut about 100 feet deep, which reaches considerably below the bed of the river (Plate IX). Mr. F. B. Peck has studied and described this region in detail and the following description of this quarry and the one at Montville is chiefly a condensation of portions of his paper.[1]

The rock used in the manufacture of pulp is hard, massive to very finely granular in texture, and very light-green or mottled-green and white in color. It consists of an intimate mixture of greenish serpentine and colorless tremolite and talc. If the constituents are thoroughly kneaded together the rock has a uniform apple-green color, is tough and compact, and has a splintery fracture.

The rock that is used for decorative purposes is a serpentine that is usually darker-green in color than that used for grinding. It is a mottled mixture of light and dark serpentine, occasionally sprinkled with grayish, pinkish, or flesh-colored dolomite crystals and sometimes veined with streaks or seams of pure white compact to fibrous calcite, in which are embedded fibers of asbestos. Much of this rock is said to furnish beautiful polished slabs and columns and should find a ready market (Plate XXI).

Among the rocks of this quarry are pearl or ash-gray crystalline dolomite and dolomitic limestone. These appear to be the

[1] The Talc deposits of Phillipsburg, N. J., and Easton, Pa. Ann. Report State Geologist for 1904, pp. 161–185.

original rocks from which the serpentinous and talcose rocks were derived. A number of other quarries have been worked in a similar material on both sides of the river. In some of them the serpentine is yellowish-green and waxy looking, as at Montville, described below. In all of them the chief object has been the stone for grinding, the decorative material being considered a by-product.

MONTVILLE SERPENTINE AND OPHICALCITE.—J. J. Gordon's quarry, 3 miles northeast of Boonton and 2 miles north of Montville, shows very similar conditions to those that prevail about Phillipsburg and Easton. Beds of very coarse-grained dolomitic limestone of ash-gray color have been intruded by fine to medium-grained granite. Masses of grayish-white diopside[1] are developed in the limestone, occasionally in crystals 3 or 4 inches long. Also scattered through the rock is considerable light greenish-yellow to yellowish-green, waxy-looking serpentine, occurring both in masses of considerable size and also disseminated through the limestone, forming ophicalcite. The quarry is not in operation.

MENDHAM OPHICALCITE.—H. C. Sander's quarry is 5 miles west of Morristown and 1 mile east of Mendham. The conditions are somewhat similar to those at Montville, described above, the stone being a white crystalline limestone of medium coarse-grained texture mottled and streaked with yellowish to dark yellowish-black translucent serpentine. It is also speckled with varying amounts of dark-green augite, brownish diopside, and flakes of graphite. The darker minerals assume a dull brownish hue on exposure and the stone then looks somewhat like some shades of the Kittatinny or "blue" limestone. The quarry has not been operated recently. The parsonage and chapel of the First Presbyterian Church of Morristown are constructed of this stone.

HOBOKEN SERPENTINE.—There is no quarry in this stone and none is likely to be opened, except possibly for purposes of

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[1] Dr. G. P. Merrill (PProc. U. S. Natl. Museum, vol. XI, 1888, p. 105,) has shown that the serpentine here has been formed by the alteration of the gray crystalline diopside.

grading streets, excavating for foundations, etc. It forms the prominent hill that projects out into Hudson River and is known as Stevens Point. It is a greenish-yellow massive serpentine containing occasional black grains of chromite. Where the stone has been exposed along the water front or in grading streets, joints are usually frequent, and some of these are filled with white talc and other light-colored magnesian minerals. The stone is secondary after a basic magnesian rock of igneous origin, which by hydration has been altered into its present condition. No other locality of this material is known in New Jersey, although the same stone occurs on Staten Island east of the trap rock, and similar serpentine, somewhat darker in color, is sometimes found in excavations on Manhattan Island.

The stone is very well adapted for rock-face construction or for tool-dressing, and it has been used locally to some extent. Serpentine of the same character and colors that occurs through the southeastern counties of Pennsylvania and central Maryland has been used in the construction of many buildings in Philadelphia, Baltimore, and Washington, and the bright greenish-yellow color produces a rather striking effect.

RESISTANCE TO FIRE.

Results of fire tests on 3-inch cubes of New Jersey building stones were published in the Annual Report for 1906.[1] The most important of these results may be summarized as follows:

Outside of the severest part of a conflagration the stone in the buildings would suffer little injury. Limestones would act best and sandstones would come next in ability to withstand the action of heat. Except in the clay rocks the cracking in the tests at 550° Centigrade (1022° Fahrenheit) was not such as would materially affect the stability of the structure if the stones had been properly set in their beds. Fine-grained crystalline rocks follow the sandstones, and last come the coarser crystallines.

Tests at 850° C. (1562° F.) approximate fairly well the probable degree of heat that is attained in conflagrations. In

[1] W. E. McCourt, Ann. Rep. State Geologist for 1906, pp. 16–76, 23 plates.

these tests the finer-grained crystalline rocks acted much better than the coarser ones. In the stones of fine texture the cracks were small and irregular, with a tendency to split off the corners. In stones of coarser texture the cracks were open and in some cases there was crumbling. Stones in which there were seams of coarser material cracked considerably more than the even-grained varieties, and banded rocks in general tended to split in the direction of the banding.

The sandstones at these extreme temperatures showed considerable variation. The coarser-grained stones and those made up of several minerals suffered worse than the finer-grained ones and those of simpler composition. A very porous stone crumbles, while dense ones resist much better. A fine-grained stone also cracks more regularly than a coarse one, and generally in the direction of the bedding planes. A sandstone with much clay or limonite in it will crack more readily than one in which the grains are bound together by silica or calcium carbonate.

The "blue" limestones suffered less in the severe tests than the crystalline white limestone, some of which flaked badly and crumbled as the point of conversion into lime was reached.

Severe flame and water tests that were made indicate the probable effects of fire on thin edges of stone, such as lintels, pillars, carving, projecting corners, etc. All classes were injured in these tests, and it is safe to say that all thin edges of stone would suffer in a conflagration, possibly so much as to need repairing. The cubes tended to peel off in concentric shells about the points of greatest attack, and similar results are observed in buildings in the burned districts of cities. Sudden cooling by a stream of water is more injurious than slow cooling.

In temperatures not exceeding 556° C. (1022° F.) there was little damage to any of the stones tested, and they resisted in the following order, the most resistant being named first: limestone, sandstone, fine-grained crystalline rocks, coarse-grained crystallines, clay rocks. At higher temperatures the stones tested resisted in the following order: fine-grained compact sandstones, medium-grained dense sandstones, fine-textured granites, fine-grained gneisses, blue limestone, open-textured sandstones, coarse granite, coarse gneiss, clay-rocks, crystalline limestone.

Stone Quarries of New Jersey.

Active or Recently Operated.

GRANITE AND GNEISS.

Morris County—

German Valley,	Gray granite,	Lyman Kice.
" "	Light gray gneiss,	" "
" "	Gray gneiss,	Chas. Anthony.
Middle Valley,		Middle Valley Trap Rock Mining Co.
Mt. Arlington,	Gray granite-gneiss,	North Jersey Stone Co., Ledgewood.
Morristown,	Gray gneiss, crushed,	P. Lubey.
"	" " "	City Quarry.
Pompton,	" " "	Colfax & Steele.
"	Pink granite,	Herbert L. Brown Co., 225 Fifth Ave., New York City.
Dover,	Light gray granite-gneiss,	Thomas Fanning.
Montville,	Gray gneiss, crushed,	D. L. & W. R. R. Co., 26 Exchange St., New York City.

Passaic County—

Haskell,	Light gray granite-gneiss,	C. Di Laura.
"	Dark greenish-black gneiss,	" " "
"	Gray gneiss, crushed,	J. P. Lange.

Sussex County—

Cranberry Lake,	White granite-gneiss,	D. L. & W. R. R. Co., 26 Exchange St., New York City.
" "	Gray granite-gneiss,	Panther Hill Granite Quarry Co., 810 Broad St., Newark.
Waterloo,	Gray and pink granite-gneiss,	Allen Granite and Construction Co., Stanhope.

SANDSTONE.

Bergen County—

Closter,	White and light gray,	Julius Gambellee, Tenafly.
"	" " " "	Taverniere & Johnson.
"	" " " "	Caesar Campanini.
Ridgefield,	" " " "	Heisenbuttle Stone Co.
"	" " " "	Stephen V. R. Martling.

Essex County—

Pleasantdale,	Brownstone,	Fred. W. Shrump & Sons.
Upper Montclair,	"	Osborne & Marsellis Co.

Hudson County—

North Arlington,	Brownstone,	Frederick A. Koch, Arlington.

Hunterdon County—

Stockton,	Light gray,	S. B. Twining Co.
Raven Rock,	White and light gray,	" " "
Byram,	Black argillite, crushed,	B. M. & J. F. Shanley Co., 26 Exchange Pl., Jersey City.

Mercer County—

Princeton,	Black and dark red argillite,	McCarthy Sons Co.
"	" " " " "	Margerum Bros.
Lawrenceville,	" " " " "	Mrs. Gertrude McC. Scudder.
"	" " " " "	New Jersey and Philadelphia Traction Co., Trenton.
Wilburtha,	Gray and brown sandstone,	Peter DeFlesco & Co.
"	" " " "	Chas. DeGrave & Bro.

Passaic County—

Passaic,	Brownstone,	Boulevard Stone Co., 358 Passaic St.
"	"	John Van Dorn, 404 Oak St.
Paterson,	"	C. Verduin, 166 Franklin St.
"	"	East Jersey Water Co., 156 Ellison St.
Albion Place,	"	The Thomas Estate.

Somerset County—

Kingston,	Brownstone,	Delaware & Raritan Canal Co., Box 236, Trenton.
Martinsville,	Gray sandstone,	Wm. E. Bartle, East Second St., Plainfield.
Watchung,	Brownstone,	Wm. E. Bartle, East Second St., Plainfield.

Sussex County—

Quarryville, ...Flagstone, ...Tannery & Hull, care of Geo. Culver.
" ...... " ....W. H. Ogden, R. F. D., No. 1, Sussex.

SLATE.

Sussex County—

Lafayette, ...Roofing slate, ...Lafayette Slate Co., A. J. Graey, Newton.
Newton, ... " " ....Newton Slate Co., Newton.

SERPENTINE AND SOAPSTONE.

Warren County—

Phillipsburg, ...Mottled green serpentine, ...Lizzie Clay and Pulp Co.

TRAP ROCK.

Bergen County—

Cliffside, ...Nicola Scioli.
" ....Thiel Contracting Co., 324 Franklin Ave., Guttenberg.

Essex County—

Caldwell, ...Essex County Pentitentiary.
" ....P. A. Matthews & Son.
Northfield, ... " " "
Cedar Grove, ...McCarthy & Sons, Princeton.
Milburn, ...C. A. Lighthipe & Son.
South Orange, ...Ludwig Batt.
" " ....Richard H. Keenan & Bro., 24 Ridgewood Road.
Upper Montclair, ...Osborne & Marsellis Co.
West Orange, ...Geo. Spottiswoode & Co., 112-114 Essex Ave., Orange.
" " ....John O'Rourke, Mt. Pleasant Ave.

Hudson County—

Fairview, ...Fairview Stone Crushing Co.
Granton, ...F. J. Marley, Little Falls.
" ....Belmont Stone Co., 3875 Boulevard, W. Hoboken.
Guttenberg, ...J. P. Diedolf, 145 Herman Ave.
" ....Joseph Devlin.
Jersey City, ...B. M. Shanley Sons Co., 859 Broad St., Newark.
" " ....O'Neill & Hopkins, Paterson Plank Road.
Secaucus (Snake Hill), ...Hudson County Penitentiary.
" " " ......New Jersey Trap Rock Co., Morristown.

West Hoboken, ... William B. Waldo, 21 Park Row, New York City.
West New York, ... Joseph Seitz, 588 Bergenline Ave.

Hunterdon County—
Byram, ... M. F. Berger Co.
Lambertville, ... B. M. & J. F. Shanley Co., 26 Exchange Pl., Jersey City.
" .... B. M. Shanley Sons Co., 859 Broad St., Newark.
" .... Lambertville Stone Quarry Co., 1220 Filbert St., Philadelphia.

Mercer County—
Hopewell, ... Joshua S. Cope.
Moore, ... Delaware River Quarry and Construction Co., 26 Exchange Place, Jersey City.
Brookville, ... Delaware River Quarry and Construction Co., 26 Exchange Place, Jersey City.
Princeton, ... Princeton Borough Quarry.
Titusville (Moore), ... M. F. Berger Co.
" " .... Mercer County Workhouse.

Morris County—
Lincoln Park, ... J. B. Salmon, Hackettstown.
Middle Valley, ... Middle Valley Traprock and Mining Co.
Millington, ... Morris County Crushed Stone Co., 15 South St., Morristown.
Whitehall (Towaco), ... A. Munson & Co., Hibernia.

Passaic County—
Mountain View, ... Helmer Hosier.
Paterson, ... F. J. Marley, Little Falls.
" .... Samuel Braen, R. F. D. No. 1.
" .... Phillip Kramer, 954 Madison Ave.
" .... McKiernan & Bergin, First National Bank.
" .... J. Smith Sowerbutt, 28 Paterson St.
" .... Paterson Crushed Stone Co., Morristown.
Great Notch, ... F. J. Marley, Little Falls.
" " .... Union Building & Construction Co., Passaic.
" " .... Francisco Bros., Little Falls.
" " .... W. A. Ferguson, Box 182, Little Falls.
" " .... Wright & Lindsley, Orange.
Preakness, ... Preakness Crushing Co., R. F. D., No. 1, Paterson.

Somerset County—
Bernardsville, ... Somerset Stone Crushing Co.
Bound Brook (Chimney Rock), . Bound Brook Crushed Stone Co., Bound Brook.

" "	Trap Rock Crusher Co.
Dunellen, ...	Dunellen Lumber & Stone Co.
"	Garrison & Gray.
Rocky Hill, ...	Delaware River Quarry & Construction Co., 26 Exchange Pl., Jersey City.
Somerville, ...	William Hardgrove, 149 W. Main St.
Warrenville, ...	E. E. Cooper, Somerville.
Scotch Plains, ...	Fanwood Stone Crushing & Quarry Co.
" "	Hatfield & Weldon.
North Plainfield, ...	N. B. Smalley & Co., Plainfield.
" "	Watchung Stone Co., 160 North Ave., Plainfield.
" "	J. H. Wilson & Co., Somerset St., Plainfield.

Union County—

Springfield, ...	R. A. Snyder Quarry Co.
"	Larson Trap Rock Co., 9 Clinton St., Newark.
"	Stewart Hartshorn, Short Hills.
Summit, ...	Commonwealth Quarry Co., 69 Union Place.
New Providence, ...	" " " " " "

LIMESTONE AND MARBLE.

Limestone quarries, many of which are operated in the State, are not listed here because they do not, at present, produce building stone except for occasional local requirements. Their products are used chiefly for flux in iron smelting furnaces, and for the manufacture of lime and cement. Most of these latter products eventually find their way into buildings and construction work of various kinds. Much of the "blue" limestone and also of the Franklin white limestone, which is strictly a marble, is entirely suitable for all the purposes of a high-class structural stone.

ACKNOWLEDGMENTS.

In the endeavor to accumulate a great variety of facts concerning widely scattered areas, the author has necessarily been placed under obligation to many people for assistance, without which a satisfactory result would have been impossible. To the owners and superintendents of many of the quarries named in the foregoing list, and to contractors, stonecutters, and dealers generally, the writer is indebted for much assistance and information. Among those not connected with the stone industry, special acknowledgment is due Dr. William S. Disbrow, of Newark, Mr. Burton H. Allbee, of Hackensack, and Mr. Gilbert Van Ingen, of Princeton, for kindly help in procuring local data

and photographs. Mr. W. S. Valiant, of the Geological Museum of Rutgers College, has rendered valuable service in connection with the laboratory examination of specimens collected. Photographs of residences have been used as illustrations with the consent of the owners, a courtesy that is much appreciated in dealing with a subject that requires illustration at almost every point.

May 15th, 1909.

PART IV.

Notes on the Mineral Industry, with Mineral Statistics.

By HENRY B. KÜMMEL.

The Mineral Industry.

BY HENRY B. KÜMMEL.

Through co-operation with the U. S. Geological Survey, the statistics of the mineral industry have been collected in a number of lines which the State Survey has not heretofore attempted. The results have justified the experiment, and it is now possible to show more fully than heretofore the extent and value of this industry in New Jersey.

The total value in 1908 amounted to $18,947,023, distributed as follows:

Value of the Mineral Industry in 1908.

	Value.	Per cent. of Whole	Increase or Decrease Compared to 1907.
Iron mining,	$1,257,076	6.63	$516,184 D
Zinc mining,	.........(a)	....	... .
Clay and clay working,	12,821,474	67.67	3,857,870 D
Stone,	1,449,867	7.65	73,445 D
Sand and gravel,	712,178	3.76	337,281 D
Portland cement,	2,420,868	12.78	1,919,022 D
Lime,	134,722	.71	32,437 D
Sand-lime brick,	20,819	.11	1,973 D
Mineral water,	126,603	.67	23,521 I
Greensand marl,	3,416	.02	....
Total,	$18,947,023	....	....

(a) Since there is but one zinc producer in New Jersey it is impossible to publish a value for the zinc ore mined, and it is not included in the total.

IRON MINING.

The iron-mining industry suffered severely as a result of the general business stagnation. Several mines which had been operated for years without interruption reported no production for 1908, while others show greatly reduced returns. The following mines were active for greater or less periods during the year: Ahles, Shoemaker, Washington, Mount Hope group, Richard, Hude, Hurd (at Wharton), Hoff, Wharton, Wood and DeCamp, Orchard and Peters. The total ore mined amounted to 432,566 long tons, all magnetite, except the product of the Ahles mine, which is a soft manganiferous ore, and that of the Shoemaker mine which is limonite. The value of all the ore at the mine was about $1,257,076, including in this total, at its estimated value, the ore of one mine whose actual value was not reported. The average value per ton of that reported is $2.94. Most of it carried from 54 to 58 per cent. metallic iron.

The reports show that 115,218 tons remained on the dumps at the mines at the close of the year.

When these figures are compared with those for 1907, they indicate a loss in tonnage of 125,571 tons, a decrease in value of $516,184, and a falling off of the average value per ton of 24 cents. From 1890, when the production was 552,996 tons, to 1897, when it was only 257,235 tons, there was a steady decrease. The year 1897 represented the low-water mark of this industry from 1864. In 1898 the production increased to 257,378 tons, and year by year for a decade there was a constant increase reaching a maximum of 558,137 tons in 1907, figures only slightly in excess of the maximum reached in 1890. In view of the general improvement in business conditions and the brighter outlook as compared to the opening months of 1908, it is not probable that the iron-mining industry of New Jersey faces another long period of stagnation and decreasing production.

Iron Ore Mined Since 1870.

Previously reported,	17,485,942
Mined in 1908,	432,566

ZINC MINES.[1]

Mr. R. M. Catlin, Superintendent of the New Jersey Zinc Company mine at Franklin Furnace reports that the mine was operated with increased production, 356,457 tons of ore being sent to the mill for concentration. This is an increase of 27,252 tons above the production of the previous year and is noteworthy as it forms almost the only exception to the well-nigh universal rule of decreased production shown in other lines.

The new Palmer shaft in the foot-wall rock was carried downward full size to 1110 feet on the incline and by winzes and raises a further distance of 202 feet was pierced, making direct connection with the surface for a distance of 1312 feet. At the 1050-foot level, a pumping station has been started, which will contain three high lift, 8-stage, 5-inch electrically driven centrifugal pumps. Most of the water will be collected in the sump at this level, and such water as may accumulate in the lower level will be raised to this station. Rails have been laid in the cross-cuts to the ore at the 300-foot, 759-foot and 950-foot levels, in which, as well as in the 1150-foot level, 6-ton electric locomotives will conduct the traffic. Acetylene lamps have now satisfactorily and entirely supplanted former illuminants.

Zinc Ore Mined Since 1880.

Previously reported,	3,380,590 tons
Mined in 1908,	356,457 tons

COPPER MINING.

The occurrence of copper in the Triassic or Newark system of rocks was discussed in the Annual Report of the State Geologist for 1906, and the various workings were there described in detail. Little or nothing can be added to what was then said regarding either the nature and occurrence of the ore or the extent of the underground workings at the various mines. Note

[1] For full discussion of the zinc mines see paper by A. C. Spencer on page 23 preceding.

should be made, however, of recent improvements in methods and equipment at the mine north of Somerville formerly owned by the American Copper Company, but now under the management of the Alpha Copper Company, and also of developments at the Pahaquarry mine in Warren County.

Somerville mine.—This mine has been frequently described in the reports of the Survey under various names: Somerville, Bridgewater, American Copper mine. The most complete descriptions of the mine and the nature and occurrence of the ore are found in the Reports for 1902 and 1906.[1] It is only necessary to say here that the underground workings which comprise several thousand feet of drifts and tunnels, demonstrate the presence of a large body of low-grade ore. The main slope is about 1,250 feet in length on a 10-degree dip to the northeast. Beyond the first 600 feet the ore carries practically only native copper. Numerous side drifts and chambers of considerable size show the continuation of the same kind of ore beyond the line of the main slope. Many openings for several miles along the face of the mountain at the same geological horizon demonstrate the occurrence at these several points of ore similar to that found in the shallower workings at the main mine. North of Bound Brook, 3.5 miles distant, another tunnel 1,000 feet in length shows ore of a similar character and in the same relationships. It is said by those familiar with these workings, some of which date back many years, that they total many thousand linear feet, but in the absence of mine maps there is much uncertainty as to the actual figures. Wherever exposed the ore is found in the trap sheet for a few inches above its base and in the upper portion of the shale, which is there somewhat indurated and changed in color. The average of 273 carefully measured sections across the ore bed, along the main slope, and in the side drifts and chambers is stated to be 2.08 feet.[2]

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[1] Weed, W. H., Annual Report of the State Geologist of N. J. for 1902, p. 125; Lewis, J. V., Annual Report of the State Geologist of N. J. for 1906, p. 131.

[2] Report furnished me by Alfred Schwarz, Manager of the mine, and made by Frederic Keffer, Engineer of the British Columbia Copper Co.

The copper occurs minutely disseminated in the shale, and also in irregularly distributed masses ranging from thin filaments and sheets to small nuggets. The ore is reported to be uniformly richer than the average at the actual contact of the trap and shale. While there is considerable irregularity in the distribution of the copper in the ore bed, yet these irregularities are local and fairly regular in their occurrence, so that taking the mine as a whole one gains the impression that the copper is rather evenly distributed. This impression is confirmed by a series of assays of 273 samples across the ore layer, taken at measured intervals along the slope, side drifts and chambers. Of these sections 52 are stated to have shown less than 1 per cent. of copper, 94 showed from 1 to 2 per cent., 64 showed from 2 to 3 per cent., 43 from 3 to 4 per cent., 5 from 6 to 7 per cent., and 7 from 7 to 8 per cent. According to this sampling the copper content averages 2.108 per cent.[1] Nothing has been observed in the mode of distribution of the ore, either in relation to the shale or to the trap, to indicate that its occurrence is limited to the vicinity of the present openings. There is nothing in the geologic structure, so far as known, or in the theories regarding the origin of the ore, which is opposed to the supposition that it extends far beyond its observed limits.

The fairly uniform distribution of the copper in the ore-bearing layer, the constant occurrence of the copper-bearing shale immediately beneath the trap, not only at the main mine, but also at the numerous other openings, and its fairly constant thickness furnish strong presumption for the belief that there is here a large body of low-grade ore, in addition to that actually blocked out and visible in the sides of the present workings. But until more extensive underground work has been done at intermediate points, it is not safe to assert that ore of similar character and value is everywhere present within the entire area bounded by the more distant explorations.

The superintendent states that the mine has been repeatedly and systematically sampled and results obtained which tallied closely. As indicated above, one series showed a trifle over 2

[1] Report by Frederic Keffer.

per cent. of copper. The others gave slightly better results. In order to work low-grade ores of this character they must be mined, milled and smelted in large amounts and at a low cost, and the loss in the tailings and slag must be reduced to a minimum.

Mining.—Since the ore occurs chiefly in a sheet of gently dipping altered shale immediately beneath a thick sheet of trap rock, the lower few inches of which is also frequently mineralized, it can be easily undercut and then shot down in large masses, where it is necessary to remove the underlying shale to secure head room. Much of the underlying shale, however, can be left undisturbed between the passageways and the ore shot out without removing much waste rock. The firm trap sheet affords a solid roof which needs no timbering. The ore can be blocked out by slopes and gangways, as is done in coal mines where the beds are horizontal or nearly so, so that many feet of working face can be readily obtained. Under these conditions mining costs ought to be low.

Milling.—The experimental mill has recently been entirely rebuilt and enlarged to a daily capacity of 350 tons. Concentration is effected by means of jigs and Wilfley tables, five of the former and three of the latter now being used. After breaking, the ore is hand cobbed as it passes along a belt elevator, the best material going directly to the smelter. Of the balance, that under one inch goes to the first jig, while the coarser material is recrushed for jigging. The second and succeeding jigs receive successively finer material, the tailings from each being recrushed before going to the next. The tailings from the fifth jig are classified before going to the Wilfley tables, so that each table deals with material of a different size. From ten to twelve tons of ore are by these means reduced to one ton of concentrates. It is stated that experimental runs show that the low-grade concentrates carry from 6 to 10 per cent. of copper, that the high-grade concentrates reach 60 per cent., and that the final tailings contain not more than 0.1 per cent. of copper. A recent analysis of a sample of tailings made in the laboratory of the Survey showed only 0.088 per cent. of copper.

Smelting.—A 35-ton reverberatory smelter has been completed, and has recently been put in operation. A sample of slag analyzed in the Survey laboratory showed 1.24 per cent. of copper. It is stated that this slag is to be further treated to recover some of this copper.

Improvements.—The changes in the mill and elsewhere have necessitated extensive improvements. All the machinery has been thoroughly overhauled and put in good condition. The boiler and engine capacity have been much increased, the mine has been equipped with an electric-lighting circuit, and the efficiency of the drills has been more than doubled.

For the first time conditions seem to be favorable for a thorough test of the value of these ores, and there is apparently good reason for hoping that the test will be economically successful. Credit is certainly due to the owners of this mine for their persistence and confidence in the possibilities of this deposit. When it is remembered that the Atlantic mine in the Lake Superior district paid dividends for many years with an ore carrying only 0.55 to 0.80 per cent. of native copper, it would seem as if efficient management only was necessary to put this mine on a paying basis, provided, of course, that the great body of ore to which all indications point shall be found to exist.

Pahaquarry Copper Mine.—The copper deposits in Pahaquarry Township, Warren County, occur in a hard gray quartzite of Silurian age which outcrops on the flank of Kittatinny Mountain several hundred feet above the river. The rocks dip steeply toward the northwest with the slope of the mountain and are exposed naturally and by stripping over a considerable area.

The copper occurs as the gray sulphide, *chalcocite,* impregnating the quartzite. Much of it is so minutely disseminated that its presence is indistinguishable with the naked eye, owing to its close resemblance in color to the rock. It occurs also in thin seams sometimes along the bedding or joint planes, sometimes within the mass of the rock. Less frequently the fractured surface of the quartzite shows dark-gray areas several inches or even a foot in diameter, where the chalcocite has partially replaced the rock. The copper-bearing rocks have been exposed for several hundred feet along the strike, and judging by numerous old shafts and tunnels opened along the sides of a deep ravine which crosses the beds, the copper-bearing rocks attain considerable depth. The facts all point to the presence of a large amount of ore-bearing rock.

It is reported that systematic sampling of the outcrop showed a copper content of about 3.25 per cent., and that the mining work which has since been done has indicated the presence of much rock which runs above these figures. As yet it has not been possible to establish the accuracy of these estimates by mill tests on large quantities of the ore.

Mining.—Since the ore beds outcrop on the hillside several hundred feet above water level, they can be worked in open cuts and quarried very cheaply with no expense for pumping and dead-work in the way of shafts, etc. A double-track gravity tramway leads from the tipple at the quarry to the mill below, where the ore is mechanically discharged into the ore bins. Under the circumstances it ought to be possible to quarry the ore and deliver it to the mill at very low costs.

Milling.—A large mill equipped with expensive machinery has been constructed for grinding, roasting and concentrating the ore. It is fitted with gas producers and a gas engine, crushers, grinders, classifiers, gas furnace and concentrating tables. The treatment proposed contemplates fine grinding of all the ore, its treatment in the furnace, concentration on tables, and shipment of the concentrates. Operations have nearly reached the stage where a fair and adequate test of the ore and method of treatment can be made. The fact that in some respects the treatment involves untried methods gives it the nature of an experiment, the outcome of which will be watched with some interest.

THE CLAY-WORKING INDUSTRY.

New Jersey ranks third of all the States in the value of its manufactured clay products, and first in the production and value of raw clay mined and sold. It is first in fireproofing (about 33 per cent. of total), second in drain tile, fourth in fire brick, sixth in common brick. It ranks second in the total value of all classes of pottery ware, being third in C. C. ware, white granite ware, etc., first in china, Delft and Belleek ware (about 58 per cent. of the whole), first in sanitary ware (about 74 per cent. of the whole), and second in porcelain electrical supplies. The total product in 1908 was valued at $12,821,474 as against $16,680,708 in 1907, a decrease of over 23 per cent. The decrease affected all lines of the industry, almost without exception, but to an unequal degree, as is shown by the detailed statements below.

Raw clay.—By far the largest amount of clay mined in New Jersey is manufactured by the miner. No attempt is made to compile statistics regarding this, as it appears in the table of manufactured products—chiefly, if not entirely, as brick and tile. However, a very considerable amount of clay, chiefly fire clay, is sold in its raw state by the miner, and it is this clay for which statistics are compiled. During 1908, clay mined and sold raw amounted to 312,717 short tons, valued at $507,780, an average of $1.62 per ton. In 1907, the figures were 440,138 tons, valued at $675,248, an average of $1.53 per ton, indicating a considerable decrease in the tonnage but a relatively higher price per ton.

The various kinds of clay mined, the number of producers, the tonnage and value are shown in the following table.

Kinds of Clay Mined and Sold in 1908.

	No. of Producers.	*Amt. in Short Tons.*	*Value.*	*Average per Ton.*
Ball clay,	4	1,134	$5,514	$4.86
Fire clay, including saggar clay,	40	234,747	382,746	1.63
Stoneware clay,	5	8,358	15,109	1.80
Brick clay,	6	25,793	28,033	1.08
Miscellaneous,[1]	14	42,685	76,378	1.79
		312,717	$507,780	$1.62

Pottery Industry.—The chief facts regarding the production in the pottery industry of New Jersey are shown in the following table. It will be seen that there was a considerable falling off in the production as compared to that of the previous year.[2]

[1] Includes Rockingham clay, pipe clay, terra cotta clay, so-called kaolin, etc.
[2] Reported by the U. S. Geological Survey.

	1907.	1908.
Number of active firms,	55	54
Red earthenware,	$21,067	$20,100
C. C. ware, white granite, semi-porcelain ware and semi-vitreous porcelain ware,	1,225,691	1,137,701
China, bone china, Delft and Belleek ware,	1,135,885	876,259
Sanitary ware,	3,615,685	3,182,771
Porcelain electrical supplies,	744,068	559,556
Miscellaneous, including stoneware, yellow and Rockingham ware, stilts, spur, pins, clay pipes, chemical ware, doorknobs, art pottery and tiles, car and druggists' earthenware,	243,230	173,604
	$6,985,626	$5,949,991

These figures show a decrease in all lines of pottery manufacture. The decrease is greatest relatively in china, and least in C. C. ware and in sanitary ware. Some items included under miscellaneous in 1908, may in the pervious year have been grouped in one or another of the other classes, so that these two totals are not strictly comparable. The total production for the State was only 85 per cent. of that of 1907.

As is well known, Trenton is the chief pottery center of the United States, its supremacy being disputed only by East Liverpool, Ohio. In 1908, the pottery products of Trenton amounted to $5,649,472, or 94.94 per cent. of the total for the State. In 1907 it was 93.32 per cent. This would seem to indicate that the Trenton manufacturers were less affected by the business depression than those in other sections of the State. Trenton produced no red earthenware, stoneware, yellow ware or rockingham ware; it manufactured, however, all the white ware, including C.C., white granite, semi-porcelain and semi-vitreous porcelain ware; all the china, bone china, delft and belleek ware; all the porcelain electric supplies made in the State, and also 94 per cent. of all the sanitary ware.

Brick and Tile.—The brick and tile industry of New Jersey, unlike the pottery industry, is not concentrated in one locality, but is well developed at many points. The various branches of the industry are, however, somewhat localized. Building brick are made in large numbers at Hackensack and Little Ferry, Sayreville and South River, Cliffwood and Keyport, and at

Trenton; fire brick at Woodbridge, Sayreville and South River; fireproofing chiefly at Woodbridge, Perth Amboy and along the Raritan River; architectural terra-cotta chiefly at Perth Amboy, South Amboy and Rocky Hill.

The total value of the manufactured product in 1908 was $6,363,703 as against $9,019,834 for 1907, a falling off of 25 per cent. This branch of the clay industry, therefore, was more depressed than either the pottery or the clay-mining industry. In nearly all lines there was both a decrease in production and in value. For example, the average selling price per thousand of common brick was $5.25 as against $5.89; of front brick $10.38 as against $13.42; of fire brick $21.79 as against $25.66. In the last case the decrease in price per thousand was more than enough to counterbalance the increased production, and the industry shows a decreased value for 1908.

The chief facts regarding the production of brick and tile are summarized in the following table:

Production of Brick and Tile in 1908 and 1907.[1]

	1908.			1907.	
	No of plants producing	No. of M.	Value.	No. of M.	Value.
Common brick,	77	300,544	$1,579,834	388,735	$2,289,883
Front brick,	9	64,301	667,682	61,521	825,767
Fancy brick,	3	62	3,619	4,605	21,869
Enameled brick,	2	} 4,320	} 241,261	not given	not given
Vitrified paving brick,	2				
Fire brick,	12	36,751	800,986	36,918	947,472
Total brick,		405,978	$3,293,382		
Draintile,	8	1,825	$30,325	....	$21,869
Architectural terra cotta,	5	.....	1,039,855	....	1,722,067
Fireproofing and hollow blocks,	12	.....	826,225	....	1,159,467
Tile (not drain),	10	.....	835,499	....	1,050,085
Miscellaneous,[2]	6	.....	338,417	....	620,482
Total, all products,			$6,363,703		$9,019,834

[1] Statistics for 1907 from the U. S. Geological Survey.

[2] Includes glass-melting pots, gas-furnace linings, underground vitrified conduits, retorts and muffles, sewer pipe, chimney brick, wall coping and stove lining.

STONE INDUSTRY.

The stone industry of the State is somewhat fully described in a preceding paper of this report,[1] so that statistics alone are given here. The production during 1908 amounted to $1,449,-867, divided as follows:

Production of Stone in 1908.

	Value.	Per Cent. of Whole.
Trap rock,	$966,714	66.6
Granite,	125,804	8.7
Sandstone,	154,422	10.6
Limestone,	172,000	11.8
Slate and serpentine,	30,927	2.2
	$1,449,867	100.0

In 1907 the production was about $1,535,000, so that these figures show a decrease for 1908.

The table below shows the value of the stone used for various important purposes. It will be noted that crushed stone formed 70.5 per cent. of the total, flux 10.3 per cent, while building stone is only 9.0 per cent. In view of the excellent qualities of much of the building stone of the State, and the nearness of the quarries to the market, there is great room for growth in this phase of the industry.

Uses of Stone and Values. 1908.

Building stone,		130,880 (9.0%)
Rough,	95,787	
Cut or dressed,	35,093	
Monument, Rough and dressed,		17,419 (1.2%)
Paving blocks,		60,843 (4.2%)
Crushed stone,		1,017,948 (70.2%)
Road metal,	609,324	
R. R. ballast,	141,750	
Concrete,	266,874	
Blast furnace flux,		149,301 (10.3%)
All other uses,		73,476 (5.0%)

[1] Lewis, J. V., p. 53.

[2] Limestone burned for lime and limestone and cement rock used in making Portland cement are not included in these figures.

Trap rock.—The trap rock industry is by far the most important branch of the stone industry of the State, its value constituting 66 per cent. of the whole. The following table shows the various number of producers, the quantities, the value and average price per unit of the different products:

Production of Trap Rock, 1908.

	No. of Producers.	Amount Short Tons.	Value.	Average Price Per Unit.
Building stone (rough and dressed)....	10	9,630	$11,399	$1.18
Road metal, ...	48	725,782	578,570	.80
R. R. ballast, ...	7	106,419	69,555	.65
Concrete, ...	27	318,390	235,967	.74
Paving blocks, ...	12	(1,666 M.)	58,169	34.91
Other uses, ...	..	18,049	13,054	.71
		1,178,270	$966,714	

In 1907, according to the U. S. Geological Survey report, the total value of trap rock was $995,436. Railroad ballast, and miscellaneous uses show aggregate losses which more than balance the gains shown by building stone, road metal, concrete and paving blocks.

Granite.—Fifteen quarries are reported as having been producers of granite during 1908. The total production was valued at $125,804, or 8.7 per cent. of the whole. In 1907 it was $77,757,[1] all classes except rubble and dressed stone for building showing marked increases. This increase in figures is due in part at least to the more complete returns made possible by cooperation between the State and U. S. Surveys. In spite of the fact that the State affords admirable granite for building purposes, as shown by Lewis in his paper on the building stones in another part of this report, the value of crushed granite for roads, ballast and concrete was far in excess of that of all other uses.

The production of granite was divided as follows:

[1] Reported by the U. S. Geological Survey.

	No. of Firms Reporting.	Value.	
Sold Rough—Building,	8	$11,910.	
" " Monumental work,	4		
" " Other purposes,	2	9,919.	
Dressed—Building,	3		
" Monuments,	2	14,098.	
Paving Blocks,	2		$25.00 per M.
Rubble,	1	3,424.	
Riprap,	1		
Crushed stone for			per ton.
Road making,	2	80,395.	.75
R. R. Ballast,	2		.44
Concrete,	4	6,058.	.65
		$125,804	

Limestone.—The limestone statistics do not include the amount nor value of the limestone used in the manufacture of lime and Portland cement, since that appears in the report of those two industries.

Production of Limestone in 1908.

Uses.	*No. of Producers.*	*Amount.*	*Value.*	*Average Per Unit.*
Road metal,	5	36,826 net tons	$20,827	$0.58
Concrete,	2			0.60
Blast furnace flux,	10	318,455 gross tons	149,301	0.47
Building stone,	2		1,872	
Other uses,	2			
			172,000	

White limestone.—Of the limestone used for flux 297,582 gross tons, or 94 per cent., was the white crystalline limestone (Franklin limestone), the balance being the blue magnesian or Kittatinny limestone. In addition there was quarried 208,087 tons of the white limestone for cement, and about 34,250 tons for lime. The total production of white limestone for all purposes was about 532,323 tons, a loss of 20,342 tons over 1907.

Sandstone.—Under the head of sandstone are included brownstone, gray sandstone, black argillite and quartzite, all of which are quarried in New Jersey. The value of the sandstone was $154,422, or 10.6 per cent. of the total—a decrease of $23,245 as compared to 1907.

The different uses and value of each is shown in the following table:

Production of Sandstone in 1908.

Uses.	*No. of Producers.*	*Value.*	*Per cent.*
Building Stone—			
Rough,	15	$72,693	47.3
Cut or dressed,	9	28,905	18.5
Rubble,	3	22,998	15.0
Road metal,	3	4,260	2.7
Concrete,	5	22,316	14.5
Curbing,	1		
Flagging,	2	3,250	2.0
Other purposes,	1		
		$154.422	100.

Slate.—Roofing slate was quarried both at Newton and Lafayette during 1908, but inasmuch as there were only two producers, the value of the slate produced has been included with that of talc and serpentine.

Serpentine and talc.—A rock composed of an intimate mixture of serpentine, tremolite and talc—chiefly the former—is quarried near Phillipsburg. It is largely ground to powder in the manufacture of mineral pulp as filler for paper.[1] In some portions of the quarry a dark-green rock is found, which, on polishing, makes a beautiful stone for interior decoration.[2]

Since there is only one producer, the value of this stone has been combined with that of slate. The combined value of the slate and serpentine quarried in 1908 was $30,927.

SAND AND GRAVEL.

The compilation of accurate statistics of the sand and gravel production is extremely difficult, owing to the large number of small producers whose pits are intermittently worked, and who

[1] Annual Report of the State Geologist for 1904, p. 161.
[2] J. V. Lewis, Plate XXI, p. 112.

rarely keep an account of their operations. While it is too much to expect that all the small producers have been included, it is not probable that returns from any large miner have been omitted. The amount mined is reported in tons, cubic yards, loads, and the units are frequently so indefinitely described that with the exception of the glass sand, no attempt has been made to show the quantity mined; values only being given.

Practically all the sand sold in New Jersey is natural as distinct from crushed rock, only a very small amount of the latter being reported. As shown by the table below, the uses of sand are various, building and molding sands being the two most important grades.

Production of Sand and Gravel in 1908 and 1907.

	No. of Producers.	Value for 1908.		1907.[1]
Building sand—				
Unclassified,	5	$32,963		
Concrete sand,	37	169,531		
Mortar sand,	16	71,924		
			$274,418	$197,996
Molding sand—				
Unclassified,	6	$104,355 (Unclassified and Brass molding)		
Brass molding,	2			
Steel molding,	18	40,208		
Iron molding,	8	13,964		
Core molding,	19	28,017		
			186,544	381,403
Glass sand,	10	(56,775 tons)	46,379	73,914
Fire sand,	12		60,667	81,963
Engine sand,	5		16,437	14,611
Furnace sand,	7		3,474	3,257
Filter sand,	4		10,990	231,742 (Filter sand and Other sand)
Other sand,	15		31,933	
Total sand,			$630,842	
Concrete gravel,	13		25,135	
Road-making gravel,	13		56,114	
Other gravel,	1		87	
			$81,336	60,373
Total sand and gravel,			$712,178	$1,045,259

[1] Statistics by the U. S. Geological Survey.

[2] Includes sand for asphalt, stone polishing, glass cutting, pottery molds, grading and top soil.

The above figures show a decided falling off in the total production for 1908, with decreases in molding sand, glass sand, fire sand, miscellaneous grades, and increases in building sand, engine sand, furnace sand and gravel.

THE PORTLAND CEMENT INDUSTRY.

The Portland cement industry shows a considerable decrease in production as compared to 1907, and a very marked falling off in prices. The three plants in Warren County report a total production of 3,208,446 barrels, valued in bulk at the mill at $2,420,868, or 75 cents per barrel. In 1907 the production was 4,517,453 barrels, valued at $4,344,090, or 96 cents per barrel, according to figures furnished the State Survey by the manufacturers. These figures show a production of 71 per cent. and a valuation of 56 per cent. as compared to the previous year. It is estimated that about 1,548,000 tons of cement rock and limestone were used to produce this amount of cement.

All the mills were shut down part of the time or ran at a greatly reduced output, and the year closed with large stocks on hand.

The three large mills in Warren County and a small mill at Perth Amboy, which has not been a producer for several years, report 58 kilns, varying in length from 60 to 150 feet. The reported daily capacity of these mills is 17,550 barrels. On this basis their yearly capacity is 6,405,750 barrels, making no allownces for shut downs. The actual production for the year was therefore almost exactly 50 per cent. of the capacity.

The writer took occasion a year ago to utter a word of protest against the misleading and highly exaggerated statements made by promoters regarding profits in the Portland cement industry. This protest was copied by some of the cement journals and building trade papers even as far west as Portland, Oregon, so that it received wide circulation. The ratio between actual production and capacity of present plants, and the prices during the past year only serve to emphasize the assertions then made. Conditions during 1908 have naturally been unfavorable for promoting enterprises of this kind, but with a revival of activity in all lines of construction, many new cement promotions will unquestionably be put before the public. Some of these may possess a fair chance of commercial success. It is safe to say, however, that many of them will serve only as a means of enriching the promoters at the expense of unwary investors. Too much emphasis cannot, therefore, be laid upon a few fundamental facts:

1. The present capacity of the mills of this State and of the industry as a whole is far in excess of the present consumption of cement, and is more than able to provide for any probable increase in the near future.

2. The margin of profit in cement manufacture is very small at the prices which will inevitably prevail during periods of business depression.

3. New companies capitalized far in excess of the actual cost of land, mill and working capital have small chance of success.

4. It is not easy to find a market for a new brand of cement in competition with well-known brands of established reputation, except at reduced prices.

LIME.

In order to avoid duplication of product, the value of the limestone used in making lime is not included in the statistics of limestone in the stone industry.

During 1908, 32,700 short tons of lime, valued at $134,722 were manufactured and sold. This was a decrease of 1,343 tons, of $32,437 in value and of 69 cents in the average value per ton as compared to 1907. Of this lime, considerably more than one-half was made from the white crystalline limestone, the balance being chiefly from the blue magnesian rock. The various uses, number of producers, amount, value and unit prices are shown in the following table.

Production of Lime in 1908.

Uses.	*No. of Producers.*	*Amount Short Tons.*	*Value.*	*Value per Ton.*
Fertilizer,	19	12,984	$33,938	$2.61
Quick Lime,	3	3,721	19,500	5.24
Dealers,	2	......	....	5.64
Hydrated lime,	1	15,995	81,284	......
Paper mills,	1			
Other uses,	1	......	....	......
		32,700	$134,722	$4.12

Fuel.—Seventeen plants used coal for fuel, two used wood, one wood and coal, one coal and gas. Omitting the mixed fuels, the amount of wood and coal used, and the lime made from each are as follows:

Fuels Used and Amount of Lime Burned With Each.

Kind of fuel.	*Quantity of Fuel.*	*Quantity of Lime Burned.*	*Amount of Fuel per Ton of Lime.*
Coal,	3,968 tons	14,889 tons	0.27 tons
Wood,	120 cords	168 tons	0.73 cord

One ton of coal to 100 bushels of lime seems to be a generally accepted rule in burning the blue or magnesian limestone, while a considerably greater amount of coal is used in burning the white limestone, which contains much less magnesian carbonate.

SAND-LIME BRICK.

Sand-lime brick were manufactured by four companies in 1908, the factories being located at Passaic, Penbryn, South River, and Atlantic City. Several additional plants were in process of construction and may be producers in 1909.

The total value of the brick sold was $20,819, divided into 840 M. common brick, valued at $6,270, and 1192 M. front brick, valued at $14,549. The average value of the common brick was $7.46 per thousand and of the front brick $12.20 per thousand.

MINERAL WATERS.

The use of bottled spring water for drinking, in preference to the public supplies under municipal or corporate control, is steadily increasing. Returns have been received from 13 individuals or companies selling bottled spring water from New Jersey in 1908. From these it appears that the sales amounted to 1,199,023 gallons, valued at $126,603, or an average of about 10½ cents per gallon retail at the spring. The retail price, delivered, varied from 7 to 20 cents per gallon, while the wholesale price at the spring ranged from 6 to 10½ cents.

In addition to the amount sold for table use, 7,650 gallons were reported sold for making soft drinks, the value of which is not included in these totals.

In 1907, the U. S. Geological Survey reported 982,445 gallons sold, valued at $103,082, an increase in 1908 of 216,578 gallons in sales and $23,521 in value.

GREENSAND MARL.

The amount of greensand marl now dug is only a small fraction of that formerly utilized. Most of it is used on the farm where mined, although some is shipped to the fertilizer factories. Returns were received from thirteen producers, indicating that about 8,246 short tons, valued at about $3,416, were dug in 1908, but owing to the indefiniteness of some returns these figures may be slightly in error.

May 20, 1909.

PUBLICATIONS.

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.

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.

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 distridution 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, 25 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.)

REPORTS 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.) (To residents of New Jersey, by express, charges collect; to non-residents, $1.50, charges prepaid.)

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

II.) (To residents of New Jersey, by express, charges collect; to non-residents, $1.40, charges prepaid.)

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

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

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, 9, 11, 12, 13, 15, 16 and 17 have already been replaced as explained below.

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. 29. Monmouth Shore, with the interior from Ernston to Lakehurst. Replaces Sheet 9. Will probably be ready in September.

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.

GEOLOGIC ATLAS OF NEW JERSEY.

The State Geological Survey, in co-operation with the U. S. Geological Survey, is engaged in the publication of a Geologic Atlas of New Jersey. It will be issued in several parts, each part containing a complete discussion of the geography and geology for the region covered. Each volume will comprise (1) pages of descriptive text, (2) a topographic map, (3) geologic maps showing the distribution and structure of the various rock formations, the occurrence of all mineral deposits of economic importance, and (4) in some cases pages of half-tone illustrations. The following folios are now ready:

THE PASSAIC FOLIO, which covers the region from Morristown to Jersey City, and from Perth Amboy and New Brunswick to Pompton and Westwood, comprising 945 square miles; scale, 2 miles to an inch. It includes 27 pages of text, a topographic map, 3 geologic maps and a page of illustrations. Price, 25 cents; postage, 15 cents; if sent by express, charges collect.

THE FRANKLIN FOLIO covers the territory from Branchville and Newton, on the west, to Stockholm on the east, and from Andover and Petersburg, on the south, to Libertyville on the north, or 235 square miles; scale, 1 inch to a mile. In addition to the regular text and maps it includes a special study and description of the famous zinc deposits at Franklin Furnace, and of the white crystalline limestones. Price, 25 cents; postage, 15 cents extra; if sent by express, charges collect.

THE PHILADELPHIA FOLIO covers parts of New Jersey and Pennsylvania adjacent to Philadelphia. It is a double folio (scale, 1 inch per mile), having four topographic maps, four geologic maps, two maps showing, by means of cross sections, the geological structure and the relation of the various rock formations to each other below the surface, a page of illustrations and twenty-four pages of descriptive text. Price, 50 cents; postage, 15 cents extra; if sent by express, charges collect.

THE TRENTON FOLIO, covering the region north, east and south of Trenton, as well as the adjacent part of Pennsylvania, is in the hands of the engravers, and will be completed as rapidly as possible.

Other folios will be prepared and issued from time to time until the entire State is covered.

Orders for these folios should be addressed to the State Geologist, Trenton, N. J., and *remittance must accompany the order.*

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, 8 vo., 220 pp., with map. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1881. Trenton, 1881, 8vo., 87+107+xiv. pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1882. Camden, 1882, 8vo., 191 pp., with maps. Out of print.

ANNUAL REPORT of the State Geologist of New Jersey for 1883. Camden, 1883, 8vo., 188 pp. (Price, 50 cents.)

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

ANNUAL REPORT of the State Geologist of New Jersey for 1885. Trenton, 1885, 8vo., 228 pp., with maps. (Postage, 9 cents.)

ANNUAL REPORT of the State Geologist of New Jersey for 1886. Trenton, 1887, 8 vo., 254 pp., with maps. (Postage, 9 cents.)

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

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

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

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

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.)

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