BULLETIN 64

TRAP ROCK MINERALS OF NEW JERSEY

by

BRIAN H. MASON
Curator of Physical Geology and Mineralogy
The American Museum of Natural History

State of New Jersey
Department of Conservation and Economic Development
SALVATORE A. BONTEMPO, *Commissioner*

Division of Planning and Development
KENNETH H. CREVELING, *Director*

Bureau of Geology and Topography
KEMBLE WIDMER, *State Geologist*

TRENTON, NEW JERSEY

1960

CONTENTS

ILLUSTRATIONS

THE MINERALS OF THE NEW JERSEY TRAP ROCKS

by Brian H. Mason

Curator of Physical Geology and Mineralogy
The American Museum of Natural History

Abstract

The trap rocks of New Jersey are intrusive into and interbedded with Triassic sedimentary rocks of the Newark Series. In many places these rocks contain fine specimens of zeolites and other secondary minerals. This paper gives a brief description of the geological setting and paragenesis of these minerals, followed by individual descriptions. The following minerals are described: actinolite, albite, allanite, analcime, apatite, anhydrite, apophyllite, aurichalcite, axinite, azurite, babingtonite, bornite, barite, calcite, chabazite, chalcocite, chalcopyrite, chlorite, chrysocolla, copper, covellite, cuprite, datolite, dolomite, epidote, galena, glauberite, goethite, gmelinite, greenockite, gypsum, hematite, heulandite, hornblende, laumontite, malachite, mesolite, natrolite, opal, orpiment, orthoclase, pectolite, prehnite, pumpellyite, pyrite, pyrolusite, quartz, scolecite, siderite, silver, sphalerite, sphene, stevensite, stilbite, stilpnomelane, talc, thaumasite, thomsonite, tourmaline, ulexite. Occurrences of the following minerals are discredited or unconfirmed: allophane, aragonite, arfvedsonite, chloanthite, chrysotile, deweylite, epistilbite, erythrite, fluorite, genthite, kaolinite, magnesite, rhodochrosite, serpentine.

Introduction

The trap rocks of northern New Jersey have been famous among mineralogists for over a century because of the variety and beauty of the zeolites and associated minerals found therein. As early as 1822 Nutall recorded prehnite, natrolite, chabazite, stilbite, and datolite from Paterson. Railroad construction, beginning in the 1830's, resulted in numerous cuttings in the Palisades diabase of Bergen Hill, near Jersey City, which produced good specimens in abundance. In 1840 Bourne described calcite, stilbite, pyrite, heulandite, laumontite, prehnite, datolite, analcime, natrolite, apophyllite, chabazite, sphalerite, and galena from railroad cuts in Bergen Hill. Later in the nineteenth century the demand for crushed rock in the northern New Jersey area led to the opening of numerous quarries both in the Palisades diabase and in the thick basalt sheets of the Watchung Mountains. From these quarries a wealth and variety of beautiful mineral specimens were obtained, and thanks to the efforts of collectors and dealers, these specimens have enriched museum and private mineral collections throughout the world. To the mineralogist the New Jersey trap rocks rank with similar occurrences in Nova Scotia, Iceland, and the Deccan of India for the quality and variety of their zeolites and associated minerals.

The literature on the minerals of the New Jersey trap rocks is extensive. Most of the recent papers, and the more important of the older publications, are listed in the references accompanying this bulletin. A very complete bibliography of publications up to 1931, and lists of minerals for each locality, form part of Manchester's book "The Minerals of New York City and Its Environs" published by the New York Mineralogical Club in 1931. This book is now out of print. A later publication which contains a great deal of general information and excellent illustrations is "The Crystal Cavities of the New Jersey Zeolite Region" by W. T. Schaller (U.S. Geological Survey Bulletin 832, 1932).

The location of many of the older quarries which were worked in the early years of this century are marked on the maps of the Passaic, Raritan, and Trenton folios of the Geologic Atlas of the United States (published by the U.S. Geological Survey, but now out of print). The locations of working quarries are marked on the current quadrangle maps published by the U.S. Geological Survey; the relevant quadrangles are (from north to south): Paterson, Orange, Caldwell, Roselle, Chatham, Bernardsville, Bound Brook, Monmouth Junction, Stockton, Pennington, and Lambertville. Locations are also shown on the New Jersey State Atlas sheets #22 through #28.

Geological Setting

The geological setting of the New Jersey trap rocks (Fig. 1) was described by Johnson (1957) as follows:

"'Trap Rock' representing both extrusive basalts and intrusive diabase and gabbroic rocks has been quarried in New Jersey for nearly 100 years. It has been used for road metal, railroad ballast, aggregate, rip-rap and jetty stone and generally it has been found to be good to excellent for these various uses, based upon properties such as specific gravity, reactivity, resistance to abrasion, bonding characteristics, etc. Because of their resistance to erosion in relation to the sedimentary rocks that border them (Triassic shales, sandstones and argillites)

these rocks form topographic highs that favor quarry face openings, especially in the Watchung Mountains. Coupled with access to the existing traffic pattern of the railroads of the early 20th Century, most of the quarries were developed along the first of the three Watchungs and still remain there, but some were also operating in the Palisades Sill in the Jersey City area early in the century and in the Sourland and Rocky Hill intrusives of west-central New Jersey. The extensive industrialization of New Jersey, the development of the greatest highway network of any state in the union, and the continuing battle against beach erosion of its 125 miles of sandy shore, has resulted in ever-increasing amounts of trap quarried in the state, despite zoning restrictions and the encroachment of residential districts into favorable outcrop areas.

"The basalt flows crop out in three ridges called the First, Second and Third Watchung Mountains. The basalts of the ridges are separated stratigraphically by sandstone and shales of the upper Newark group of Late Triassic (Karnic) age, and similar sediments also overlie the basalt of the third ridge. The flows and interbedded sediments form a canoe-shaped syncline and are cut off by the "border fault" that separates the Triassic piedmont from the pre-Cambrian terrain to the northwest (see map, Fig. 1).

"Although each of the ridges consists of multiple flows, there are only slight differences in the composition of the various sheets (Lewis, 1906, 1907). In areas that have been sampled or drilled, as many as four zones of amygdaloidal basalt have been encountered, marking the tops of flows. As might be expected, the tops of the flows or the zones of vesicular trap roll considerably, and each individual flow does not have nearly the lateral continuity that previous investigators anticipated. Ropy flow-structures are a common feature at the upper surface of the various flows, and considerable brecciation may be seen at the contacts. Except for the vesicular zones which are glassy and filled with a variety of secondary minerals, the rocks are generally fine granular to aphanitic. Rarely there are visible phenocrysts in a dense ground mass. Occasional beds of red-colored tuffs have been encountered in drill cores at Millington, Summit and Oldwick (New Germantown).

"Microscopically the rock varies from a brown structureless glass to a fine-grained granular or ophitic augite-plagioclase rock with magnetite grains and olivine crystals. Phenocrysts of augite, and less commonly of feldspar, represent an earlier stage of crystallization (Lewis, 1907). As might be expected, vugs and cavities are fairly common and are usually lined with quartz, zeolites and associated silicate minerals, calcite, and rarely aragonite. The paragenesis of these secondary minerals has been described in detail (Fenner, 1911).

"No source vents have been recognized with certainty but numerous intrusive basic dikes cut the Brunswick shale stratigraphically below the First Watchung Mountain as well as other parts of northern and central New Jersey. It is barely possible that they represent fissure fillings which fed the flows.

"The diabase intrusives, like the basalt areas, form rather prominent topographic highs. They crop out in the Palisades of the Hudson, in Rocky Hill, Sourland Mountain, Cushetunk Mountain, Round Mountain and elsewhere in the Piedmont belt of New Jersey. Structurally they occur as thick sheets or sills that are concordant with sedimentary rocks above and below them. Prominent north-south joints at right angles to the sheet and secondary joints in an east-west direction sometimes develop into small offset faults. Horizontal sheeting and platy-jointing are especially prominent in the Palisades from Jersey City northward (Lewis, 1907). Here, differentiation by gravity during crystallization has produced an olivine rich facies that can be examined at Fort Lee, New Jersey. Megascopically the rock shows considerable variation along its nearly 100 miles of outcrop, but in general it is a dark gray to medium gray rock with locally developed greenish tints developed in the altered chloritic parts. The texture is medium to coarse with porphyritic facies at or near the contacts (Lewis, 1906; 1907). It is said that this rock where quarried is the densest, most resistant rock used as aggregate in the state.

"Microscopically the typical diabase consists of augite, plagioclase feldspar, quartz, orthoclase and magnetite in that order of abundance. The olivine facies already referred to consists of nearly pure, granular olivine. It contains a nearly uniform distribution of lath-shaped feldspar crystals and Lewis determines it as a quartzose diabase.

"Only three quarries operate the diabase for aggregate, partly because of unfavorable geographic location and the blasting characteristics that are more difficult and costly than in the basalt, due to differences in the jointing."

Paragenesis

Schaller (1932) has discussed in considerable detail the sequence of formation of the different minerals of the trap rocks, and distinguishes six periods of mineralization. He summarizes these periods (Table 1) as follows:

"Period 1. Solidification of basaltic glass and trap rock.

"Period 2. Saline period. Anhydrite and glauberite begin to form. Both crystallize out and replace the already formed lava rock. Considerable overlapping of periods 1 and 2. Additional water has come in from outside sources, and silica now becomes stable as an individual compound and comes out as quartz.

"Period 3. Quartz period. Much quartz forms, replacing the lava but not the anhydrite or the glauberite, because the solutions, having partly attacked the lava, are supersaturated with silica and are about saturated with anhydrite and glauberite and therefore are neutral in their reaction to the already formed sulphates. Glauberite stops forming and begins to dissolve.

"Period 4. Prehnite period. Additional water again comes in, and the solutions are no longer saturated with glauberite and begin to dissolve it, but they are nearly saturated with calcium sulphate and therefore still remain neutral to anhydrite. Glauberite is mostly dissolved away. Rhombic cavities are formed. Anhydrite stops forming. The excess of lime and soda added to the solutions throws out the minerals of period 4, all high in lime. Thus prehnite, for example, forms before the anhydrite is attacked and dissolved and coats and preserves it. Anhydrite begins to be dissolved when the solutions are impoverished in lime by the precipitation of prehnite, datolite, and pectolite and by additional water coming in. The solutions are now no longer saturated or neutral with reference to anhydrite. Rectangular cavities are formed. Anhydrite is dissolved except that which is protected by lava or quartz from the action of solutions.

"Period 5. Zeolite period. The abundance of zeolites is partly due to the increased content of lime and soda, supplied by the saline minerals, anhydrite and glauberite.

"Period 6. Calcite period. Any remaining anhydrite may be changed to gypsum and to thaumasite."

This scheme applies to that part of the First Watchung Mountain between Paterson and Upper Montclair, where crystal cavities after glauberite and anhydrite are common and abundant. The introduction of glauberite and anhydrite, and their subsequent solution to produce these cavities, resulted from the outpouring of the Watchung basalts into saline lakes which evidently existed in this region in Triassic times. In other areas of the Watchung basalts, and in the intrusive diabases, no glauberite and anhydrite crystallized and therefore no crystal cavities were formed. In these areas, Period 2 of Schaller did not occur. The remaining periods were much as Schaller describes them, with the omission of complications produced by the solution of anhydrite and glauberite. Similarly in these areas we find no

TABLE 1.—*Sequence of principal minerals in the New Jersey trap rocks* (After Schaller)

MINERAL	PERIOD 1	PERIOD 2	PERIOD 3	PERIOD 4	PERIOD 5	PERIOD 6
Labradorite	—					
Augite	—					
Olivine	—					
Magnetite	—					
Anhydrite		—	......rectangular and lamellar cavities......	......rectangular and lamellar cavities......	......rectangular and lamellar cavities......	
Glauberite		—	......rhombic cavities......	......rhombic cavities......	......rhombic cavities......	
Gypsum						—
Thaumasite						—
Albite			—			
Quartz			—			
Babingtonite			—	—	—	—
Calcite				—	—	—
Prehnite				—		
Datolite				—		
Pectolite				—		
Apophyllite					—	
Chabazite					—	
Gmelinite					—	
Heulandite					—	
Stilbite					—	
Natrolite					—	
Mesolite					—	
Scolecite					—	
Chalcopyrite					—	
Pyrite					—	
Goethite						—
Malachite						—

gypsum or thaumasite in Period 6, since there is no anhydrite to provide the necessary sulphate ions.

The sequence of formation of the principal minerals is given in Table 1.

Localities

The localities for the minerals fall naturally into three groups: (a) those in the Palisades sill; (b) those in the Watchung basalts; (c) those in the diabase intrusions between the Raritan River and the Delaware River.

The localities in the first group are often referred to under the general name Bergen Hill, which applies to that section of the Palisades ridge extending from Bergen Point to Edgewater, in which most of the tunnelling and quarrying has been concentrated, and from which practically all the fine mineral specimens have been derived. In going from south to north the principal municipalities, which have been quoted as mineral localities, are as follows: Bayonne, Jersey City, Hoboken, Union City, Weehawken, West New York, Guttenberg, and Edgewater. The actual localities have generally been the railroad cuts and tunnels, the principal ones being as follows (also from south to north): (1) Pennsylvania Railroad cut; (2) Bergen Archways and Erie Railroad tunnel; (3) Delaware, Lackawanna & Western Railroad tunnels; (4) Pennsylvania Railroad tunnels; (5) West Shore Railroad (New York Central System) tunnel; (6) New York, Susquehanna and Western Railroad tunnel; of these 1, 2, and 3 are in Jersey City, 4 and 5 in Weehawken and Union City, and 6 in Edgewater (also referred to as Shady Side).

Mt. Pleasant was a spur of Bergen Hill, jutting out on the east side; it was completely removed by the Pennsylvania Railroad to make room for a car yard and roundhouse.

It should be noted that the serpentine, brucite, dolomite, hydromagnesite, and magnesite recorded from Hoboken did not come from the trap rocks, but from a serpentine body at Castle Point.

Snake Hill (also known as Laurel Hill) is an offshoot of the Palisades sill in the marshes of the Hackensack River, about two miles west of Jersey City. The county jail is located on the hill, and the quarry is often referred as to the Penitentiary Quarry.

The Watchung basalts form three more or less parallel ridges, the First (easternmost), Second, and Third Watchung Mountains. The greatest abundance and variety of minerals have been found in the First Watchung Mountain. Quarries in the Second and Third Watchung Mountains have produced little in the way of mineral specimens. However, even in the First Watchung Mountain many quarries are practically barren of minerals. The finest and most abundant specimens have come from quarries working in pillow lavas, whereas quarries working massive or columnar basalts usually produce few or none of the secondary minerals.

From north to south along the First Watchung Mountain, quarries have been operated at Hawthorne, Paterson, Great Notch, Upper Montclair, Eagle Rock, West Orange, Maplewood, Short Hills, Summit, Mountainside, Scotch Plains, Plainfield, Bound Brook (Chimney Rock), and Hilltop. The most productive quarries have been in the Paterson - Great Notch - Upper Montclair area, and the following are often referred to as specific localities:

Prospect Park quarry, also known as Vandermade and as Sowerbutt quarry, in the Prospect Park section of Paterson, at the end of Planten Avenue. This quarry was opened in 1920 and is still operating.

Hoxie's quarry, half a block south of Union Avenue and Marion Street, Paterson. This quarry was worked in the latter part of the last century. It was closed about 1891 and is now built over.

McKiernan and Bergin's quarry, on McBride Avenue in West Paterson, sometimes referred to as Hawkins quarry. It was worked in the latter part of the last century and the early years of this, being closed down about 1916.

New Street quarries, located on both sides of New Street, in West Paterson. Local collectors distinguish the old or upper quarry (worked 1893-1925) on the east side of the road from the new or lower quarry (worked 1900-1936) along the railroad track. The old or upper quarry is also known as Burger's quarry.

Great Notch quarries. There have been several quarries in the Great Notch area, two of which are still working. However, the one that produced the great abundance of fine specimens was the Francisco Bros. quarry, situated about 300 yards southwest of the Great Notch station of the Erie Railroad. It was worked from 1905 to 1922. The quarries in the Great Notch area have been well described by Sachs (1940).

Upper Montclair quarry, also known as Osborne and Marsellis quarry, or McDowell's quarry. Situated on Edgecliff Road in Upper Montclair, it was worked from about 1890 to 1918. It has been described by Drake (1943).

The diabase intrusions between the Raritan and Delaware Rivers have been quarried at a number of places, notably at Rocky Hill, about four miles north of Princeton; near Hopewell; on the northeast end of Pennington Mountain; and at several places on the Delaware River near Lambertville—2½ miles north of Lambertville, on Mt. Gilboa; on Goat Hill, one mile south of Lambertville (Barber and Ireland's quarry); on Belle Mountain, 2½ miles south of Lambertville (Mercer County Workhouse quarry); and at Moore (also known as Moore's Station); on the western end of Baldpate Mountain, 3 miles south of Lambertville.

The list of the active traprock quarries (1959) indicating their location and the quarry owners, former and present, is as follows:

Present Owner

Houdaille Industries, Inc.:
Locations: Great Notch (formerly owned by Consolidated Stone and Sand Company)
Bound Brook (Chimney Rock), Summit, Millington } Formerly owned by North Jersey Quarry Company

Sowerbutt Quarries, Inc.:
Location: Prospect Park (Planten Ave.)

Kingston Traprock:
Locations: Rocky Hill, Pennington Quarry, Lambertville Quarry } Formerly owned by Lambertville and Pennington Quarry Companies

Sam'l Braen's Sons:
Locations: Haledon (Harrisburg Turnpike), Hawthorne } Formerly owned by Sowerbutt Bros.

Fanwood Stone Crushing & Quarry Company:
Location: Scotch Plains

Great Notch Corp.:
Location: Great Notch

M. L. Kernan Quarry:
Location: South Orange (500 Tillou Rd.)

Mercer County Workhouse:
Location: Moore

Orange Quarry Company:
Location: West Orange (Eagle Rock Avenue)

Barlow Materials Company:
Location: Oldwick (formerly owned by Preen Crushed Stone)

Union Building & Construction Corp.:
Location: Clifton (Valley Road)

Somerset Crushed Stone Company:
Location: Bernardsville

The Zeolite Group

The minerals of the zeolite group are probably the best known and most characteristic of the secondary minerals of the New Jersey trap rocks. Fine specimens from Bergen Hill, Paterson, and Great Notch can be seen in museums all over the world. For the scientifically minded, these minerals have an attractiveness and interest over and above their aesthetic appeal. To the geologist, their relationship to the enclosing rock and the cause and manner of their deposition are matters of great significance. Their mode of occurrence indicates that they were deposited from aqueous solutions at moderate temperatures after the trap rock had crystallized. The veins and pockets in which they are found have many similarities with metalliferous veins, and a full understanding of the processes involved in the formation of the zeolites would be of the greatest value in interpreting many features of the economically important metalliferous deposits. To the geochemist, the zeolites are intriguing as a group including a large number of minerals with similar and even overlapping compositions, and much laboratory work on the synthesis of these minerals and their stability fields has been carried out in recent years. Finally, the zeolites have now achieved industrial importance; their peculiar properties, especially of adsorption of gases, promise significant commercial applications.

At this point we should perhaps have a clear concept of what minerals are zeolites and why they are considered to form a distinct group. They can be defined as follows:

"The zeolite minerals are hydrated aluminosilicates of the alkali and alkaline earth elements, which can lose a part or the whole of their water without change of crystal structure."

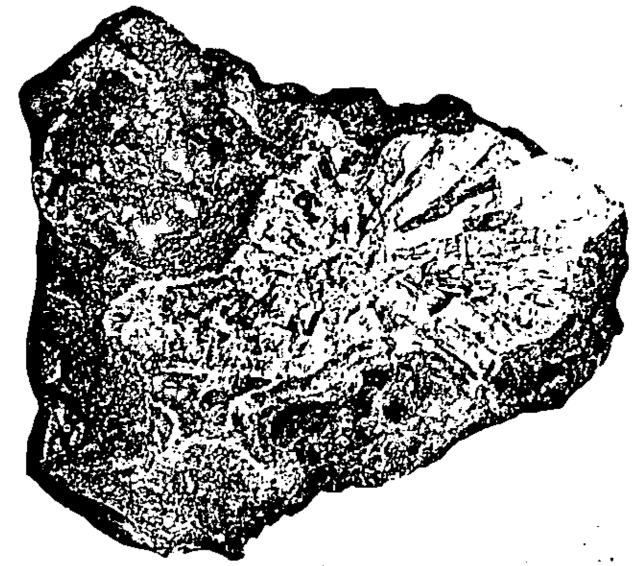

FIGURE 2. Radiating tabular crystals of anhydrite partly replaced by thaumasite. New Street Quarry, Paterson, N. J. (AMNH No. 18199).

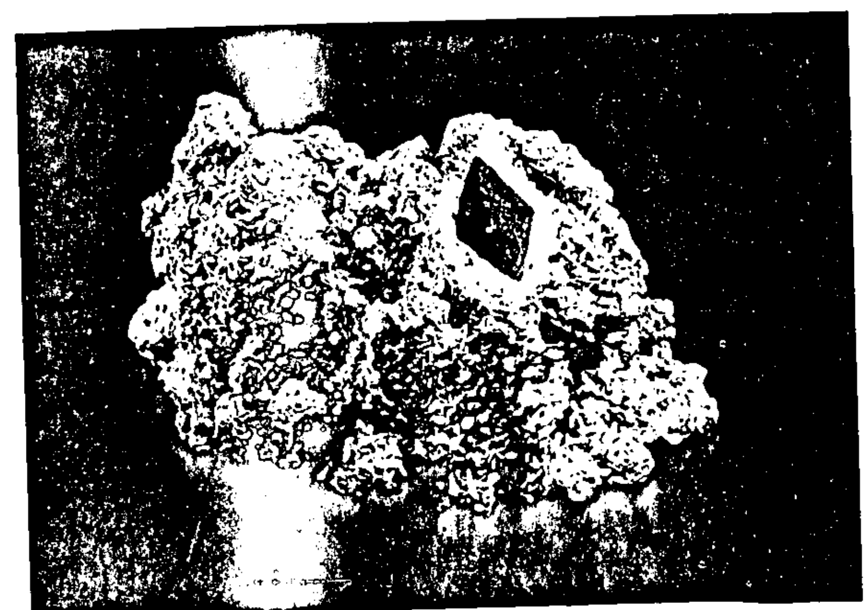

FIGURE 3. Rhomboidal cavity in quartz, after glauberite, the small white crystals are stilbite. West Paterson, N. J. (AMNH No. 18213).

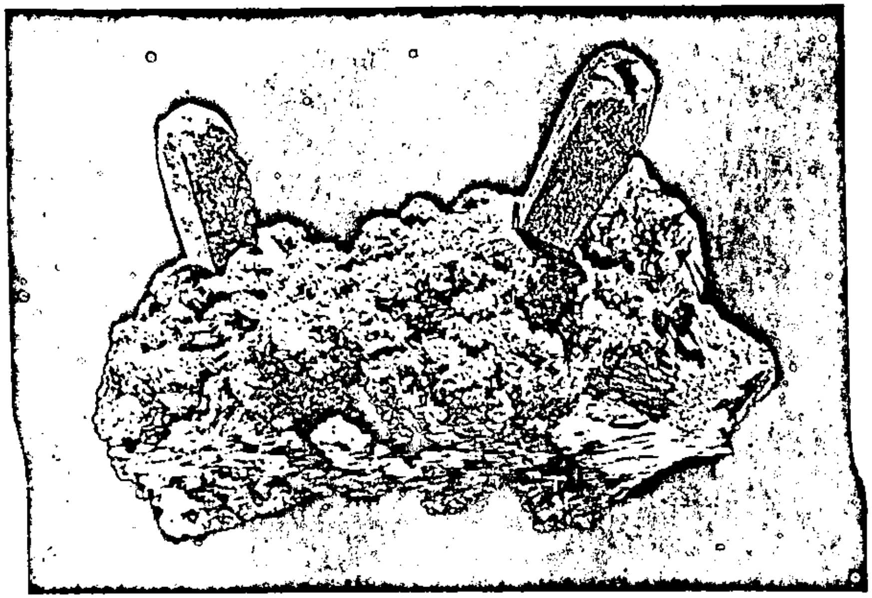

FIGURE 4. Quartz Pseudomorph after glauberite; the small white crystals are stilbite. New Street Quarry, Paterson, N. J. (AMNH No. 18027).

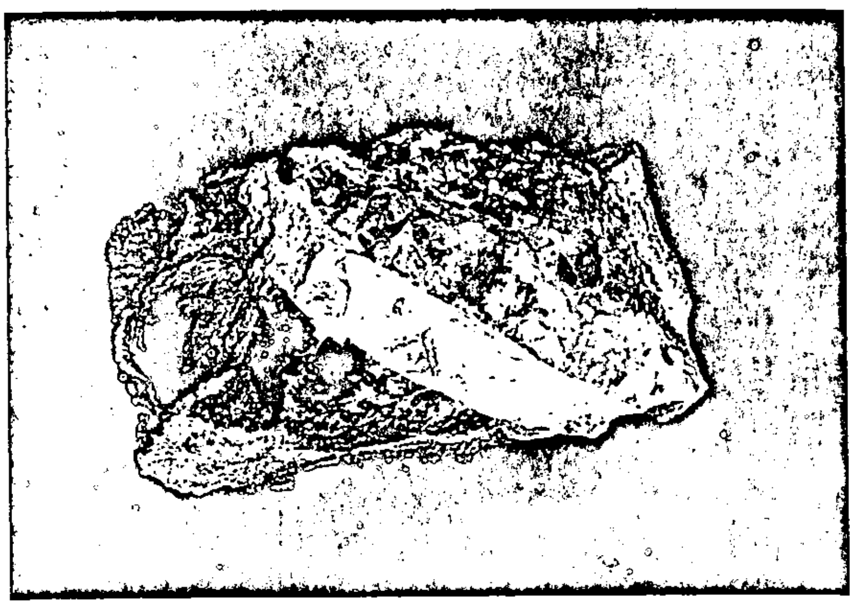

FIGURE 5. Thaumasite (white), pseudomorphous after anhydrite. New Street Quarry, Paterson, N. J. (AMNH No. 18221).

This definition is based partly on chemical composition and partly on the crystal structure. To understand the zeolites one must understand something of the way in which the atoms are linked together in the crystals. All the zeolites have what the crystal chemist calls framework structures, in which the silicon and aluminum atoms are linked through oxygen atoms in a rigid three-dimensional framework. In silicates each silicon atom is at the center of a group of four oxygen atoms, the whole forming a group approximately tetrahedral in shape. By linking through corners, i.e., by sharing oxygen atoms, these silicon-oxygen tetrahedrons can be built up into a variety of three-dimensional frameworks. When every tetrahedron shares each oxygen with a neighboring tetrahedron the Si:O ratio is 1:2; we have the compound SiO_2, which we know as the minerals quartz, tridymite, and cristobalite. These minerals all have framework structures, but the arrangement of the silicon-oxygen tetrahedra within the framework is different in each of them.

Now the silicon atom and the aluminum atom are quite similar in size, and it is possible to have frameworks in which some of the silicon atoms are replaced by aluminum. This replacement, however, results in an electrical imbalance, since the Al atoms have three positive charges, whereas the Si atom has four. In SiO_2 the four positive charges are balanced by the two negative charges on each of the oxygens. When aluminum atoms are introduced, the framework acquires a net negative charge; electrical equilibrium is restored by introducing positively charged atoms (cations) into suitable interstices of the structure. In the zeolites these cations are usually Ca (with two positive charges) and Na (with one); other cations sometimes present are K, Ba, and Sr.

The zeolites have particularly open framework structures with holes which accommodate the sodium and calcium atoms and the water molecules, and channels along which they can migrate. It is these channels which allow the water molecules to escape without affecting the structure. A zeolite may be compared to a house, the furniture of which (the water molecules) is not an essential constituent and may be removed without affecting the house. This is in contrast to most hydrated compounds, in which the water molecules are part of the structure, and cannot be removed without destroying the structure itself.

Because of their very open structures, the zeolite minerals have low densities, about 2.0—2.3, except for those containing the heavy barium atoms. In comparison it may be noted that quartz has a density of 2.65 and albite a density of 2.62. The refractive indices of the zeolite minerals are also unusually low for silicate minerals, for the same reason.

There are between 20 and 30 distinct species of zeolites, ten of which—analcime, chabazite, gmelinite, heulandite, stilbite, laumontite, thomsonite, natrolite, mesolite and scolecite—are found in the New Jersey trap rocks. These ten are all sodium, sodium-calcium, or calcium zeolites; zeolites containing potassium, strontium, or barium are not known from these rocks. Since many of these zeolites contain the same elements, it is difficult to identify the individual zeolites by simple chemical tests. Density also is not a useful diagnostic feature. Crystal form is probably the most readily applied distinguishing feature; the zeolites usually crystallize well, and their forms are generally distinctive. However, the three prismatic or acicular zeolites—natrolite, mesolite, and scolecite—can only be distinguished one from the other by optical tests with the polarizing microscope.

Descriptions of Minerals

The minerals are described under the classification used in most textbooks of mineralogy—a chemical classification utilizing the following groupings: native elements, sulphides, oxides and hydroxides, carbonates and borates, sulphates, phosphates, and silicates. For each mineral a brief general description of the form and habit and physical properties is given. For the non-opaque minerals the optical properties are noted, although it is realized that few amateurs have the facilities for determining these; nevertheless they do provide a rapid method of identification, and for some closely similar minerals, such as natrolite, mesolite, and scolecite, the only certain means of distinguishing between them. Following the general descriptions, notes are given on the occurrence of the minerals.

This bulletin contains descriptions of 60 minerals, many of which, of course, occur rarely and in very small amount. Minerals seen only as constituents of the trap rocks themselves—labradorite, pyroxene, olivine, biotite, ilmenite, and magnetite—are not included.

NATIVE ELEMENTS

SILVER

Ag Isometric

Silver usually occurs in branching wire-like aggregates or irregular masses, plates and scales. The hardness is 3 and the density 10.5. It is sectile (can be cut with a knife) and malleable (can be hammered out into thin plates). The color and streak are silver-white, but native silver is usually colored black by a thin tarnish of silver sulphide.

Some years ago a single find of native silver was made at the Prospect Park quarry in Paterson. It yielded two specimens, each with wire-like pieces of silver an inch or more long, on calcite. One of these specimens is now in the Paterson Museum. Manchester (1931) records the occurrence of silver at Plainfield and Hopewell, but these occurrences are unconfirmed, and no specimens from these localities are known. Silver has been found as tiny strings and threads associated with the native copper at Chimney Rock.

COPPER

Cu Isometric

Native copper usually occurs in irregular masses, plates, and in twisted and wire-like forms. The hardness is 3 and the density 8.9. It is sectile and malleable. The color is copper-red on a fresh surface, but specimens are usually brown to black with a dull luster because of tarnish.

Native copper has been recorded from Bergen Hill, Paterson, and Chimney Rock. An exceptional specimen weighing 96 pounds was found at the Chimney Rock quarry in 1927; it was discovered when the crusher jammed on it. This specimen is in the mineral collection of Rutgers University.

Copper has been mined in association with the New Jersey trap rocks at a number of localities. The most successful mining operations were in pre-Revolutionary days, and most of the mines have been abandoned for a century or longer. A detailed account of copper mining in New Jersey is given by Woodward (1944). The principal ore mineral was the sulphide chalcocite, but native copper was present in many deposits.

SULPHIDES

PYRITE

FeS_2 Isometric

Pyrite frequently occurs in good crystals, the commonest forms being the cube, the octahedron, the pyritohedron (or pentagonal dodecahedron), and combinations of these. It has no cleavage. The hardness is 6½ and the density 5.02. The color is pale brass-yellow and the streak brownish-black. It has a brilliant metallic luster, sometimes obscured by tarnish.

Pyrite is widespread in small amounts at most localities for secondary minerals in the New Jersey trap rocks. It usually occurs as tiny cubic crystals, often coating the surface of quartz and calcite crystals.

CHALCOCITE

Cu_2S Orthorhombic

Chalcocite occurs as short prismatic or thick tabular crystals, and also massive. Crystals are frequently twinned on (110), giving pseudo-hexagonal forms. It has poor (110) cleavage. The hardness is 2½ and it can be cut with a knife. The density is 5.77. The color is black, and the streak is black. It has a metallic luster.

Chalcocite occurs in small amounts in cavities in the New Jersey trap rocks, sometimes in well-formed crystals coated with chrysocolla or malachite. It has been recorded from Paterson, Upper Montclair, Summit, Plainfield, Chimney Rock, and Rocky Hill. In the copper mines in the Triassic sediments associated with the trap rocks, chalcocite was evidently the most important ore mineral, according to Woodward (1944).

CHALCOPYRITE

$CuFeS_2$ Tetragonal

Chalcopyrite, also known as copper pyrites, occurs as sphenoidal crystals which are often pseudo-tetrahedral in aspect. It has no cleavage. The hardness is 4 and the density 4.28. The color is brass-yellow, frequently tarnished bronze or blue-black. The streak is greenish-black and the luster metallic.

Chalcopyrite is widespread in small amounts as a secondary mineral in the New Jersey trap rocks, having been recorded from most localities. It usually occurs as pseudo-tetrahedral crystals up to 10 mm. on the edge, or as irregular masses. A five-pound mass has been

collected at the Prospect Park quarry. Wherry (1919) has described the crystallography of chalcopyrite from the Bergen Archways, recognizing nine different forms.

BORNITE

Cu_5FeS_4 Isometric

Bornite seldom occurs in crystals, usually being found in massive or granular forms. The hardness is 3 and the density 5.07. The color is reddish-brown on a fresh fracture, but it rapidly acquires a purplish iridescent tarnish which is a characteristic feature of this mineral. The streak is gray-black and the luster metallic.

Bornite is less widespread than chalcopyrite in the New Jersey trap rocks, having been recorded from Paterson, Summit, and Chimney Rock. However, a single mass weighing several tons was found in the Prospect Park quarry some years ago.

COVELLITE

CuS Hexagonal

Covellite sometimes occurs as tabular hexagonal crystals, but more commonly massive, as coatings or disseminations through other copper minerals. It has perfect basal cleavage, giving flexible plates. The hardness is 2 and the density is 4.6. The color is dark indigo-blue, and the streak black. It has a metallic luster.

Covellite is rare in the New Jersey trap rocks, having been recorded only from the Prospect Park quarry, where it has been found in small but characteristic masses.

GALENA

PbS Isometric

Galena usually occurs in cubic crystals or massive. It has perfect cubic cleavage. The hardness is 2½ and the density is 7.57. The color and streak are lead-gray and the luster is metallic. Galena alters to cerussite and anglesite, and specimens sometimes have a white or gray coating of these minerals.

Galena has been found in small amounts at a number of localities in the New Jersey trap rocks. Kato (1891) records it as widely distributed in the Bergen Hill area, occurring in cubes up to 10 mm. on edge in calcite and quartz veins. It has been found as small cubes at the New Street and Prospect Park quarries in Paterson, and is also recorded from Summit, Snake Hill, Rocky Hill, and Hopewell.

SPHALERITE

ZnS — Isometric

Sphalerite occurs as complex tetrahedral crystals, often twinned, also massive and granular. It has perfect dodecahedral cleavage. The hardness is 4 and the density 3.9 - 4.1. The color ranges from pale yellow through various shades of brown to black; the deepening color reflects a partial replacement of zinc by iron. The streak is white to pale brown, and the luster is resinous.

Sphalerite has been recorded from Bergen Hill, Snake Hill, Paterson, Summit, Plainfield, and Hopewell. At the Erie Cut in Bergen Hill it was found in black massive crystalline aggregates up to three inches in diameter, associated with calcite, datolite, and stilbite. Specimens from Snake Hill show beautiful yellow tetrahedral crystals up to 1 mm. across, associated with calcite and stilbite.

GREENOCKITE

CdS — Hexagonal

Greenockite, cadmium sulphide, usually occurs as a powdery yellow coating, but is occasionally found as tiny (about 1 mm.) yellow-brown crystals with a resinous luster. The hardness is 3 and the density is 4.8.

Greenockite is a very rare mineral in the New Jersey trap rocks. It has been found at Paterson (New Street and Prospect Park quarries), and is doubtfully recorded from Bergen Hill. Whitlock (1929) has described the faces on a 2 mm. crystal from the lower New Street quarry. The crystal was implanted on a rounded aggregate of light green prehnite. This mode of occurrence is exactly analogous with the original find of greenockite at Bishopton, Scotland.

ORPIMENT

As_2S_3 — Monoclinic

Orpiment rarely occurs as crystals, being usually found in foliated or columnar masses. It has one perfect cleavage parallel to the side pinacoid (010). The hardness is 2 and the density is 3.49. The color and streak are bright yellow. The luster is resinous, or pearly on cleavage surfaces.

Orpiment is very rare in the New Jersey trap rocks, having been recorded only from the lower New Street quarry at Paterson, and then in very small amount. One specimen is preserved in the Paterson Museum.

OXIDES AND HYDROXIDES

CUPRITE

Cu_2O — Isometric

Cuprite commonly occurs in crystals showing the cube, octahedron, and dodecahedron, frequently in combination; sometimes in long hair-like crystals (var. *chalcotrichite*). The hardness is 4 and the density is 6.1. The color is bright red in chalcotrichite, dark red to red-brown in other forms; streak dark red. The luster is adamantine or sub-metallic.

Cuprite occurs sparsely in the New Jersey trap rocks, generally on or in association with native copper. It has been recorded from the Prospect Park quarry, from Plainfield, and from Chimney Rock; from the latter locality it is known in the variety chalcotrichite.

HEMATITE

Fe_2O_3 — Rhombohedral

Hematite occurs in a variety of forms: as splendent black crystals (var. *specularite*), sometimes grouped in rosette-like forms (*iron roses*); also massive, compact, fibrous, botryoidal, or earthy; and as a fine-grained red pigment on or in other minerals. In crystallized material the hardness is 6 and the density 5.26. The color of the crystals is black and of the massive and earthy varieties red or red-brown. The streak is red to reddish-brown. Crystallized material has a metallic luster.

Hematite is widely distributed in small amounts in the New Jersey trap rocks. It occurs as small black crystals, frequently grouped in "iron roses", and as fine-grained red pigment coating quartz and calcite crystals or included in crystals of the zeolite minerals. Frondel (1934) has noted that the forms of quartz crystals are selectively filmed by hematite, the film generally being present on $(10\bar{1}1)$ and $(10\bar{1}0)$ and absent from $(01\bar{1}1)$; on calcite crystals the form [illegible] is filmed in preference to the other forms.

Hematite has been recorded from the following localities: Bergen Hill, Paterson, Little Falls, Great Notch, Upper Montclair, Summit, and Chimney Rock.

GOETHITE

$FeOOH$ — Orthorhombic

Goethite occurs in small prismatic or platy crystals, and also massive, in radiating fibrous aggregates, and earthy (var. *limonite*). The hardness is 5½ in well-crystallized specimens, but earthy material can be much softer. The density is 4.37, but impurities may reduce the apparent density greatly. The color is yellowish brown to dark brown, and the streak yellowish brown. The luster is adamantine to dull.

Goethite is not common in the New Jersey trap rocks. It has been found as radiating tufts and aggregates coating quartz from the Prospect Park quarry, and it has also been recorded from Hawthorne, Great Notch, Upper Montclair, and Rocky Hill.

PYROLUSITE

MnO_2 Tetragonal

Pyrolusite usually occurs as coarse to fine-grained crystalline masses, and as dendritic films on joint surfaces of rocks. Coarsely crystalline material can be quite hard, but much pyrolusite is soft and earthy, soiling the fingers when touched. The density is 4.75. The color and streak are black, and the luster metallic to dull.

Pyrolusite is a mineralogical curiosity in the New Jersey trap rocks, occurring only as dendritic films on joint surfaces. Such dendrites are known from Braen's quarry in Hawthorne, New Street and Prospect Park quarries in Paterson, Great Notch, and at Wilson's quarry in Plainfield.

CARBONATES AND BORATES

CALCITE

$CaCO_3$ Trigonal

Calcite commonly occurs as crystals which are extremely varied in their development; more forms have been recorded for calcite than for any other mineral. It has perfect rhombohedral cleavage; transparent cleavage fragments show double refraction (a dot observed through a cleavage fragment appears doubled). The hardness is 3 and the density is 2.71. Calcite is colorless, white, or pale shades of yellow or pink, unless colored by inclusions. The streak is white and the luster is vitreous.

Calcite is almost universally present in cavities and veins in the New Jersey trap rocks. Crystals up to three feet long have been recorded. Some of these crystals have yielded large clear cleavage rhombohedrons, the variety known as *Iceland spar*. The most common form of crystals is the scalenohedral or "dog-tooth" type, but many different forms have been recorded; Whitlock (1927), in his monograph on the crystallography of these calcites, enumerates 75 in all.

SIDERITE

$FeCO_3$ Rhombohedral

Siderite occurs as rhombohedral crystals, and also massive and granular; massive varieties sometimes have botryoidal or globular surfaces (var. *spherosiderite*). It has perfect rhombohedral cleavage. The hardness is 4 and the density 3.7 - 4.0. The color is yellow-brown or reddish-brown to black. The streak is white and the luster is vitreous.

Siderite, both as rhombohedral crystals and as the variety spherosiderite, has been found at Bergen Hill. It has also been recorded from Paterson, and from the Eagle Rock quarry in West Orange.

DOLOMITE

$CaMg(CO_3)_2$ Rhombohedral

Dolomite occurs as rhombohedral crystals or as granular masses. It has perfect rhombohedral cleavage. The hardness is 3½ - 4 and the density 2.85. The color is usually white, yellow, or yellow-brown. The streak is white and the luster is vitreous, or somewhat pearly on cleavage surfaces.

Dolomite has been found at Paterson as yellow-brown granular material associated with calcite. It resembles calcite but can be distinguished by not effervescing in cold dilute HCl.

MALACHITE

$Cu_2(OH)_2CO_3$ Monoclinic

Malachite occurs as tufts or rosettes of acicular crystals, or massive and incrusting, and coating copper sulphide minerals as an alteration product. The hardness is 4 and the density 4.05. The color is green and the streak pale green. The luster may be silky to dull.

Malachite is known in small amount from a number of localities in the New Jersey trap rocks, where it has formed by the alteration of copper sulphides. It has been recorded from Snake Hill, Paterson, Plainfield, Chimney Rock, Rocky Hill, and Hopewell.

AZURITE

$Cu_3(OH)_2(CO_3)_2$ Monoclinic

Azurite occurs as prismatic or tabular crystals, but is more commonly massive or earthy. The hardness is 4 and the density is 3.77. In crystals the color is dark blue, and in massive and earthy varieties light to dark blue; the streak is light blue. The luster is vitreous to earthy.

Azurite is found in association with malachite, but is less common. In the New Jersey trap rocks it has been recorded only from Paterson.

AURICHALCITE

$(Zn,Cu)_5(OH)_6(CO_3)_2$ Orthorhombic

Aurichalcite occurs as delicate acicular or lath-like crystals forming tufted, feathery, or plumose incrustations. It has perfect (010) cleavage. The hardness is 1 - 2 and the density is about 3.6. The color is pale blue or blue-green. The streak is white and luster silky to pearly.

Aurichalcite occurs as pale blue rosettes of pearly plates associated with chalcopyrite in calcite veinlets at Moore.

ULEXITE

$NaCaB_5O_9.8H_2O$ Triclinic

Ulexite usually occurs as masses of fibers, as crusts, veins, or nodules. The hardness is 2½ and the density 2.00. The color is white and the streak is white. The luster is silky.

The refractive indices are: $\alpha = 1.493$, $\beta = 1.506$, $\gamma = 1.519$. Ulexite is optically positive, with an axial angle about 75°.

Ulexite has been recorded only once from the New Jersey trap rocks. Darton (1882) collected the mineral (which he called *hayesine*, a synonym of ulexite) in a railroad tunnel being cut through Bergen Hill. He describes it as occurring in matted asbestos-like fibers on the surface of calcite crystals in a cavity in the trap rock. He had less than a gram of material, a large part of which was used up in the chemical analysis. No specimens appear to have been preserved.

SULPHATES

BARITE

$BaSO_4$ Orthorhombic

Barite occurs as tabular crystals flattened parallel to (001) and with prominent prism faces, or as platy aggregates. It has perfect (001) and good (210) cleavages, giving diamond-shaped cleavage fragments. The hardness is 3 - 3½ and the density 4.5. The color is usually white or pale blue. The streak is white and the luster vitreous or somewhat pearly.

The optical properties are: $\alpha = 1.636$, $\beta = 1.637$, $\gamma = 1.648$; it is optically positive with an axial angle about 40°.

Barite has been recorded from Bergen Hill, Paterson, Great Notch, and near Hopewell. Crystals up to ½" long were found at Bergen Hill. At the Prospect Park quarry in Paterson a vein of barite was exposed between 1925 and 1928 and many large rough crystals taken out. Near Hopewell several prospect pits were opened to exploit the barite, but the total amount produced was probably small.

ANHYDRITE

$CaSO_4$ Orthorhombic

Anhydrite usually occurs as tabular rectangular crystals bounded by the three pinacoids (100), (010), and (001), or as cleavable or granular masses (Fig. 2). It has good cleavage parallel to each of the three pinacoids. The hardness is 3½ and the density is 3.00. Anhydrite may be colorless, white, or pale shades of blue; pink, or gray. The streak is white and the luster is vitreous.

The refractive indices are: $\alpha = 1.570$, $\beta = 1.575$, $\gamma = 1.614$. Anhydrite is optically positive, with an axial angle of 43°.

Anhydrite was first found in the New Jersey trap rocks at the upper New Street quarry in Paterson in 1914. Manchester (1931) records that about a ton of anhydrite was thrown out on the floor of the quarry after one of the large blasts at this quarry. It has also been found in the Prospect Park quarry. The discovery of anhydrite solved the mystery of the rectangular cavities found not only in the Paterson quarries but also in those at Great Notch and Upper Montclair. However, at the latter localities no trace of the original anhydrite has survived. Anhydrite crystals, partly altered to gypsum, have been found at the Chimney Rock quarry.

GLAUBERITE

$CaNa_2(SO_4)_2$ Monoclinic

Glauberite usually occurs as long prismatic crystals which are combinations of the forms (111) and (001), or as wedge-shaped crystals which are combinations of (111) and (110). It has perfect basal cleavage. The hardness is 2½ - 3 and the density 2.81. The color is usually white, yellowish, or gray. The streak is white and the luster vitreous or waxy.

The refractive indices are: $\alpha = 1.515$, $\beta = 1.535$, $\gamma = 1.536$. Glauberite is optically negative with an axial angle of 7°.

The former occurrence of glauberite in considerable amount at

Paterson, Great Notch, and Upper Montclair is indicated by the abundance of the rhomboidal cavities or molds, representing solution cavities after glauberite crystals (Fig. 3). Sometimes these molds have been filled by quartz, giving perfect pseudomorphs after the glauberite (Fig. 4). Quartz pseudomorphs up to three inches long have been collected at Paterson. Unaltered glauberite crystals are very rare in the New Jersey trap rocks, but Hawkins (1933) described such crystals from the New Street quarry at Paterson; many of these are partly or completely altered to gypsum.

GYPSUM

$CaSO_4.2H_2O$ Monoclinic

Gypsum is a common mineral which occurs as well-formed crystals or transparent plates (var. *selenite*), as parallel fibrous masses (var. *satin spar*), and as fine-grained masses (var. *alabaster*). It has perfect (010) cleavage. The hardness is 2 and the density 2.32. Gypsum is colorless or white, but may be tinted yellow, pink or brown by impurities. The streak is white, and luster is vitreous, on cleavage surfaces pearly.

The refractive indices are: $\alpha = 1.521$, $\beta = 1.523$, $\gamma = 1.530$. Gypsum is optically positive with an axial angle about 58°.

Gypsum occurs at Paterson replacing anhydrite, when it is finely granular, white, and opaque. It also occurs as a very late mineral, filling the center of cavities; in this mode of occurrence it is present as transparent selenite. In this form it has been found at Great Notch and Upper Montclair also.

THAUMASITE

$Ca_3H_2(CO_3)(SiO_4)(SO_4).13H_2O$ Hexagonal

Thaumasite is a remarkable mineral in that it contains three different acid radicals—carbonate, silicate, and sulphate. It occurs as hexagonal crystals 1 - 2 mm. long, and as snow-like masses. The hardness is 3½ and the density is 1.91. It is colorless, white, or pale green. The streak is white and the luster is vitreous.

The refractive indices are: $\epsilon = 1.464$, $\omega = 1.500$.

Thaumasite has formed in the New Jersey trap rocks by the alteration of anhydrite and gypsum, and has been recorded from the lower New Street quarry in Paterson and Francisco Bros. quarry in Great Notch. It occurs as pseudomorphs after anhydrite (Fig. 5), and as a very late mineral filling cavities lined with prehnite and the zeolites.

PHOSPHATES

APATITE

$Ca_5(PO_4)_3F$ Hexagonal

Apatite often occurs in well-formed hexagonal prisms, but may be massive or granular. It has an indistinct basal cleavage, and a conchoidal or uneven fracture. The hardness is 5 and the density 3.18. The color is usually green, but brown or red varieties are not uncommon. The streak is white and the luster vitreous or somewhat resinous.

Apatite is rare as a secondary mineral of the trap rocks, although it is present as a microscopic constituent of the trap rocks themselves. Transparent green crystals, up to 2 cm. long of this mineral, embedded in quartz, have been found at Bergen Hill.

SILICATES

QUARTZ

SiO_2 Trigonal

Quartz (and opal) can be classified with the oxide minerals, but since their crystal structures are essentially similar to those of the silicates, they are now usually included in this group.

Quartz crystals are commonly prismatic, terminated by two sets of rhombohedrons. When these two sets are equally developed the appearance is that of a hexagonal pyramid, but usually inequality in the rate of growth causes one set to be better developed than the other. Quartz has no cleavage, and a conchoidal fracture. The hardness is 7 and the density 2.65. It is usually colorless or white, but can occur in practically any shade. The streak is white, and the luster is vitreous in macrocrystalline varieties, often waxy or dull in cryptocrystalline varieties.

Quartz is optically positive, with refractive indices $\omega = 1.544$, $\epsilon = 1.553$.

Quartz occurs in two distinct types, the macrocrystalline and the cryptocrystalline varieties, the latter often being classed as the subspecies *chalcedony*. Many names are current for different varieties of quartz: *rock crystal* is transparent colorless material; *amethyst* is transparent purple; *smoky quartz* is the transparent and semi-transparent brown, gray to nearly black varieties; *agate* is banded chalcedony, the banding being due to intermittent deposition in cavities, the bands being parallel to the walls of the cavity.

Quartz is a common and widespread secondary mineral in the New Jersey trap rocks. It has usually formed at an early stage, and lines the walls of cavities and veins. Fine deep-colored amethyst and smoky quartz have been collected at the New Street quarries, and fine amethyst at the Prospect Park quarry; some of the amethyst has been cut into gemstones. Agates have been found at Bergen Hill, Snake Hill, Hawthorne (Braen's quarry), Paterson (Prospect Park quarry), Great Notch, Upper Montclair, Summit, and Chimney Rock.

OPAL

$SiO_2.nH_2O$ Amorphous

Opal is an example of a solidified colloidal gel, and is essentially amorphous, although X-ray powder photographs sometimes show weak and diffuse reflections indicating cristobalite-like groupings in the material. The water content varies from specimen to specimen, but is generally between 3% and 10%. It occurs massive, often in rounded or botryoidal forms. The hardness is 5½—6½, and the density 2.0—2.2. It is usually colorless (var. *hyalite*) or white (*common* or *milky opal*, sometimes known as *cacholong*), but may be red (var. *fire opal*) brown, or gray, the color being usually due to fine-grained impurities. The streak is white and the luster vitreous to waxy or pearly, in colored varieties somewhat resinous.

Opal is optically isotropic, with refractive index 1.44—1.46.

Opal occurs in small amounts in the New Jersey trap rocks, often as a thin white coating on the trap rock itself. It has been recorded from Bergen Hill (both hyalite and fire opal), and from Paterson, Great Notch, Upper Montclair, and Summit, and recently from Chimney Rock.

ORTHOCLASE

$KAlSi_3O_8$ Monoclinic

Orthoclase frequently occurs as short prismatic crystals, often twinned. It has perfect cleavage parallel to the base (001), and good cleavage parallel to the side pinacoid (010). The hardness is 6 and the density 2.56. It is usually colorless, white, or pink, and the streak is white. The luster is vitreous.

Orthoclase is optically negative, with refractive indices $\alpha = 1.519$, $\beta = 1.523$, $\gamma = 1.525$.

Orthoclase is recorded by Manchester (1931) from Paterson and Summit. Specimens so labelled in museum collections have proved to be albite. However, a genuine specimen of orthoclase from Summit was recently given to me by Mr. J. Stromwasser. It consists of a crust

about 1 mm. thick of tiny pink orthoclase crystals coating a crystal of quartz. In view of the practical absence of potassium from all the minerals (except apophyllite) of the New Jersey trap rocks, orthoclase is probably extremely rare.

ALBITE

$NaAlSi_3O_8$ Triclinic

Albite, the sodium end-member of the plagioclase feldspar series, usually occurs in aggregates of small platy crystals, and sometimes in sheaf-like forms not unlike stilbite. It has perfect cleavage parallel to (001) and good cleavage parallel to (010). The hardness is 6 and the density is 2.62. Pure albite is white, but it is frequently tinted pink or brown by inclusions of hematite or goethite. The streak is white.

The optical properties are: $\alpha = 1.527$, $\beta = 1.531$, $\gamma = 1.538$. These refractive indices are for pure $NaAlSi_3O_8$ and are increased by substitution of CaAl for NaSi; however, the albite in the cavities of the trap rock is usually very close to $NaAlSi_3O_8$ in composition.

Albite commonly occurs lining the walls of cavities and veins in the trap rock, as the earliest secondary mineral to form. This albite is often partly replaced by later minerals, such as prehnite, natrolite, pectolite, and datolite. Albite also occurs at a later stage of mineral deposition, as crusts of crystals on quartz; in some specimens from Great Notch the albite forms hemispherical aggregates up to 1 cm. in diameter which evidently grew on anhydrite plates that have later been dissolved away.

Albite has been recorded from Bergen Hill, Paterson, Great Notch, Summit, Plainfield, Chimney Rock, and Rocky Hill, and is probably present in other localities also. Albite from the lower New Street quarry was described and analysed by Fenner (1926), who showed that it was practically pure $NaAlSi_3O_8$.

The following ten silicate minerals belong to the Zeolite group:

ANALCIME

$NaAlSi_2O_6.H_2O$ Isometric

Analcime (also known as *analcite*) characteristically occurs in trapezohedral crystals, sometimes an inch or more across. It has no distinct cleavage. The hardness is 5 and the density 2.3. It is usually

FIGURE 6. Analcime in trapezohedral crystals. Bergen Hill, N. J. (AMNH No. 13106).

FIGURE 7. Chabazite crystals, large and small. West Paterson, N. J. (AMNH No. 13031).

FIGURE 8. Heulandite (large prismatic crystals) with stilbite (smaller sheaf-like aggregates). Paterson, N. J. (AMNH No. 31941).

FIGURE 9. Thomsonite, in an aggregate of radiating platy crystals. Paterson, N. J. (AMNH No. 17515).

colorless or white, but may be stained pink by inclusions of iron oxides. The streak is white and the luster is vitreous.

The refractive index of analcime is 1.48—1.49; it is usually isotropic, but may show very weak birefringence, about 0.001.

Analcime is common and widely distributed in the New Jersey trap rocks, being recorded from Bergen Hill, Snake Hill, Paterson, Upper Montclair, Summit, Plainfield, Chimney Rock, and Moore. Remarkably fine specimens were taken from the railroad tunnels through Bergen Hill (Fig. 6).

CHABAZITE

$CaAl_2Si_4O_{12}.6H_2O$ — Trigonal

Chabazite occurs as crystals which look like cubes but are actually rhombohedrons with angles close to 90° (Fig. 7). The crystals sometimes show penetration twins. It has poor rhombohedral cleavage. The hardness is 4 and the density 2.05—2.15. It is usually colorless or white, sometimes tinted yellow, pink, or red. The streak is white and the luster vitreous.

The refractive index of chabazite is 1.48—1.49, and the birefringence is very weak, about 0.003.

Chabazite has been found at Bergen Hill, Snake Hill, Paterson, Great Notch, and Upper Montclair; at the last locality the crystals were garnet red in color, evidently due to tiny hematite inclusions.

GMELINITE

$Na_2Al_2Si_4O_{12}.6H_2O$ — Trigonal

Gmelinite can be considered the sodium analog of chabazite. Its crystal structure is similar, and it frequently occurs in an intimate intergrowth with chabazite. The crystals are sometimes hexagonal prisms terminated by pyramids (resembling quartz) but more commonly are complexly twinned with a pyramidal appearance. Gmelinite has a distinct prismatic cleavage. The hardness is 4½ and the density is 2.04—2.17. It is colorless, white, or pink. The streak is white and the luster is vitreous.

The refractive index of gmelinite is 1.47—1.48, lower than that of chabazite; the birefringence is very weak, about 0.002. The optical properties of gmelinite vary somewhat, evidently as the result of partial substitution of sodium by calcium.

Gmelinite is not uncommon in the New Jersey trap rocks. It has been recorded from Bergen Hill, Snake Hill, Paterson, Little Falls, Great Notch, Plainfield, and Hopewell.

HEULANDITE

$CaAl_2Si_7O_{18}.6H_2O$ — Monoclinic

Heulandite usually occurs in trapezoidal crystals tabular parallel to (010), the crystals often being canoe- or coffin-shaped (Fig. 8). It has perfect (010) cleavage. The hardness is 4, except on the cleavage surface, where it is 3; the density is 2.2. Heulandite is colorless or white, sometimes stained yellow, pink or brown by iron oxides. The luster is vitreous, pearly on cleavage surfaces.

The optical properties are: $\alpha = 1.496$, $\beta = 1.497$, $\gamma = 1.501$. Cleavage flakes of heulandite give a centered acute bisectrix interference figure.

Heulandite is one of the most common zeolites in the New Jersey trap rocks and occurs at most localities. Excellent specimens have been collected at Bergen Hill, Snake Hill, Paterson, Great Notch, Summit, and Moore. It is associated with other zeolites, especially stilbite, and with quartz and calcite.

STILBITE

$CaAl_2Si_7O_{18}.7H_2O$ — Monoclinic

Stilbite characteristically occurs in rough sheaf-like crystals which are aggregates of cruciform penetration twins (Fig. 8). Occasionally, however, it is found in rounded or globular masses (var. *spherostilbite*), or as small tabular pseudo-orthorhombic crystals (var. *epidesmine*). When stilbite completely fills a cavity it is generally in the form of a radiating platy mass. It has perfect (010) cleavage. The hardness is 4 and the density 2.1—2.2. It is usually colorless, white, or cream-colored, but may be stained pink or brown by iron oxides. The luster is vitreous, pearly on the cleavage surfaces.

The optical properties are: α = 1.482-1.492, β = 1.491-1.500, γ = 1.493-1.502; the extinction angle $X \wedge c$ is zero or very small, up to 7°.

Stilbite and heulandite are similar in chemical composition and physical properties, but are easily distinguished by their very different crystal form.

Stilbite is one of the most common zeolites in the New Jersey trap rocks, and has been found at practically every locality. Exceptionally fine specimens have been collected in the Paterson area, and at Upper Montclair and Great Notch.

THOMSONITE

$NaCa_2Al_5Si_5O_{20}.6H_2O$ — Orthorhombic

Thomsonite is a sodium-calcium zeolite, whose composition may

FIGURE 10. Stellate groupings of laumontite crystals, with cuboidal apophyllite crystals. Paterson, N. J. (AMNH No. 12960).

vary somewhat from the formula given above by the substitution of NaSi for CaAl and Na_2 for Ca. It generally occurs as sheaf-like or globular aggregates of platy crystals (Fig. 9), but is also found in radiating needle-like crystals. The sheaf-like aggregates resemble stilbite, but are generally smaller, not more than half an inch long. Thomsonite has perfect (010) cleavage. The hardness is 5 and the density 2.3—2.4. It is usually white, but may be tinted pink or brown with iron oxides. The streak is white and the luster is vitreous, or pearly on cleavage surfaces.

The refractive indices vary with variation in composition: $\alpha = 1.511$—1.529, $\beta = 1.513$—1.531, $\gamma = 1.518$—1.545. Thomsonite is optically positive, with an axial angle 50° - 75°; since $Z = b$ thomsonite shows both positive and negative elongation, a useful diagnostic property.

Thomsonite has been recorded from Bergen Hill, Paterson, and Great Notch. It was evidently quite rare at Bergen Hill, but was fairly common at the lower New Street quarry in Paterson; some specimens from the latter have globular aggregates of thomsonite up to 2 inches across, generally on prehnite. Analyses of thomsonite from Paterson have been published by Canfield (1911) and Hey (1932).

LAUMONTITE

$CaAl_2Si_4O_{12}.4H_2O$ Monoclinic

Laumontite generally occurs as radiating aggregates of chalky white lath-like or prismatic crystals, up to 1 cm. long (Fig. 10); also as individual prismatic crystals with oblique terminations. The chalky white crystals familiar to collectors are actually partly dehydrated laumontite, sometimes known by the varietal names *leonhardite* or *caporcianite*. The fully-hydrated laumontite, occasionally found when water-filled cavities are broken into, occurs as water-clear transparent crystals. On exposure to the atmosphere these crystals lose about one-eighth of the water of crystallization and become white and opaque.

Laumontite has perfect (010) and (110) cleavages. The hardness is 4, but the partly dehydrated material may appear softer than this, because of its friability. The density is 2.25—2.30.

The optical properties of the fully hydrated material are: $\alpha = 1.510$-1.514; $\beta = 1.58$ - 1.522; $\gamma = 1.521$ - 1.525. For the partly dehydrated mineral $\alpha = 1.502$ - 1.507; $\beta = 1.512$ - 1.516; $\gamma = 1.514$ - 1.518.

Laumontite is usually the last of the zeolites to form. It has been observed encrusting chabazite, apophyllite, and prehnite. It has been recorded from Bergen Hill, Snake Hill, Paterson, Great Notch, Upper Montclair, and Summit.

FIGURE 11. Prismatic crystals of natrolite, on small analcite crystals. Bergen Hill, N. J. (AMNH No. 13157).

NATROLITE

$Na_2Al_2Si_3O_{10}.2H_2O$ Orthorhombic

Natrolite occurs in prismatic crystals, generally elongated and needle-like, and terminated by pyramid faces (Fig. 11); often these crystals are aggregated into radiating globular forms. It has perfect (110) cleavage. The hardness is 5 and the density 2.25. It is colorless or white, sometimes chalky in appearance. The streak is white and the luster vitreous.

The optical properties are: $\alpha = 1.480$, $\beta = 1.483$, $\gamma = 1.490$. The low refractive index and the moderate birefringence serve to distinguish natrolite from the very similar mesolite and scolecite.

Natrolite is a common zeolite of the New Jersey trap rocks. It has been recorded from Bergen Hill, Snake Hill, Paterson, Great Notch, Summit, Plainfield, Rocky Hill, and Moore. The finest specimens have been taken from Bergen Hill. Chemical analyses of natrolite from Moore and from Snake Hill are given by Hey (1932).

MESOLITE

$Na_2Ca_2Al_6Si_9O_{30}.8H_2O$ Monoclinic

Mesolite usually occurs in long needle-like crystals (in some specimens from Paterson the crystals are 50 mm. long and less than 0.5 mm. wide); occasionally the needle-like crystals are aggregated into radiating masses (Fig. 12). It has perfect prismatic cleavage. The hardness is 5 and the density is 2.26. Mesolite is colorless or white. The streak is white and the luster is vitreous or silky.

The optical properties are: $\beta = 1.505 - 1.507$, with extremely low birefringence, less than 0.001. Between crossed nicols mesolite therefore appears isotropic or almost isotropic, a useful distinction from natrolite and scolecite.

Mesolite has been recorded from Bergen Hill and the New Street quarry in Paterson; a specimen from Paterson was analysed by Hey (1933). It may be more common than is generally thought, since most of the needle-like material from Paterson labelled "natrolite" has proved to be mesolite. Natrolite crystals from Bergen Hill are sometimes tipped with silky mesolite in crystallographic continuity. One specimen of massive mesolite from Paterson was partly altered to chalky natrolite.

FIGURE 12. Radiating needle-like crystals of mesolite, on calcite. West Paterson, N. J. (AMNH No. 17544).

SCOLECITE

$CaAl_2Si_3O_{10}.3H_2O$ Monoclinic

Scolecite occurs in slender prismatic crystals, usually aggregated into radiating masses. It has perfect prismatic cleavage. The hardness is 5 and the density is 2.27. It is colorless or white. The streak is white and the luster is vitreous.

The optical properties are: $\alpha = 1.513$, $\beta = 1.519$, $\gamma = 1.520$. Scolecite has oblique extinction, the angle $X \wedge c$ being 15°-18°.

Scolecite has been found at Bergen Hill, Paterson, Great Notch, Upper Montclair, and Moore. Some of the specimens from Great Notch show a partial alteration to white chalky natrolite.

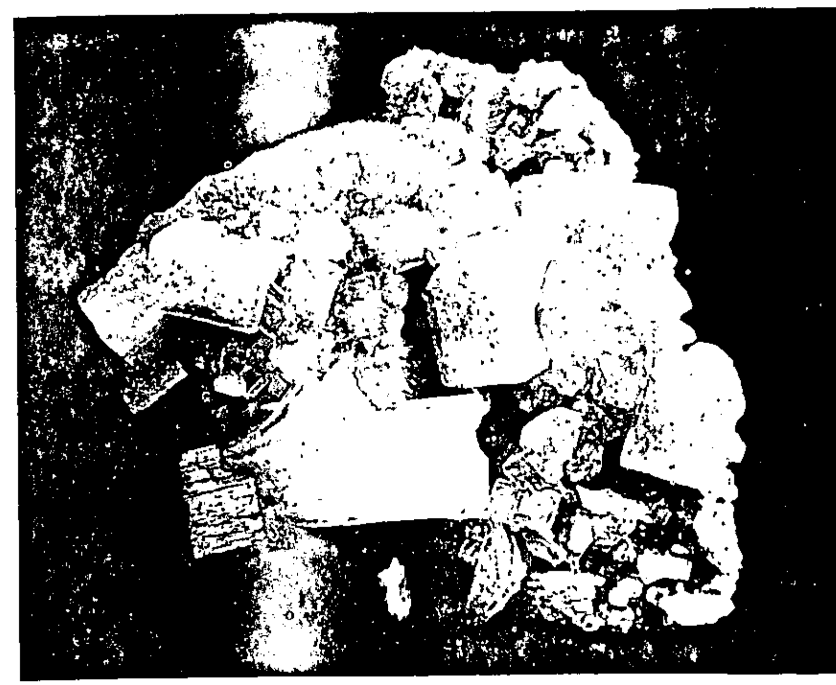

FIGURE 13. Apophyllite crystals. Great Notch, N. J. (AMNH No. 18553).

APOPHYLLITE

$KCa_4Si_8O_{20}F.8H_2O$ Tetragonal

Apophyllite usually occurs in good crystals which are combinations of prisms (100), pyramids (111), and basal planes (001) (Fig. 13). Sometimes the crystals appear to be isometric combinations of cube and octahedron faces, but the true symmetry is revealed by the single perfect cleavage parallel to (001) and the difference in luster between basal planes and other faces. The hardness is 5 and the density is 2.35. Apophyllite is colorless or white, occasionally tinted yellow, pink, or green; the streak is white. The luster is pearly on (001) and vitreous on other faces.

The optical properties are: $\omega = 1.535, \epsilon = 1.537$. Since fragments always lie on (001) they give a centered uniaxial interference figure.

Apophyllite is a common mineral of the New Jersey trap rocks. Excellent specimens have been collected from Bergen Hill, Snake Hill, Paterson, Great Notch, and Summit. It is usually associated with the zeolites.

DATOLITE

$Ca(OH)BSiO_4$ Monoclinic

Datolite usually occurs in short prismatic or pyramidal crystals, often with a variety of forms. It has no cleavage. The hardness is 6½ and the density 3.0. It is transparent and colorless or pale shades of yellow and green. The streak is white and the luster vitreous.

The optical properties are: $\alpha = 1.626$, $\beta = 1.654$, $\gamma = 1.670$; optically negative, $2V = 74°$.

Datolite is common and widely distributed in the New Jersey trap rocks. It often forms the lining of the cavities, having been deposited prior to the zeolites. Fine single crystals were collected from the railroad cuts at Bergen Hill. The New Street quarry in Paterson was noted for its datolites; clusters and groups up to eighteen inches across made up of crystals up to an inch or more in diameter were found. It has also been recorded from the other quarries at Paterson, and at Snake Hill, Hawthorne, Great Notch, Upper Montclair, Summit, Plainfield, Scotch Plains, Chimney Rock, and Rocky Hill.

PREHNITE

$CaAl_2Si_3O_{10}(OH)_2$ Orthorhombic

Prehnite usually occurs as massive, globular, encrusting or stalactitic masses with a crystalline surface (Fig. 14); occasionally, however, small individual crystals with a prismatic habit are found lining cavities. It has good basal cleavage. The hardness is 6½ and the density 2.9. The color is characteristically pale green, although the small individual crystals are usually white or colorless. The streak is white and the luster vitreous.

The optical properties are: $\alpha = 1.612 - 1.632$, $\beta = 1.618 - 1.642$,

FIGURE 14. Pale green prehnite (white incrustation is calcite); the prehnite formed around tabular anhydrite crystals, which were later dissolved, leaving rectangular cavities. Paterson, N. J. (AMNH No. 31256).

$\gamma = 1.641 - 1.665$; the variation in refractive indices is due to the partial replacement of aluminum by ferric iron.

Prehnite is abundant and widespread in the New Jersey trap rocks, occurring at most localities. It usually occurs lining cavities, and has formed earlier than the zeolites. Some of the finest specimens of prehnite have come from quarries in the Paterson area. Good prismatic microcrystals have been found at the Lambertville quarry, and at the Prospect Park quarry.

FIGURE 15. Pectolite, in radiating groups of terminated crystals. Bergen Hills, N. J. (AMNH No. 9833).

PECTOLITE

$CaNaHSi_3O_9$ Triclinic

Pectolite occurs as aggregates of needle-like crystals, often radiating and forming globular masses up to two inches and more in diameter (Figs. 15, 16). Specimens should be handled with care, as the needle-like crystals readily penetrate the skin. It has perfect (001) and (100) cleavage. The hardness is 5 and the density is 2.86. The color is white or pink, the streak white. The luster is vitreous or silky.

The optical properties are: $\alpha = 1.600$, $\beta = 1.605$, $\gamma = 1.636$; the extinction angle $Z \wedge b = 13°$.

Pectolite is one of the most common minerals of the New Jersey trap rocks, and can be found in most localities. Excellent specimens have been collected from Bergen Hill, Snake Hill, Paterson, and Great Notch.

The pink varieties are sometimes known as *manganpectolite,* but analysis has shown that the amount of manganese in these specimens is quite low.

The pectolite from the New Jersey trap rocks is sometimes partly or completely altered to the clay mineral *stevensite.*

FIGURE 16. Hemispherical aggregates of pectolite crystals, up to four inches in diameter; white interstitial material is thaumasite. West Paterson, N. J. (AMNH No. 31940).

STEVENSITE

$Mg_3Si_4O_{10}(OH)_2.nH_2O$ Monoclinic

Stevensite is a member of the montmorillonite group of clay minerals. It typically occurs as pseudomorphs after pectolite. The hardness is 2½ and the density is 2.2—2.6. The color is usually pink, but it may be yellow or brown. The streak is white or pink and the luster is usually earthy, although in some specimens it may be slightly resinous.

Stevensite was originally described in material from Bergen Hill by Leeds (1873). It was thoroughly re-examined by Faust and Murata (1953), who showed that it was a member of the montmorillonite group, and pointed out that material from the New Jersey trap rocks previously labelled "talc" and "deweylite" was actually stevensite.

Stevensite has been recorded from Bergen Hill, Snake Hill, Paterson, Great Notch, Summit, and Springfield. It has been formed by the late stage hydrothermal replacement of pectolite.

TALC

$Mg_3Si_4O_{10}(OH)_2$ Monoclinic

Talc never occurs in crystals, being generally found as compact fine-grained aggregates. The hardness is 1 and the density 2.82. It is usually white or pale green in color, but may be stained brown or gray by impurities; the streak is white. The luster is greasy or dull.

The optical properties are: $\alpha = 1.54$, $\beta = 1.58$. Since talc usually occurs as an aggregate of microscopic flakes all lying approximately on the (001) cleavage surfaces, in immersion mounts the refractive index is close to 1.58 and the grains show low to moderate birefringence.

Talc, pseudomorphous after pectolite, was recorded from Bergen Hill by Leeds (1873), but Faust and Murata (1953) have shown that this material is actually stevensite. However, a specimen of gray-white material from the Prospect Park quarry, Paterson, pseudomorphous after pectolite, proved to be talc, as did similar material from the New Street quarry.

BABINGTONITE

$(Ca,Fe)SiO_3$ Triclinic

Babingtonite occurs as tufts of microscopic prismatic crystals, or as thin plates often grouped in spherical or rosette-like groups (Fig. 17). It has perfect (001) cleavage. The hardness is 6 and the density 3.36.

FIGURE 17. Rosette-like groupings of dark green babingtonite crystals on calcite. Great Notch, N. J. (AMNH No. 17725).

The color is dark green to black, but the crystals are frequently coated with a white or pale blue film. Under the microscope this film is seen to consist of a white to pale green fibrous pyroxene with extinction angle about 45° and $\alpha = 1.69$, $\gamma = 1.72$, probably intermediate between diopside and hedenbergite in composition. Other crystals are coated with a brown fibrous mineral, which is the acmite variety of the pyroxene aegirine. The streak of babingtonite is green and the luster is vitreous.

The optical properties are: $\alpha = 1.71 - 1.73$, $\beta = 1.73 - 1.75$, $\gamma = 1.75 - 1.77$; the pleochroism is strong and characteristic, with X = emerald green, Y = pale brown, Z = dark brown.

Babingtonite was first recognized from the New Jersey trap rocks by Fenner (1914), who had earlier (1910) seen it in material from Paterson and at that time thought it to be an amphibole, possibly arfvedsonite. It occurs at Paterson, Great Notch, Upper Montclair, and at the Eagle Rock quarry in West Orange. The mineral is usually implanted on quartz and is sometimes included in later-formed crystals of zeolites.

ACTINOLITE

$Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$ Monoclinic

Actinolite, a mineral of the amphibole group, usually occurs as aggregates of prismatic or needle-like crystals; it commonly has a fibrous appearance. The color is pale green or gray-green, and the streak is white. The hardness is 6 and the density 3.0—3.3, increasing with increasing replacement of magnesium by iron. The luster is vitreous.

The optical properties are: $\alpha = 1.62 - 1.66$, $\beta = 1.63 - 1.67$, $\gamma = 1.64 - 1.68$. Actinolite shows oblique extinction, the angle $Z \wedge c$ being 15° - 20°.

Specimens from the Kingston Traprock Quarry at Lambertville show microscopic pale green crystals of actinolite up to 2 mm. long and fibrous aggregates, associated with axinite. It probably occurs at other localities also. However, the highly pleochroic green prismatic mineral from Paterson tentatively identified as actinolite by Fenner (1910) was later shown to be babingtonite.

HORNBLENDE

$NaCa_2(Mg,Fe,Al)_5(Al,Si)_8O_{22}(OH)_2$ Monoclinic

Hornblende, the most common species of the amphibole group, usually occurs as long prismatic crystals with a characteristic green color. However, in the New Jersey trap rocks it is present as very fine fibres (var. *byssolite*), often matted together in the forms known as *mountain leather* or *mountain cork*. The color of these forms is white. The true hardness of the mineral is 6 and the density is 3.0—3.4; however, the matted fibres include a great deal of air and the density appears much less—specimens of mountain cork and mountain leather will often float on water.

These forms have often been identified with the iron-free amphibole tremolite, on account of the white color. However, Shannon (1926) analysed similar material from Goose Creek, Virginia, and showed that it contained a considerable amount of iron. The optical properties also support the identification as hornblende; the refractive index γ for these forms ranges from 1.64 to 1.68, whereas pure tremolite has $\gamma = 1.625$.

Byssolite has been found at Bergen Hill and Snake Hill; it is evidently one of the last minerals to form, since it coats the surface of the earlier minerals. Mountain leather has been found at Bergen Hill and at the Prospect Park quarry in Paterson, and mountain cork at Barber and Ireland's quarry, Lambertville.

CHLORITE

$(Mg,Fe,Al)_6(Al,Si)_4O_{10}(OH)_8$ Monoclinic

Chlorite usually occurs as scaly aggregates and as fine-grained or earthy masses of a dark green color. The fine-grained masses often have a black slickensided surface with a high polish. It also occurs as fibrous veinlets, and filling vesicles in the trap rock itself. It has perfect mica-like cleavage. The hardness is 2½ and the density is usually between 2.7 and 2.9, depending upon the composition, the iron-rich varieties having the higher density. The streak is gray-green. The massive material often has a soapy or greasy feel.

The refractive index (γ) of chlorite varies from 1.56 to 1.67, depending on the composition; for the common chlorites the refractive index is 1.60—1.64.

Chlorite is common and abundant in the New Jersey trap rocks, and undoubtedly occurs at most localities. *Diabantite*, which is a subspecies of chlorite, has been recorded from Bergen Hill, Snake Hill, and Paterson; however, specimens so labelled have all proved to be babingtonite. The specimen illustrated in Manchester's book (Plate 19) is babingtonite.

STILPNOMELANE

$(Fe,Al,Mg)_7Si_8O_{20}(OH)_{10}$ Monoclinic

Stilpnomelane (also known as *chalcodite*) is a mica-like mineral, occurring in minute flakes, sometimes aggregated in veinlets or radiating spherules. The color is usually golden brown to greenish brown, with a submetallic luster; some specimens have the appearance of being coated with bronze paint. The hardness is 2, and the density 2.75—2.85. The composition varies considerably in the relative proportions of iron, aluminum, and magnesium.

As a result of the variation in composition, the optical properties vary considerably; the refractive index γ is 1.71 for material from Rocky Hill, 1.66 for material from Goat Hill and Snake Hill. The mineral is strongly pleochroic in shades of yellow and brown, and has a high birefringence.

Stilpnomelane resembles chlorite, but can generally be distinguished by its golden-bronze color; its optical properties are distinctive.

Stilpnomelane, in veinlets of calcite, has been recorded and chemically analysed from Rocky Hill by Clarke and Darton (1899). At Goat Hill, near Lambertville, it is associated with pectolite in veinlets up to 5 mm. thick; it was described and analysed by Shannon (1921).

It has also been found at Snake Hill as microscopic flakes coating the surface of datolite crystals, itself partly covered with apophyllite and stilbite. Stilpnomelane is also reported as having been found at Moore.

AXINITE

$(Ca,Fe,Mn)_3Al_2(BO_3)(Si_4O_{12})OH$ Triclinic

Axinite usually occurs as wedge-shaped crystals or aggregates of crystals. It has good (100) cleavage. The hardness is 7 and the density 3.3. The color is characteristically clove-brown to gray-violet. The streak is white and the luster is vitreous.

The optical properties are: $\alpha = 1.676 — 1.690$, $\beta = 1.684 — 1.698$, $\gamma = 1.685 — 1.699$. The birefringence is rather weak, about 0.010. It is optically negative, with an axial angle of 70° — 80°.

Axinite occurs in violet-brown aggregates, up to 5 mm. across, in hydrothermally altered diabase at Brookville, and also as individual crystals of microscopic size in cavities. Tomlinson (1945) records it in some quantity in the quarry at Lambertville.

TOURMALINE

$Na(Mg,Fe)_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$ Trigonal

Tourmaline generally occurs in prismatic crystals, often with rounded triangular cross-sections; the prism faces are usually vertically striated. The hardness is 7½ and the density 3.0—3.2. The color is usually black, although varieties of tourmaline may show practically any color. The streak is white and the luster vitreous.

The refractive indices of tourmaline vary considerably with composition; for common black tourmaline $\omega = 1.65 — 1.69$, $\epsilon = 1.63 — 1.66$.

Tourmaline occurs rarely in small amounts in the New Jersey trap rocks. Tomlinson (1945) described an occurrence in a vuggy pocket in the diabase quarry at Lambertville; Manchester (1931) records it from Chimney Rock and Rocky Hill.

EPIDOTE

$Ca_2(Al,Fe)_3Si_3O_{12}(OH)$ Monoclinic

Epidote occurs as good prismatic crystals elongated parallel to the *b* axis, and also massive or granular. It has perfect basal cleavage. The hardness is 7 and the density 3.3—3.6, increasing with the iron content. The color is yellow green to dark green, and the streak is white or grayish white. The luster is vitreous.

The optical properties are: $\alpha = 1.71 — 1.73$, $\beta = 1.72 — 1.76$, $\gamma = 1.73 — 1.78$. It is optically negative with a large axial angle.

Epidote has been recorded from Bergen Hill, Paterson, Great Notch, Rocky Hill, and Moore. At Moore it occurs as incrustations of tiny crystals associated with calcite and stilbite.

ALLANITE

$(Ca,Ce)_2(Al,Fe,Mg)_3Si_3O_{12}(OH)$ Monoclinic

Allanite is an epidote in which some of the calcium has been partly replaced by cerium and other rare earth elements. It is sometimes slightly radioactive from the presence of a small amount of thorium and uranium. It occurs as tabular or elongate crystals, or as embedded grains. The hardness is 6½ and the density is variable, from 4.0 down to 2.7. The color is black and the streak gray-brown. The luster is vitreous or pitchy.

The optical properties of allanite vary considerably from specimen to specimen, but in the material from Snake Hill mentioned below they are: $\alpha = 1.79$, $\gamma = 1.81$; strongly pleochroic from pale brown to dark brown.

Allanite has been identified in a specimen from Snake Hill, occurring as lustrous black prismatic crystals up to 5 mm. long in granular calcite. It is of interest as being the only rare earth mineral recorded from the New Jersey trap rocks. Testing with a Geiger counter showed no radioactivity in the mineral, indicating an absence of thorium and uranium.

PUMPELLYITE

$Ca_4(Al,Fe)_6Si_6O_{23}(OH)_3.2H_2O$ Monoclinic

At the single locality so far known for this mineral in New Jersey, it occurs lining vesicles in the trap rock, as light to dark blue-green fibrous crusts, up to 1 mm. thick. The hardness is 6½ and the density 3.20. The streak is pale green.

The optical properties are: $\alpha = 1.679$, $\beta = 1.682$, $\gamma = 1.694$; pleochroic, X = pale yellow, Y = blue green, Z = pale yellow.

Pumpellyite was first identified from the New Jersey trap rocks in 1957, in material collected by Mr. George Jellenik from the Houdaille quarry at Summit. It is probably not uncommon in the trap rocks, but could be easily misidentified as chlorite. It can readily be distinguished from chlorite by its much greater hardness; it cannot be scratched with a knife.

In some of the vesicles the pumpellyite has been followed by prehnite, analcime, and chlorite, in that order of deposition.

SPHENE

$CaTiSiO_5$ Monoclinic

Sphene (also known as *titanite*) generally occurs as small wedge-shaped crystals, sometimes in cruciform twins. It has distinct (110) cleavage. The hardness is 6 and the density is 3.5. The color is usually yellow to brown, the streak white, and the luster adamantine.

Sphene has only once been recorded from the New Jersey trap rocks, by Kato (1891), who found it as small lustrous yellow-brown crystals in a quarry in the Jersey City section of Bergen Hill.

CHRYSOCOLLA

$CuSiO_3.2H_2O$ Orthorhombic

Chrysocolla is a secondary copper mineral, and is never found in crystals. It has no cleavage and a conchoidal fracture. The hardness is 4 and the density is variable, about 2.5. The color is green or blue, and the streak white. The luster is vitreous.

Chrysocolla is not a common mineral in the New Jersey trap rocks, but has been recorded at a number of localities, where it has evidently formed by the alteration of copper sulphides. It has been found at Paterson, Great Notch, Upper Montclair, Summit, Plainfield, Chimney Rock, and Rocky Hill.

Discredited or Unconfirmed Occurrences

Allophane: Recorded from Bergen Hill and Plainfield by Manchester (1931). All the specimens of so-called allophane which I have examined have proved to be stevensite or opal.

Aragonite: Recorded by Manchester (1931) from Bergen Hill, Paterson, and Upper Montclair. However, all the specimens labelled "aragonite" which I have examined, including the chalky coralloid forms considered typical of aragonite, have proved to be calcite. Some of these may be paramorphs of calcite after aragonite.

Arfvedsonite: Arfvedsonite was tentatively identified from Paterson by Fenner (1910); however the mineral was later shown to be babingtonite.

Chloanthite: Recorded (with a query) from Paterson by Manchester (1931). I have seen no specimens, and the occurrence is unlikely; possibly a specimen of this mineral from Franklin has been wrongly ascribed to Paterson.

Chrysotile: Recorded as fibrous veinlets from the lower New Street quarry and Prospect Park in Paterson by Hawkins and Whitlock (1933). However, specimens of the so-called chrysotile from these localities have proved to be chlorite.

Deweylite: Recorded from the lower New Street quarry and Prospect Park by Hawkins and Whitlock (1933), and from Bergen Hill by Selfridge (1936). However, Faust and Murata (1953) have shown that Selfridge's deweylite is actually stevensite, and this is probably true also for the other recorded deweylites.

Epistilbite: Originally recorded (with a query) from railroad cuts in Bergen Hill by Bourne (1841). This record has apparently been repeated by later writers, without the discovery of further specimens. I have seen no epistilbite from Bergen Hill or any other locality in New Jersey. The spheroidal masses of a yellow zeolite from Summit which have been labelled epistilbite are actually stilbite. Canfield (1911) gives reasons for believing that the reported epistilbite from Bergen Hill was actually thomsonite.

Erythrite: Hawkins and Whitlock (1933) state that one specimen of erythrite was found at the lower New Street quarry and is preserved in the Paterson Museum. Examination of this specimen shows that the matrix on which the erythrite occurs is not trap rock, but granite; the specimen cannot have come from a trap rock quarry and has evidently been mislabelled as to locality.

Fluorite: Recorded from Bergen Hill and Summit by Manchester (1931). I have seen no specimens, but the occurrence is not unlikely.

Genthite: Recorded by Hawkins and Whitlock (1933) as thin crusts in the lower New Street quarry at Paterson. A specimen so labelled in the Paterson Museum proved to be stevensite. The absence of any primary nickel minerals at this locality makes the occurrence of genthite improbable.

Kaolinite: The kaolinite recorded by Hawkins and Whitlock (1933) as a decomposition product at the Prospect Park quarry was probably stevensite.

Magnesite: Recorded from the New Street quarries at Paterson by Hawkins and Whitlock (1933). However, specimens labelled magnesite or breunnerite (a variety of magnesite) from this locality have proved to be dolomite.

Rhodochrosite: Recorded by Manchester (1931) from Bound Brook, presumably from the Chimney Rock quarry. I have seen no specimens, and other supposed rhodochrosites have proved to be red-tinted calcite.

Serpentine: Hawkins and Whitlock (1933) state: "Various colors (of serpentine) occur at all the Paterson localities. The best specimens have been collected from the Prospect Park quarry." Specimens from these localities labelled serpentine have proved to be chlorite, and the occurrence is therefore not confirmed.

References

Bascom, F. (and others). Description of the Trenton quadrangle: U. S. Geol. Survey Geol. Atlas, Trenton folio (no. 167), New Jersey-Pennsylvania, 24 pp., 3 figs., 3 maps, 1909.

Bayley, W. S. (and Salisbury, R. D., and Kummel, H. B.). Description of the Raritan quadrangle: U. S. Geol. Survey Geol. Atlas, Raritan folio (no. 191), New Jersey, 32 pp., 21 figs., 5 maps, 1914; abstract, Washington Acad. Sci. Jour., vol. 4, p. 371, 1914.

Bourne, W. O. Notice of a locality of zeolites, etc., at Bergen, Bergen County, New Jersey: Am. Jour. Sci. and Arts, 1st ser., vol. 40, pp. 69-73, 1841.

Canfield, F. A. Thomsonite in New Jersey: Sch. Mines Quart., vol. 32, pp. 215-216, 1911.

Clarke, F. W. (and Darton, N. H.). On a hydromica from New Jersey: U. S. Geol. Survey Bull. 167, pp. 154-155, 1900; reprinted, Am. Jour. Sci., 4th ser., vol. 7, pp. 365-366, 1899.

Darton, N. H. On a new locality for hayesine and its novel occurrence; Am. Jour. Sci., 3d ser., vol. 23, pp. 458-459, 1882.

———— (and others). Description of the Passaic quadrangle: U. S. Geol. Survey Geol. Atlas, Passaic folio (no. 157), New Jersey-New York, 27 pp., 4 maps, 32 figs., 1908.

Drake, H. Y. The quarry at Upper Montclair, N. J.: Rocks and Minerals, vol. 18, pp. 332-333, 1943.

Faust, G. T. (and Murata, K. J.). Stevensite, redefined as a member of the montmorillonite group: Am. Mineralogist, vol. 38, pp. 973-987, 1953.

Fenner, C. N. The Watchung basalt and the paragenesis of the zeolites and other secondary minerals: New York Acad. Sci. Annals, vol. 20, pp. 93-187, 4 pls., 29 figs., 1910.

———— Babingtonite from Passaic County, New Jersey: Washington Acad. Sci. Jour., vol. 4, pp. 552-558, 1 fig., 1914.

———— An unusual occurrence of albite: Am. Mineralogist, vol. 11, pp. 255-259, 1926.

Frondel, C. Some instances of incrustations selective upon crystal forms: Am. Mus. Novitates no. 695, 6 pp., 1934.

Hawkins, A. C. Glauberite crystals from West Paterson, New Jersey: Am. Mineralogist, vol. 18, pp. 273-274, 1 fig., 1933.

———— (and Whitlock, H. P.). Minerals of the trap rock quarries of Paterson, New Jersey: 16th Internat. Geol. Cong., United States, 1933, Guidebook 9, New York Excursions, pp. 128-139, 2 figs., 1933.

Hey, M. H. Studies on the zeolites. Part II. Thomsonite (including farselite) and gonnardite: Mineralog. Mag., vol. 23, pp. 51-125, 1932.

———— Studies on the zeolites. Part III. Natrolite and metanatrolite: Mineralog. Mag., vol. 23, pp. 243-289, 1932.

———— Studies on the zeolites. Part V. Mesolite: Mineralog. Mag., vol. 23, pp. 421-447, 1933.

Johnson, H. Trap rock aggregates in New Jersey: Geol. Soc. Am., Guidebook for field trips Atlantic City meeting, pp. 42-44, 1957.

Kato, F. Y. Some of Bergen Hill's rare minerals, a description of unusual occurrences at this locality in Hudson County, N. J.: Mineralogists' Monthly, vol. 6, pp, 85-89, 1891.

Leeds, A. R. Contributions to mineralogy . . . 2. talc pseudomorphous after pectolite: Am. Jour. Sci. and Arts, 3d ser., vol. 6, pp. 23-24, 1873.

Lewis, J. V. The origin and relations of the Newark rocks: New Jersey Geol. Survey Ann. Rept. State Geol. for 1906, pp. 99-129, 2 pls., 4 figs., maps, 1907.

———— Petrography of the Newark igneous rocks of New Jersey: New Jersey Geol. Survey Ann. Rept. State Geol. for 1907, pp. 97-167, 40 pls., map, 1908; abstract, Science, new ser., vol. 28, p. 574, 1908.

Manchester, J. G. The minerals of the Bergen archways (New Jersey): Am. Mineralogist, vol. 4, pp. 107-116, 4 pls., 5 figs., 1919.

———— The minerals of New York City and its environs: New York Mineralog. Club Bull., vol. 3, 168 pp., xviii pp., 128 pls., map, 1931.

Merrill, F. J. H. (and others). Description of the New York City district: U. S. Geol. Survey Geol. Atlas, New York City Folio (no. 83), Paterson, Harlem, Staten Island and Brooklyn quadrangles, New York-New Jersey, 19 pp., 24 figs., 13 maps, 1902.

Nutall, T. Observations and geological remarks on the minerals of Paterson and the Valley of Sparta, in New Jersey: New York Medical and Phys. Jour., vol. 1, 1822, pp. 194-204; reprinted, Am. Jour. Sci. and Arts, 1st. ser., vol. 5, pp. 239-248, 1822.

Sachs, W. P. The story of the Great Notch quarry: Rocks and Minerals, vol. 15, pp. 111-115, illus., 1940.

Schaller, W. T. The crystal cavities of the New Jersey zeolite region: U. S. Geol. Survey Bull. 832, 90 pp., 32 pls., 33 figs., map, 1932.

Selfridge, G. C. An X-ray and optical investigation of the serpentine minerals: Am. Mineralogist, vol. 21, pp. 463-503, 4 pls., 5 figs., 1936.

Shannon, E. V. Notes on anglesite, anthophyllite, calcite, datolite, sillimanite, stilpnomelane, tetrahedrite, and triplite: U. S. Nat. Mus. Proc., vol. 58, pp. 451-453, 1921.

———— The mineralogy and petrology of intrusive Triassic diabase at Goose Creek, Loudoun County, Virginia: U. S. Nat. Mus. Proc., vol. 66, 86 pp., 1926.

Tomlinson, W. H. Occurrence of borosilicates in diabase at Lambertville, New Jersey: Am. Mineralogist, vol. 30, pp. 203-204, 1945.

Wherry, E. T. Chalcopyrite crystals from the Bergen archways (New Jersey): Am. Mineralogist, vol. 4, pp. 116-118, 2 figs., 1919.

Whitlock, H. P. A study of the crystallography of the calcites of the New Jersey diabase region: Am. Mus. Nat. History Bull., vol. 56, pp. 351-377, 25 figs., 1927.

———— A crystallographic note on greenockite from West Paterson, New Jersey: Am. Mus. Novitates no. 372, 2 pp., 2 figs., 1929.

Woodward, H. P. Copper mines and mining in New Jersey: New Jersey Geol. Survey Bull. 57, 156 pp., 1944.