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ON THE ORIGIN AND SEQUENCES OF THE MINERALS OF THE NEWARK (TRIASSIC) IGNEOUS ROCKS OF NEW JERSEY

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ON THE ORIGIN AND SEQUENCES OF THE MINERALS OF THE NEWARK (TRIASSIC) IGNEOUS ROCKS\(^1\) OF NEW JERSEY.

BY WALLACE GOOLD LEISON.


Pill. XI–XIII. Dec. 27, 1909.)

As early as the year 1850 most of the minerals which occur in trap rocks had been found in the trap at Bergen Hill, N. J., but evidently near the surface and not in notably fine specimens.\(^2\) The Erie railroad tunnel, technically known as Bergen Tunnel No. 1, begun in June, 1856, bored through the ridge by the tedious method of hand drilling and blasting with black powder by August 20, 1859, and opened for traffic early in 1861,\(^3\) first reached the deeper recesses of the New Jersey trap in this locality and so disclosed the wealth of zeolites and associated minerals which has made it famous. Bergen Tunnel No. 2,\(^4\) and others also productive of such minerals followed, but the exigencies of tunneling opposed investigation of the conditions under which they occurred. Not until later, when high explosives, percussion machine drills, rock crushers and the rotary kiln for making cement were perfected and led to the opening of numerous and extensive quarries throughout the State for the production of broken stone to be used in the macadam and concrete industries, were the minerals of the New Jersey trap satisfactorily accessible for study in situ.

The visitor to a trap quarry productive of minerals finds that at every

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2. See J. D. Dana, Syst. Min., 31. ed. 1850.
3. From private records. See also H. S. DRINKE, Tunneling Explosives and Rock Drills, N. Y., p. 1084. 1882.
4. DRINKE: op. cit., p. 1038. The Delaware Lackawanna & Western Railroad tunnel, cut between 1869 and 1874. Hand labor in heading, Ingersol drills in bottom. Rend Rock powder used in preference to dynamite.
depth so far reached the trap rock is riven by splits, joints and seams, or is cellular with cavities, many of which are lined with clusters of beautiful crystals or filled solidly with minerals quite foreign to the trap in composition. Few investigations appear to have extended as yet below tide level or the water table. Conceding trap to be of igneous origin it might be expected that some of these minerals would be of like origin, but such is rarely the case. As a rule they are minerals which are destructible by even a moderate heat (unless perhaps under pressure), and most of them contain considerable water in their composition.

Calcite, which is usually predominant among these minerals, occurring in rhombohedral, prismatic and scalenohedral crystals and in masses with rhombohedral cleavage, would be converted at a moderate heat into quicklime. Gypsum, which contains about 20% of water, would be dehydrated into plaster of Paris. Thaumasite, which occurs liberally in some of the quarries, contains both of these minerals. Pectolite, which is of very general occurrence, contains from 3% to 9% of water and would be dehydrated. Quartz, which occurs as rock crystal and chalcedony, is disintegrated when heated, probably by vapor pressure generated from liquids in microscopic cavities.

The zeolites proper, of which the crystals chiefly consist and which are the minerals more exclusively characteristic of the trap, would, as their name implies, fuse into shapeless masses. All contain water of crystallization. Many circumstances observed in the New Jersey localities seem to indicate that these minerals have been or are now being produced simply by crystallization from solution, the solvent being probably water and the dissolved material, chiefly the trap rock itself.

An average of four analyses, three by R. B. Gage and one by L. C. Eakins of the diabase of the Newark Formation from New Jersey localities near those productive of trap minerals, gives its composition approximately as follows:

<p>| | | |</p>
<table>
<thead>
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<tbody>
<tr>
<td>SiO₂</td>
<td>53.36</td>
<td>Na₂O</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>13.40</td>
<td>K₂O</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>1.78</td>
<td>TiO₂</td>
</tr>
<tr>
<td>FeO</td>
<td>9.93</td>
<td>P₂O₅</td>
</tr>
<tr>
<td>MgO</td>
<td>8.14</td>
<td>MnO</td>
</tr>
<tr>
<td>CaO</td>
<td>8.30</td>
<td></td>
</tr>
</tbody>
</table>

\[ 100.22 \]

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These appear to be analyses of typical trap rock, not of the special sheets and fragments which occupy the joints in the diabase, or the fragments which make up the brecciated facies, or the material of the amygdaloidal or vesicular trap which seem most productive of trap minerals. From these analyses, however, trap rock appears to contain all the constituents usually found in the common trap minerals, with the singular exception of boron, which is a principal constituent of datolite and fluorine, and of which apophyllite generally but not always contains a small proportion. Datolite is a basic orthosilicate of boron and calcium \(^1\) which occurs liberally in some of the New Jersey quarries, sparingly or not at all in others, usually directly upon the trap.

The origin of the trap minerals, as well as many others, has long been attributed to the action of water, by some under ordinary present temperature conditions,\(^2\) by others to magmatic water and hydrothermal processes.\(^3\) In the New Jersey trap the frequent occurrence in cavities or parts of fissures of the remains of previously formed crystals now apparently undergoing solution and in close juxtaposition thereto of exquisitely perfect crystals both microscopic and macroscopic in beautiful groups, apparently now in process of development, seems to indicate that water under present conditions is still actively engaged in both their dissolution and their generation. Some interesting results apparently of these contending processes occur in crystals of calcite at Upper Montclair, N. J., consisting of etchings and oscillations of growth. Such a crystal is shown in Plate XI, Fig. 1.\(^4\)

Probably both rain and spring water take part in the production of trap minerals. With reference to the solubility of New Jersey trap in meteoric water, the following experiment is of interest: A quantity of hard trap rock from a quarry at Upper Montclair, N. J., broken into pieces about 6 mm. in diameter was washed free from dust with distilled water and air-dried on filtering paper. Then 100 grammes of this broken stone was submerged in 200 cc. of distilled water in a covered glass jar. It was frequently stirred, and the water gradually became turbid with flocculi of a dark greenish color. Sixteen days later the water was poured off the trap rock, each piece of the latter washed with a jet of distilled water, the solution and wash water filtered and then evaporated at 100\(^\circ\) C. in a platinum dish to dryness. With the same broken stone, again air dried, the experiment was repeated.

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\(^1\) E. S. Dana: Syst. Min., N. Y., p. 504, 1892.  
\(^4\) Photographed from a specimen in the collection of Mr. George E. Ashby, of New York.
Exp. 1. The residue weighed 0.0378 gramme
Exp. 2. " " " " 0.0367 " "
Average 0.0372 "

Hence one liter of water acting for sixteen days on 500 grammes of this broken trap would dissolve 0.1860 gramme of its constituent material. The above residues were chiefly white, and dissolved almost entirely in hydrochloric acid, with slight effervescence. A small quantity of a brownish material, apparently organic matter, remained. With the spectroscope, the solution gave lines of sodium and calcium.

In the residue No. 2 above silica and alumina were determined as follows:

\[
\begin{align*}
\text{SiO}_2 & \quad 0.0052 \text{ gramme} \\
\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3 & \quad 0.0023 \ " \\
\end{align*}
\]

Hence one liter of water acting for sixteen days on 500 grammes of the above broken trap would dissolve 0.0260 gramme of silica and 0.0115 gramme of alumina.

The greenish flocculent matter collected on the filter was dried, ignited and weighed, as follows:

\[
\begin{align*}
\text{Experiment 1,} & \quad 0.0514 \text{ gramme} \\
\text{Experiment 2,} & \quad 0.0536 \ " \\
\end{align*}
\]

Hence one liter of water acting for sixteen days on 500 grammes of the above trap would remove

\[
\begin{align*}
\text{Experiment 1,} & \quad 0.2570 \text{ gramme} \\
\text{Experiment 2,} & \quad 0.4680 \ " \\
\end{align*}
\]

This substance before ignition resembled diabantite. After ignition, it had a ferruginous orange color. A small quantity of the natural soft coating was taken from one side of a crevice in a specimen of trap, and after ignition it had a similar color.

Trap rock being thus soluble in pure water, it would probably be still more soluble in meteoric water which had absorbed carbonic acid, oxygen, organic acids or other such substances before reaching it. Rain becomes charged with gases acquired from the air in falling, taking up from 3 to 30 cc. per liter. The oxygen is found in larger proportion than in air, being sometimes as much as 38% of the dissolved gases. It also contains about 3% of carbonic acid and traces of carbonate and nitrate of ammonia and free nitric acid, besides small solid particles of dust, salts and organic matter.¹

¹ V. B. Lewes: Service Chemistry, p. 103. London, 1895.
volcanic districts it thus absorbs sulphurous acid and hydric sulphide; over bog lands, marsh gas; and in manufacturing districts, hydric chloride and chlorine.\(^1\) Rain and dew spreading over growing land vegetation would seem likely to acquire considerable of the oxygen exhaled as a function of growth. The seepage and overflow of pools and streamlets in which algae are flourishing would be highly charged with oxygen. I have collected in a few days about half a liter of oxygen, pure enough to relight a glowing taper, by simply inverting a jar over a rank growth of filamentous algae in a self-sustaining aquarium. Any meteoric water seeping through decaying vegetation would seem likely to absorb considerable carbonic acid and perhaps crenic\(^2\) or other organic acids and compounds, and such water previously oxygenated would seem likely to acquire a greater charge of carbonic acid by its own reaction upon such material.\(^3\) Oxygenated water reaching the trap more directly would evidently have a reaction upon it differing from the above.

"By the continuous action of water charged with carbonic acid, even in small proportion, granite and other hard rocks are disintegrated, and the changes effected, insignificant as at first sight they may appear, in the lapse of time become of great extent and importance."\(^4\)

To determine whether the New Jersey trap rock is more soluble in water charged with carbonic acid than in pure water, the experiment previously described was repeated, with the modification that for about an hour each morning and evening of the sixteen days, carbonic anhydride, freed from every trace of hydrochloric acid vapor, was allowed to bubble slowly through the water in which the trap was immersed. The total amount of gas generated by about 15 cc. of commercial hydrochloric acid acting on an excess of marble was the quantity usually transmitted. The residue from the 200 cc. of the solution was white and weighed 0.1226 gramme. Hence one liter of water thus partly charged with carbonic acid acting upon 500 grammes of trap from Upper Montclair, N. J., for sixteen days would dissolve 0.6130 grammes of its constituent material.

The trap solution was much less turbid than that in pure water. The material which caused its turbidity collected upon the filter contained some particles which appeared to be trap mechanically separated. These were removed and weighed 2.4 milligrammes after ignition. The remainder of the material weighed 21.4 milligrammes. The latter would correspond to 0.1070 grammes produced by the action of one liter of water containing \(\text{CO}_2\) on 500 grammes of trap in sixteen days.

\(^1\) V. B. Lewis: _op. cit._, p. 215.
\(^3\) V. B. Lewis: _op. cit._, p. 100.
That meteoric waters charged with such other substances as those above mentioned would have a much greater solvent action than pure water upon trap rock, while probable, seems not to have been as yet experimentally established.

In either case meteoric water, penetrating the New Jersey trap from above, finds its way downward through numerous crevices and joints in the rock, even when they are only of microscopic width, dissolves the trap on both sides of, and thus gradually widens them. The more or less concentrated solution collects in natural cavities or larger crevices previously formed and there, apparently, deposits chiefly in crystals the complex materials it carries.¹

By what process is the solution caused to deposit its contents? It seems little likely to be evaporation, but there are several other known processes which jointly or separately could possibly result in the production of these minerals from solution under the apparent conditions. For example, the water could become charged with a soluble constituent of the trap, part or all of which it might have to deposit, as in its further progress it acquired another constituent.² This is a known process of deposition from solution but not of common occurrence.

Another cause for the deposition of substances from solution is a change of solubility with change of temperature. Some substances are more soluble in warm, others in cold water. A change of one degree in temperature in a saturated solution could cause some deposition of its contents. Water, upon freezing, excludes all substances it may hold in solution, whether solid, liquid or gaseous. In case such a solution as that above described were frozen in a fissure in the rock, upon again becoming liquid it could drain away without redissolving the material it had deposited.

Variations of pressure, acting in most cases inversely to variations of temperature, increase or decrease the saturation capacity of solvents.³ Thus the solvent action of meteoric water may be increased the deeper a descending column penetrates below the surface. Upon the subsidence of such a column to a subsurface level during a dry interval, or upon the escape of such water as spring water with consequent release of pressure, this condition is reversed and perhaps a deposition of dissolved material may occur.

The principle of diffusion also may be involved in the sorting out of the dissolved substances and their deposition to form these minerals.⁴ It seems

¹ According to Bischoff (Chem. & Phys. Geol. V. 2, pp. 115 & 137, London, 1856) analcite and natrolite are the only zeolites which do not contain silicate of lime and the only ones that could have been produced from water containing CO₂.
⁴ W. A. Miller, op. cit., p. 70.
likely, however, that their production is chiefly due to chemical reactions resulting in the formation of less, from more soluble substances in solution.

Several crystallized minerals, including some zeolites, have been artificially produced from aqueous solution, both accidentally and intentionally.\(^1\)

That water percolating from above is concerned in the production of the New Jersey trap minerals appears to be indicated by the circumstance that crystals which occur on the upper sides of cavities are usually unimpaired, even though colored, while those which occur on the under sides have usually occluded a sedimentary material resembling yellow or red oxide of iron or a ferruginous clay in fine particles, which also frequently covers them with a coating evidently imbedded in the surface and impossible to remove. Clusters of crystals projecting from the sides of cavities are frequently thus coated on the upper, while unsullied on the under surfaces, a circumstance of common occurrence with calcite and prehnite. The lustrous undersurface of such an occurrence of reniform prehnite is shown in Plate XI, Fig. 2. The material of this coating, which is also often occluded throughout a crystal, consists perhaps of the 2% to 3% of ferric iron with other undissolved residues of the trap and some clay from the top soil all carried down mechanically by the water. It sometimes has a bright red color as though chiefly a ferric compound, thus occurring on crystallized quartz and heulandite at West Paterson and stilbite and heulandite at Upper Montclair, common, and on heulandite at Great Notch, rare.

Spring water would act upon the trap somewhat differently from rain water for several reasons, and coming perhaps through various other rocks before entering the trap may so acquire the boric acid and fluorine required and be accountable for the production of datolite, which occurs liberally in some quarries and contains the large proportion of 21% of boric acid; and also such apophyllite as contains fluorine.

Release of pressure may account for the deposition by spring waters of such crystallized minerals in the trap, as it does for the escape of gases and the deposition of sulphur from sulphur waters, iron carbonate and oxides from chalybeate waters, and calcareous and siliceous sinters from hot-spring waters.

The microscopic crevices through which the water enters cavities in the rock are often disclosed at Great Notch, N. J., by the sledge hammer. Large yellow calcite crystals somewhat resembling those of Joplin, Mo., occur there in such cavities, but any attempt to trim the rock away around such a crystal usually results in its splitting directly through the cavity and the destruction of the crystal. The parted sides of the split are often covered

\(^1\) W. A. MILLER, op. cit., p. 96.
with a thin dark colored film and show that the split followed a seam which
was almost imperceptible before it was thus disclosed.¹

To study the conditions existing in a crevice or cavity containing minerals
previously undisturbed, it is necessary for the investigator to be present
when it is first exposed directly after a blast. Although I have spent many
days in quarries, I have been favored with few such opportunities, perhaps
a dozen in all, and have invariably found the contents of the cavity saturated
with moisture. In some cases the crevice or cavity was filled with a viscid
material resembling paste in appearance and covering clusters of superior
crystals.² I have seen cavities of various sizes, partly or entirely filled with
water and often containing no mineral deposit whatever, exposed by the
sledge hammer in apparently solid trap.

Probably the water reaches such cavities through microscopic crevices,
although Bischoff ³ credits it with penetrating through the pores of the rock.
Occasionally a cavity is filled with material resembling wet snow, covering
groups of crystals, sometimes on a lining of pectolite. This material is
sometimes thumisite penetrated by concretions and needles of pectolite,
sometimes apparently laumontite, in microscopic crystals. In some cases
a narrow crevice will be lined on opposite sides with two different minerals,
as heulandite and calcite, almost in contact, but each free from the other.
In other cases the crevice will be filled solid, where it is narrow, with a single
mineral, and where it is wider this divides into linings with finely crystallized
faces.

The deposition of two or three of the trap minerals synchronously or in
close alternation produces occasional cryptocrystalline masses attractive in
appearance, but having the composition and structure of a rock rather than
a mineral. Such would be a solid mass composed of needles of pectolite
or natrolite carrying parasitic crystals of apophyllite, gmelinite or calcite as
illustrated in Plate XI, Figs. 3 and 4, and Plate XII, Figs. 1 and 2. Someti
times, as in Plate XI, Fig. 3, the parasitic mineral is distinguishable through
out the resulting solid, but usually the mass appears, deceptively, to consist
only of the predominant mineral, while it approximates a solid solution in
character, as is the case with much of the pectolite from Woodcliff, N. J.
(Plate XIII, Fig. 3) in which many of the needles are invested with micro
scopic crystals of calcite. To this may perhaps be attributed the exception
ally strong yellow fluorescence and triphosphorescence of the Woodcliff and some other pectolites, as the thermo- and triphosphor-

² A gelatinous substance having the composition of chabazite has been noted between cal
cite crystals by Renier. E. S. Dana, Syst. Min., p. 599. N. Y., 1892.
escence of certain tremolites have been attributed to a somewhat similar inclusion of dolomite.\(^1\)

In several localities a mineral occurs in flexible filaments sometimes as fine as hair.\(^2\) One or more of these, perhaps two centimeters in length, may project from a face of a crystal of datolite or calcite, or they may be attached in clusters directly to the trap or to a film of diabantite upon the trap as in the example from Snake Hill illustrated in Plate XII, Fig. 3. Often they cross a cavity between adjacent groups of datolite crystals intersecting in all directions. Each filament frequently supports a series of crystals of calcite, datolite, apophyllite or other minerals like beads upon a thread or dew drops on a spider's web, ranging in size from microscopic to macroscopic and with all faces complete.

A large quantity of such a filamentary mineral was recently found by Mr. James G. Manchester, of New York, thus associated with datolite in a nearly vertical crevice in the Erie Railroad cut through Bergen Hill. In part it was massed together resembling asbestos, in part disposed as above described (Plate XII, Fig. 4). Throughout it was invested with crystals of various sizes and kinds, a large quantity of which, chiefly datolite, fell from the cavity like sand when it was disturbed. Many of these were euhedral and probably had been supported on the filaments.\(^3\) The matted filaments, when mounted in balsam, were found to entangle a multitude of microscopic crystals of several minerals easily distinguishable from each other in polarized light. At Great Notch a similar filamentary mineral has been noted (but rarely) forming fringes on microscopic plates of a black mineral.

Commonly all these minerals are separated from the trap by a thin film of a material varying from gray to greenish black in color and often having the feel of talc (Plate XII, Figs. 2 and 3). Apparently similar material of a greenish black color occasionally fills small crevices in the trap and in many cases occurs in large quantity, as at Woodcliff (Guttenberg) where, together with prehnite invested with beautiful microscopic crystals of other trap minerals and numerous large crystals of such minerals, it occupies the interstices between fragments and sheets of partly decomposed trap that fill a nearly vertical fault or shear zone about a meter wide in the Palisade

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\(^1\) Bourquin, quoted by Parker Cleveland: Elem. Treatise on Mineralogy and Geology, p. 323. Boston, 1816.

\(^2\) This is probably a fibrous natrolite which according to Mr. F. A. Canfield was called fibrolated-natrolite by Dr. A. E. Foote. This name is however not mentioned in Dana, Syst. Min., New York, 1892. Fine specimens from Bergen Tunnel No. 2 are in the collection of Mr. Canfield at Dover, N. J.

\(^3\) Since this paper was presented, these datolite crystals have been described by W. E. Ford and J. L. Pogue, Am. Jour. Sci., IV, xxviii, p. 187, Aug., 1909.
This material appears to be the so-called diabantite and simply an insoluble residue of trap otherwise dissolved in water.

Dr. Alexis A. Julien in a recent discussion of the composition of minerals has suggested that diabantite is not a mineral but a mixture of minerals which as deduced from analyses by G. W. Hawes of the trap at Farmington, Conn., are as follows: pyroxene (residual), enstatite (residual), prochlorite, ekmanite, deweylite, limonite, periclase. He considers the first two of these to be residues from the solution of the trap and the remainder recombinations of its dissolved constituents.

According to Dana diabantite is apparently a product of the alteration of the augite of the diabase; according to Emerson, the first product of the decomposition of the diabase "and seems to have been formed by slow deposition from water." 6

In each quarry the minerals have usually a prevailing characteristic color, ranging from pure white in some quarries to yellowish white, greenish white, yellow, orange, red and brown in others. This seems due to the iron in the trap, chiefly perhaps to its liberal content of ferrous iron. As a quarry is extended, however, rock of a different facies may be encountered, and in course of time the preponderant species of minerals and their prevailing color are liable to change.

Although Bischoff and subsequently others have recorded many details of this kind relating to the occurrence of minerals in general it seemed to me that a record of some of those observed in the New Jersey trap quarries may help eventually to disclose the genesis of the zeolitic group. Among such details the order of generation of the species seems important and following is a list of such sequences in their occurrence as I have noted them in New Jersey localities, arranged alphabetically.

Sequence or order of occurrence of the minerals.

Albite. Sequent on calcite, chabazite, diabantite and quartz, West Paterson.

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2 Id., p. 152.
3 Annals N. Y. Acad. Sci. XVIII, 139-142. 1908.
4 Syst. Min., 659-660, 1892.
8 Identified by Dr. C. Palache according to Mr. F. A. Canfield.
Analcite. Sequent on trap, Shadyside;\(^4\) on pink and white apophyllite, Snake Hill;\(^3\) on calcite, Shadyside, West Paterson and Erie Cut;\(^2\) on datolite, Erie Cut; on gmelinite, Snake Hill;\(^4\) on white and red heulandite, West Paterson; on natrolite and terminated pectolite, Snake Hill.

Apophyllite. Sequent on trap, many localities; on analcite, Erie cut, (Pl. XIII, Fig. 1) on calcite, West Paterson, Shadyside and Snake Hill; on datolite, Erie cut (common) and Snake Hill; on diabantite, Shadyside; on laumontite, Snake Hill and Great Notch; on natrolite, Snake Hill; on pectolite, in microscopic crystals (Plate XI, Fig. 3) and large crystals, Snake Hill; in large crystals, Hoxie's quarry, Paterson, and Berger's quarry, West Paterson; on prehnite Woodcliff;\(^5\) on quartz crystals, Hoxie's quarry, Paterson; on quartz pseudomorph, Great Notch; on stilbite, Shadyside.

Calcite. Sequent on calcite, one habit on another, Erie cut;\(^6\) on chabazite, West Paterson; on datolite, in large rhombohedrons, Erie cut and Snake Hill; on diabantite in rhombohedrons, Shadyside, in scalenohedrons, Woodcliff; on heulandite, West Paterson; on natrolite, Great Notch (Plate XII, Fig. 1) and Woodcliff (Plate XII, Fig. 2); on pectolite, Woodcliff and West Paterson; on prehnite in scalenohedrons, Great Notch, and Woodcliff (Plate XII, Fig. 2) on quartz (rock crystal, amethyst, chalcedony or pseudomorphous), Great Notch, West Paterson and Snake Hill; on stilbite in scalenohedrons, Upper Montclair (Plate XIII, Fig. 2); impaled on flexible filaments of an unidentified mineral in rhombohedrons, Snake Hill (Plate XII, Fig. 3).

Chabazite. Sequent on calcite, West Paterson; on datolite, West Paterson; on quartz, West Paterson and Great Notch; on stilbite, West Paterson.

Chalcopyrite. Sequent on calcite, Erie cut, Snake Hill and Homestead;\(^7\) on datolite, Erie cut.

Datolite. Sequent on apophyllite, Erie cut; on gmelinite and pectolite, West Paterson; on a filamentary mineral Erie cut (Plate XII, Fig. 4) and Snake Hill.

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1 Shadyside. The Hudson River terminal of the N. Y. Susquehanna and Western R. R. tunnel.
2 Snake Hill. The Penitentiary Quarry is to be understood unless others are mentioned.
3 Erie Cut herein signifies the new open cut now in process of construction (1909) through Bergen Hill by the Erie Railroad.
4 And Pinnacle Island, Nova Scotia.
5 Woodcliff is a small settlement on the Palisades where part of the cliff was removed. It is a section of Guttenberg.
6 H. P. Whipple; N. Y. State Museum, fifth report of the director, p. 219. 1908.
7 Homestead is the western terminal of the new Pennsylvania R. R. tunnels through Bergen Hill to Manhattan Borough, New York.
Diabantite? Sequent on datolite and gmelinite, Snake Hill.
Epidote. Sequent on quartz (rare), Great Notch.
Galena. Sequent on calcite, Homestead.
Gmelinite. Sequent on calcite, datolite, heulandite and pectolite, Snake Hill (Plate XI, Fig. 4).
Hematite. Transparent sequent on calcite and laumontite, ordinary on white and amethystine quartz, West Paterson.
Heulandite. Sequent on calcite, West Paterson; on datolite, West Paterson and Snake Hill; on gmelinite, West Paterson; on pectolite, Hoxic's quarry, Paterson, and West Paterson; on quartz, pseudomorphous, Hoxic's quarry, Paterson; on quartz, crystallized, white and amethystine, West Paterson.
Laumontite. Sequent on apophyllite, Snake Hill; on calcite, Great Notch; on datolite, Snake Hill; on gmelinite, Snake Hill; on heulandite, Hoxic's quarry, Paterson, and Great Notch; on natrolite, Great Notch.
Natrolite. Sequent on apophyllite, Snake Hill and Erie cut; on calcite, Snake Hill and Woodcliff; on datolite, Snake Hill and Erie cut; on diabantite, Shadyside and Woodcliff (Plate XII, Fig. 2); on pectolite, Snake Hill; ordinary and with fibrous terminations, on prehnite, Woodcliff and Bergen tunnel No. 2; fibrous on trap, Bergen tunnel No. 2.¹
Pectolite. Sequent on calcite, Hoxic's quarry (rare); and Woodcliff; on prehnite, Woodcliff (Plate XIII, Fig. 3); on quartz (pseudomorphous), West Paterson; on quartz (chalcedony), Hoxic's quarry, Paterson; on thumiasite, West Paterson and Great Notch.
Prehnite. Sequent on datolite, in crystals and globular, West Paterson, incrusting large crystals of datolite, Hoxic's quarry, Paterson; on diabantite, Woodcliff; on pectolite and also pseudomorphous after a radiated mineral probably pectolite, West Paterson; on pectolite, Upper Montclair; on quartz crystals, in separate microscopic crystals (rare) in hemispherical forms and in incrustations with and without datolite (common), Great Notch; on soplecite, West Paterson.
Pyrite. Sequent on analcite, Snake Hill (rare) and Erie cut (Plate XIII, Fig. 1); on apophyllite, in brilliant microscopic crystals, Snake Hill (common), and Erie cut (Plate XIII, Fig. 1); on calcite, in microscopic cubes Shadyside; on plates and scalenohedrons, private quarry, Snake Hill; on rhombohedral crystals, Erie cut; on datolite in microscopic cubes, Snake Hill and Erie cut; on diabantite, in various forms, Shadyside; on heulandite, microscopic in cubes (common), in square prisms several diameters in length and in rectangular plates (rare), Shadyside (Plate XIII, Fig. 4); on

¹ In the collection of Mr. F. A. Canfield, Dover, N. J.
stilbite, in microscopic crystals, Snake Hill Shadyside, and Erie cut (common).

**Quartz. 1. Rock Crystal.** Sequent on chabazite, West Paterson; on pseudomorphous quartz, Upper Montclair, Great Notch, West Paterson and Hoxie’s quarry, Paterson;

2. Amethyst. Sequent on pseudomorphous quartz, Hoxie’s quarry, Paterson, and West Paterson;

3. Chalcedony. Sequent, usually on the trap, several quarries.

**Scolecite.** Sequent on prehnite, West Paterson.

**Selenite.** Sequent on trap, Great Notch and West Paterson.

**Stilbite.** Sequent on apophyllite, Snake Hill, common (the reverse rare); on calcite in microscopic crystals, private quarry, Snake Hill, and Erie cut, common; in large clusters, West Paterson and Upper Montclair; on datolite in microscopic crystals, Snake Hill and Erie cut; on heulandite, Millington and West Paterson; on quartz, crystallized, Great Notch and West Paterson; on pseudomorphous quartz, Upper Montclair (common).

**Thaumasite.** Sequent on heulandite, West Paterson; on pectolite, West Paterson and Great Notch; on stilbite, West Paterson.

Unidentified mineral in filaments. Sequent on trap and diabantite, Snake Hill (Plate XII, Fig. 3), Erie cut and Woodcliff; on calcite and datolite, Erie cut (Plate XII, Fig. 4) and Snake Hill.

**Summary of Sequences.**

1. Trap, datolite, apophyllite, pyrite, analcite; not common. Snake Hill and Erie cut (best specimen).

2. Trap, datolite, heulandite, gmelinite. West Paterson.

3. Trap, datolite, gmelinite, laumontite. Snake Hill.

4. Trap, calcite, drusy quartz, heulandite. West Paterson.

5. Trap, calcite, quartz (crystallized), datolite, prehnite in balls. Great Notch.

6. Trap, calcite, quartz (crystallized), prehnite in microscopic crystals. Great Notch.

7. Trap, pectolite, natrolite, analcite. Snake Hill.

8. Trap, stilbite, calcite, quartz (pseudomorphous), stilbite. Upper Montclair.

**Conclusions.**

The quantitative estimates of the solubility of trap above given apply only to the material employed. Determinations of the solubility of various other
samples would obviously be necessary to serve as a basis for general conclusions.

As regards sequences these notes seem to indicate no conspicuously prevalent order in the genesis of the New Jersey trap minerals.

Quartz, calcite and datolite appear to be, in the order named, most generally deposited first upon the trap. One or another of these three minerals usually thus prevails in a given quarry or part of a quarry at a given time; but in the same quarry at a later time, when a different texture of rock is in process of excavation, another of them may be the prevalent mineral thus deposited. Likewise, in two adjacent quarries or even parts of the same quarry the prevalent minerals differ considerably. Thus, datolite has been plentiful in one of the two adjacent quarries at Snake Hill and seldom found in the other. Again, in one of two adjacent quarries at Great Notch datolite in opaque crystals and prehnite in spheroids, both on crystallized quartz, were extremely prevalent and almost no thaumasite occurred. In the other quarry, now being actively worked, thaumasite is abundant and the above-mentioned combination rare or absent. In fact, the prevalent minerals often differ greatly as new mineral-producing rock areas but a few yards distant are reached.

The minerals sequent upon datolite, calcite and quartz seem to be more numerous in the order named. Of the species which are more plentiful, apophyllite appears to occur upon the larger number of other species. Calcic sulphate not of frequent occurrence in the ordinary form of selcinite is plentiful as a constituent of thaumasite. Conclusions in regard to sequences must, however, be only tentative until records of other localities are available for reference.
PLATE I.

Fig. 1. CALCITE, Upper Montclair, N. J. Natural size. From the collection of Mr. George E. Ashby of N. Y.

The faces of the interior crystal are comparatively smooth but are formed only of a thin film perforated with minute holes within which it consists chiefly of thin parallel plates with intervening spaces partly filled with a loose dark colored powder which may be washed out leaving them vacant. Surrounding this interior crystal is a much less corroded envelope with terminations in fair condition. The specimen was found as shown in the illustration with both envelopes partly removed, disclosing its internal structure. The small projection on the left is stilbite to which it was attached (compare Plate III, Fig. 2.)

Fig. 2. PREHNITE, Hoxie's Quarry, Paterson, N. J.

A specimen which projected from the side of a cavity. The side shown was the under side and is unsullied. The opposite side is sullied with a coating of sediment partly included. Collected June 23, 1892.

Fig. 3. APOPHYLLITE parasitic on PROTOLITE, Snake Hill, N. J.

Photomicrograph. Magnified 4 diameters. Both minerals apparently are in process of deposition. The resulting solid mass resembles pectolite, but consists largely of occluded apophyllite discernible all through it. Collected May 30, 1899.

Fig. 4. GMELENITE, CALCITE and other minerals.

These are supported on and between acicular crystals of pectolite apparently in process of deposition, thus resulting in a solid mass resembling pectolite but occluding all these minerals. Photomicrograph. Magnified 4 diameters. Collected May 30, 1899.
PLATE II.

Fig. 1. Scalenohedrons of Calcite parasitic on crystals of Natrolite. From the exterior of a spheroidal aggregation solid within. A specimen from Great Notch, N. J., in the collection of Mr. James G. Manchester, of New York. Photomicrograph. Enlarged 4f diameters. The resulting solid resembles massive natrolite, but evidently contains much calcite, thus inclosed. Collected in July, 1909.

Fig. 2. Natrolite and Przemska supporting sequest Calcite. The resulting solid natrolite will consist largely of inclosed calcite. Collected Nov. 16, 1895.

Fig. 3. A filamentary mineral, on a thin coating of Diabase on trap and supporting parasitic crystals of various minerals. Snake Hill, N. J. The larger and more conspicuous of these are rhombohedrons of calcite. Photomicrograph. Magnified 3f diameters.

Fig. 4. A filamentary mineral in a cavity between crystals of dolomite and calcite. Erie Cut, Bergen Hill, N. J. Photomicrograph. Magnified 3f diameters. The filaments support parasitic crystals of various minerals, the larger and more numerous of which are dolomite. Collected February 27, 1909.
PLATE III.

Fig. 1. Apophyllite and Analcite on Dapolite. Erie Cut. Bergen Hill, N. J. The Apophyllite crystals in some cases appear to be sequent upon the analcite and certain of their faces are besprinkled with minute cubic crystals of pyrite, too small to be visible in the illustration. In a few cases similar sporadic cubes of pyrite occur on the analcite. Collected February 27, 1909.

Fig. 2. Calcite sequent on Stilbite. Upper Montclair, N. J. The calcite crystals here commonly include stilbite, and stilbite is frequently sequent on the calcite. Collected, April 24, 1894.

Fig. 3. Pectolite sequent upon a plate of Prehnite. Woodcliff, N. J. Collected April 23, 1896.

Fig. 4. Pyrite in prisms and cubes on Heulandite. Shadyside, N. J. Photomicrograph. Magnified 34 diameters. Collected August 5, 1893.
The New York Mineralogical Club.

The New York Mineralogical Club was organized in October, 1886, but it was not until the eighth meeting that officers were elected. Those then chosen were George F. Kunz, Secretary; B. B. Chamberlin, Treasurer; Daniel S. Martin, Rev. J. Selden Spencer, E. A. Hutchins and George F. Kunz, Executive Committee; R. P. Whitfield and L. P. Gratacap, Curators. For several years there was no president, the host of the evening filling that office for the occasion, since the meetings were held at private houses.

The object of the Club is to develop and maintain an interest in the minerals and rocks of Manhattan Island through collecting and the study and comparison of existing collections. The principal series in existence at the time of the organization of the Club was that of the late Benjamin B. Chamberlin, who had devoted more than twenty years to the study and to the collection of minerals on Manhattan Island. After the death of Mr. Chamberlin this collection was acquired by the Club, and it is now permanently deposited in the American Museum of Natural History. With this has been deposited the George F. Kunz Collection, besides many gifts to and purchases by the club, the whole forming a nearly complete representation of Manhattan Island minerals, which is now on exhibition in the Morgan Hall of Mineralogy.

The Club meets once in two months, usually at the American Museum of Natural History, for the consideration of papers upon mineralogical topics. Summer meetings in the shape of field excursions are made from time to time to nearby points of interest to the collector. Persons interested in mineralogy are invited to correspond with the Secretary regarding membership in the Club. The Club is an affiliated society of the New York Academy of Sciences.