The Minerals of Iceland

With a Note on

Zeolitic Occurrences and Associations

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THE MINERALS OF ICELAND WITH A NOTE ON ZEOLITIC OCCURRENCES AND ASSOCIATIONS.¹

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The mineralogical aspect of Iceland furnishes a limited field of study. The development within its wide area of the salts of the metallic bases, the groups of the sulphides, arsenides, antimonides, tellurides, selenides and the sulpho-salts which succeed them, is undiscoverable. The haloids are signal deprived of recognition, the oxides excluding quartz secure a feeble representation, or at most appear conspicuously in the products of decomposition of the iron-bearing volcanic extrusives while the silicates, except in the group especially associated in your minds with Iceland, attain no mineralogical pre-eminence, and only conclusively appeal to the petrographer as constituents of its immense volcanies, and the oxygen salts, omitting calcite and in a few places sphaerosiderite, though they might reasonably claim the privilege of birth there, seem quite prohibited.

When we recall the profusion of minerals in the Vesuvian district, the valuable offerings to the cabinets from Kalinka and Raddusa, the beautiful products of the changing ancient slags of Laurium, the abundant art which nature has shown in using for mineralogical ornament the trachytes and rhyolithes of Mexico, Utah and Colorado, we might indulge in some surprise that Iceland, with its enormous vulcanism, has not a more richly filled and more copiously extended catalogue of minerals. It is more than probable that mineral discoveries in Iceland will be forthcoming, and that the palagonites of the interior may yield upon exploration, some further contrib-

¹ Read at the regular meeting of the New York Mineralogical Club at the American Museum of Natural History, December 12, 1907. Illustrated with specimens.
butions to the increasing mineral species of the cabinets. We are inclined naturally to speculate upon what would have been the probable results of such extraordinary extrusions as are seen everywhere in Iceland, if they had taken place in sedimentary rocks, summoning, as they inevitably would have, through metamorphism, a train of mineral inclusions at all the zones of contact.

And indeed in the very class of beautiful silicates which has practically made Iceland the Mecca of the collector, it offers no exhaustive exhibit. Mordenite, found in the trap of Nova Scotia and in the amygdaloid of the Yellowstone river, is not found in the basalts of Iceland; brevsterite, found at the Giant's Causeway in Ireland, coating cavities, has not up to this time been reported from Iceland, the phillipsite which secures so extended a distribution also in the basalts of the Giant's Causeway, at Capo di Bove, in Sicily, in Germany, in France, has been but scantily taken at Dyrhólf, a region by-the-by on the west coast of Iceland where mineralogical research might, I think, be well repaid, and where indeed levyntite, a rare mineral in Iceland, is now found; harmotome probably cannot be found in Iceland; gismonite found in the Faroe islands is absent from Iceland; laumontite found in the Faroe islands is certainly rare in Iceland, laubanita has never been reported. Though chabazite is developed gmelnine is not. Faujasite, edingtonite are missing and while marvelous scoleces come from Iceland, some of which I saw in Edinburgh, natrolite singularly has not yet—so far as I know—been uncovered; I speak of specimens of cabinet interest. Williams found it at Syðsfjörði in needles, and has reported it from Faskrúdsfjörð as well crystallized. Mesolite can be ascribed to Iceland, though not common; certainly thomsonite is developed there, and ptilolite, and so out of the whole group of the zeolites, for which it has practically secured its mineralogical reputation, less than fifty percent are represented. As regards minerals so often associated with zeolites as to be in our minds natural members of the group, datolite and phehinite, have not, I believe, been found.

The zeolites that secure development in Iceland are indeed well represented, so far as beauty and development are concerned, and, because these minerals are essentially restricted to almost one locality or one region, we are driven to conclude that the accidents and limitations of exploration are more to blame for Iceland's imperfect record than any typical default in her mineralogical laboratories. As Iceland is more carefully quarried, as industrial enterprise, with the mineralogist as its natural concomitant, succeeds the work of the geologist and lithologist, Iceland, if she does not display new minerals, will greatly increase the number of her localities for those she has.
In regard to the calcite of Iceland—the famous Iceland spar—nothing I think can be added to the observations of Hægymnus Abrahall in 1890. At that time, as to-day, there was a prevalent and certainly to-day correct impression that the spar in large pieces of perfect quality was rare. It is found at Helgeistades Reydarfiord, and the quarry belongs, as it did when Abrahall was there, to the family of Tulinius, who sell the spar with the most appreciative care at Eskiford. Here weighed with precision on little scales, it brings about one dollar an ounce, if of very pure and infallible quality. It is found in a large cavity some fifteen by thirty-six feet in dimensions, and which formerly was almost filled with this remarkable deposit. It is to-day a cave lined with the attached calcite, occasionally full of water, in which walking is painful because of the sharp edges of the mineral not entirely covered with a sticky red clay. The original contents have been described as composed of "immense crystals, fitted so closely together as to form a compact mass, like a lump of sugar, with grains averaging ten inches across." It was remarked by Abrahall that the water running through the cave at the time of his visit was incapable of forming calcspat. It contained an excess of siliceous acid, and either etched the surface of the spar, or covered it with stilbite, an association familiar to everyone. The Icelandic or the Danish government has been interested in this quarry, but apparently its interest was either short-lived or misrepresented. I think now Herr Tulinius controls its output, although his proprietary rights seemed shared with Herr Gunnarsson of Seydisförd. In 1877 Mr. Labonne reported the calcite as abundant, and alludes to ramifying veins in the surrounding rock, and intimated that these converging or radiating veins would repay working. This cavity has not been exhausted, and its contents not completely estimated. When the government took a hand in the extraction of the mineral, the water was pumped out, and a large block of clear spar removed, which was sold at a good price in London. The calcite is rendered semi-opaque by innumerable cracks, following cleavage planes—with sometimes curious conchoidal fractures. A good deal of dirt adheres to surfaces along these cracks, and a microscopic feathering of incipient stilbite. The formation of this deposit might invite discussion. The cave is at some elevation and receives abundantly water from superficial drainage. It appears to have been fed by a carbonate of lime solution, and, from the immensity of the deposit and its general purity, I am inclined to think that the solutions seeped slowly in, after comparative filtration of impurities, and that the growth uninterruptedly inward of the spar was practically the formation of an enormous lime amygdale, with little or no individual development of crystals, the whole mass cleaving into rhombohedral units. It must not be supposed that the cavity is occupied from
wall to wall with the finest quality of calcite of the optical perfection of the best Neuchâtel prisms. These exquisite cleavages are included sections. Des Cloizeaux saw this locality in 1848, and described a block of calcite taken from it about eighteen feet wide and nine feet high, and rudely rhombohedral. He speaks of the cavity as a steam chamber, and doubtless this ascription of the origin of the "hole" to a huge vacuoole in lava, something like the enormously larger Shertshellar caves, is correct.

It is not an unwarranted assumption to place the formation, in time, of this extraordinary deposit near enough to the period of the igneous outflow, to have involved the agencies of heat and heated waters, and perhaps of carbonic anhydride exhalations. This calcite deposit, as do the zeolitic formations, presuppose of course extensive decomposition of the basalt, and this no less even if the immediate area of decomposition was much more deeply seated, the lime salt finding its way in solution to such opportunities of deposit as this cavern afforded. And the source of the lime must have been largely the pyroxenes and amphiboles of the basalt, though labradorite was probably quite able to supply it, if labradorite is a prevailing plagioclase in these rocks. But the calcites more generally may be attributed to the decomposition of the pyroxenes and amphiboles, as the zeolites in these rocks reasonably intimate a partial re-organization of the feldspars, minerals to which as we all know, they are chemically allied. Calcite (double spar) is also found at Djupiford on the west coast, at Skardsheidi at Eaja near Reykjavik where the lime has been used in cements.

I did not reach Berufjord. Had I attempted it, I would have suffered the discouragement of a shipwreck, as the next steamer stopping there inconveniently went on the rocks in the Faroe islands near Thorshavn before her arrival. Williams, an associate of this society, has described the locality in the following words: "on the south shore of the bay called Berufjord, the zeolites occur in a low cliff of trap from twenty to forty feet high. During stormy weather the seas pound against the cliffs and complete the work that the frost began in the winter season, that of mining the zeolites.

"They occur in geodes, or pockets, to be more exact, and often the pockets are filled with a very sticky red clay, which is hard to remove from the crystals. But many of the pockets are dry and the crystals white as snow. The heulandite and stilbite are very large. One heulandite was over three inches long, and many others over two inches, and very perfect crystals at that. The stilblites occur in large groups, often on heulandite. Ptilolite occurs here. Many of the pockets contain quartz with a greenish coating, while others contain nothing but quartz. Scolecite occurs in radiating groups of crystals, five or six inches long, and many have terminations.
Epistilbite is not plentiful, but I got a few fine specimens. Apophyllite, calcite, and amethyst also occur at this locality; the calcite in golden colored crystals."

The genesis of these attractive objects has been a subject of very varied and profound study and the extraordinary facts they present of varying, or I might say changing symmetry through loss of water have been much examined.

De Lapparent has divided these minerals into groups of chemical similarity, as the sodium, sodium-calcium, calcium-potassium, calcium potassium and sodium, calcium, and barium zeolites, and has placed among them datolite, prehnite, hromilite and apophyllite. While this diverges from the system we are more accustomed to, the constant association of datolite, prehnite, and apophyllite with the recognized zeolites lends to such a classification, to the field collector at least, an adaptive plausibility; they certainly are all derivative or secondary products. Mallard has gone further, and violated the restrictive hypothesis as to the chemical constitution of a zeolite, by including amongst them Bravaisite, a silicate containing iron and magnesium, carpholite containing manganese, glauconite containing iron, nontronite containing iron, chlorophylite containing iron and magnesium, and the rather indefinite compound called palagonite. But none of these, as with the minerals given in Dana's appendix to the zeolites, are known from Iceland.

For the most part these minerals are silicates of aluminum and calcium, with sodium and potassium, and, in the case of brezwaterite, phillipsite and edingtonite, contain barium and strontium, while magnesium and iron may be said to be quite absent in the composition of all. It is always convenient, in alluding to them, to include apophyllite, among them. The molecules of water involved in their constitution have been separated into water of constitution and water of crystallization, and it is not perhaps to-day quite clear how exactly to define or measure the quantitative limits of either.

But the obvious fact of their paragenesis is that they are products of decomposition. They are not metamorphic sequelæ; they advertise and illustrate a secondary growth, consequent upon a falling apart of earlier formed silicates, and silicates too, which have had an entirely contrasted origin, as crystallizations from fused and solidifying magmas. And they further, in their association show a succession of generations — encrusting or overlying each other, with distinct reference to a sort of serial development. R. Braun, in his examination of the development of albite, analcite, natrolite, prehnite and calcite in the decomposed diabase at Friedensdorf near Marburg has pointed out a plain succession, and alternations of suc-
cession, on the walls of the encrusted rock. The albite in places was directly attached to the rock, in other spots it encrusted an earlier developed analcite, while other minerals covered or were implanted on the albite; the analcite was usually attached to the diabase, frequently covered with calcite, which again had suffered removal through natural solution; again the analcite covers prehnite and in other points completely reverses the succession, being older than the prehnite. Prehnite and calcite made up the larger part of the contents of these mineral fissures, and the prehnite was so intergrown with the calcite that the latter penetrated it in thin plates which when removed by acid left knife-like incisions in the prehnite. Braun demonstrated that there was an alternating and reciprocal condition of age in the two minerals, one being older at one point, the other older at a second. These conditions recall phenomena you are all familiar with in the paragenesis of West Paterson zeolites. The same thing was noted, I mean the intergrowth of calc-spar and prehnite, by Bischof at Dillingen, by Fischer near Freiburg. Natrolite was rare at Friedensdorf, almost unknown, and coated the albite. Calcite seemed universally the last formed of the series. Finally, reviewing the various associations, Braun says, "in general the following succession was determined, analcite, albite, prehnite, prehnite and calcite, analcite of a second generation, calcite; nevertheless albite was frequently older than analcite, seldom younger than prehnite." This succession, as all successions in these minerals, must not, says Braun, be misunderstood. It does not mean that the later minerals have been formed from the earlier. It simply points to a static chronology in their appearance. And he pictures the possible conditions in these words; "while analcite and albite were forming prehnite already may have began its separation; analcite continually declines, and then prehnite becomes associated with calcite; prehnite at the end forms delicate crystallizations in the calcite, and finally calcite alone remains in the process of growth. And, from the fact that the crystals of calcite are etched, we can conclude that the period of its formation has also terminated." He points significantly to the conclusion also, that the mother liquor, if I may use that term, with lapse of time becomes more saturated with free carbonic anhydride, a fact which might throw some light upon the evidence of wholesale removals by solution in zeolitic cavities. And now, a word upon the process of decomposition which, while not perhaps repeated under all circumstances of zeolitic formation, including of course these Iceland occurrences, does afford a very instructive basis for speculation. And in this connection it may be recalled that the basalts have been regarded as effusive diabases, so that Braun's study of the diabase of Marburg might throw some light on the genesis of the zeolites in the basalt of Iceland. It is
assumed by Braun, and the view has certainly universal acceptance, that the feldspathic elements of the diabase are decomposed by circulating water, holding carbonic acid; this brings about the change in the feldspars, forming alkaline carbonate calcium carbonate, and free silicic acid, which, with the aluminium of the feldspars forms clay (kaolin) or related products. The important agent for the succeeding steps of mineral propagation is the carbonate of sodium or potassium solution. J. Lemberg has shown that the action of this solution upon feldspar is to form analcite, and at comparatively low temperature, at least under 200° Fahr., with a separation of silica; Braun notes in the case he studied that prehnite and secondary albite with much calcite also was formed and, for this reason, that while the water increases its content of carbonic acid through the disappearance of the sodium from solution, in the formation of Analcite, the increase leads to the deposition of lime carbonate, as calcite, and then the superabundant lime silicate is deposited as prehnite, and these two, calcite and prehnite, alternate in deposition with the oscillating predominance of either in the menstruum of mineral salts in the cavities of the rock; while the secondary albite is formed at a time when the water contains but small quantities of carbonic acid, otherwise its own formation would be prohibited. Braun found the analcite formed on the secondary albite, which indeed seemed to blend into the derivative analcite, while he quotes instances in which the original feldspar of the diabase includes prehnite, with the secondary albite outside, and finally analcite, while natrolite, as a sodium aluminium silicate, and epidote, as a calcium aluminium silicate are also formed, though here I think his discussion becomes vague.

At any rate the process seems to start with the decomposing effectiveness of carbonated waters, the formation of alkaline solution, the generation of free silicic acid, and the deposit of the sodium aluminium, potassium aluminium, calcium aluminium salts, all holding water, as zeolites, and a plentiful addition of calcite. It is pretty clear that this is a very generalized explanation, that the study of the paragenesis of these minerals will involve a study, particularly a chemical study, of the parent rock, from which they have formed, and doubtless in nature, as we know how localities vary, in the production of these species, changing temperatures or even pressures influence results.

When we examine these specimens of zeolites from Iceland we find quite universally on the floor of the cavity or the walls of the crevice, a layer of decomposed material, perhaps the thinnest film, on which the crystals are grown, though again as you can see in many specimens, the crystals sometimes appear as immediate developments from the rock. In almost all such cases, the rock is of course greatly changed, and crystalliza-
tion of derivative minerals has been started in small or minute cavities, mere pin holes. Succeeding the first alteration skin quite frequently comes a layer of amorphous or subcrystalline quartz, then may follow fibrous beds — mesolite perhaps and natrolite and the nominative species, whatever it may be, succeeds. As a rule stilbite seems to form last, frequently following heulandite, as if after the calcium aluminium silicate had formed, the sodium came into such proportions as to facilitate the production of stilbite. In one instance as I see it laumontite has formed before heulandite, which covers it, and as heulandite contains probably more sodium than laumontite, which contains none, this illustrates a succession similar to the sequence of stilbite after heulandite. Again we have in a specimen from Iceland natrolite underlying the stilbite, when the much more highly alkalized silicate is, so to speak, thrown down first, to be succeeded by the calcium silicate, in which case the menstruum was first relieved of its sodium, or excess of sodium content, before the calcium aluminium salt could be crystallized. Of course in such speculations the assumption is tacitly made that the cavity in which the zeolites were formed was a more or less closed chamber like a beaker glass, containing a solution of salts, which, according to their varying solubility coat its sides with a definite succession, a fact in nature more completely illustrated in saline basins. This is probably quite erroneous or only true in some instances. Although such a supposition seems warranted in cases, as with apophyllite, studing the apices of Guanajuato amethysts, or as in an example here, of needles penetrating microscopic apophyllite. The succession we see in these cavities presents rather a successive arrival at the walls of the cavity of the solutions, in each one of which predominates the salt that encrusts the deposited burden of some preceding solution as for example in fissure veins; and this again cannot be too formally held, as we see the plainest evidence of contemporaneity in the minerals, as in an instance here of scolecite and stilbite; while in the example of stilbite on calcite we are taught quite clearly that the stilbite has been formed in part from the substance of the already crystallized calcite. We may therefore instructively reflect that each occurrence, having an individual history fails to repeat in every detail the history of its neighbors. It is also apparent that there is what might be called a mineral quality to localities — I mean with regard to these zeolites — and that the results of the decomposition of similar rocks greatly or sensibly vary. In these Icelandic zeolites one would say that acidic rather than basic salts prevailed; that pitblite occurs and mordenite does not, that heulandite and stilbite are formed, and Prehnite is not, and that of those zeolites which are formed the acidic are the more common. Potassium zeolites seem absent from Iceland.
It often seems singular that datolite is not found in the Icelandic geodes, a mineral so commonly making the flooring for the development of later zeolitic minerals in the New Jersey and Massachusetts traps, and for that matter throughout the world. It is at any rate a highly basic mineral, a fact which may or may not have a causal connection with its infrequency. Perhaps the appearance or absence of these minerals with very similar composition has to do with the molecules of water combined in them, as we know driving off this water begets changes in them. These peculiarities exist elsewhere. Near Rome phillipsite is much more common than gismondite, at Montclair, N. J., I think stilbite preponderates among the zeolites, and datolite, as a related mineral, in Massachusetts trap effaces its associates. A statistical review, if such a thing were possible, of zeolitic localities would prove interesting.

In regard to the influence of heat upon the formation of these minerals, it is a plausible suggestion that its greater or less absence had something to do with the formation of the solutions from which the zeolites were formed, and therefore medially with the formation of the zeolites themselves. C. Doelter in a very interesting article on the artificial reproduction of zeolites and their chemical constitution, proved quite clearly that by their decomposition at more or less high temperatures, much pressure, and in water holding carbonic acid they could be recrystallized. The temperatures used were 120°-160° Centigrade; while in liquid carbonic acid many zeolites were altered at 25° C. Results were naturally quicker under heat, but it is not quite clear that the decomposition and recrystallization could have been effected at all without its intervention, and we cannot ascribe the formation of zeolites in nature to silicates decomposed by liquid carbonic acid.

Doelter formed analcite, heulandite and chabazite synthetically from solutions holding siliceic acid, alumina, carbonate of lime, and carbonate of soda, in closed tubes at a temperature of 130°-190° C. Heat, if it is to be involved as a useful agent in forming these beautiful minerals, has certainly been on tap in Iceland in large quantities.
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. Huetlins 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.