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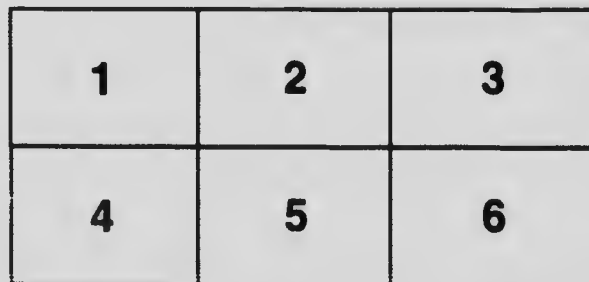
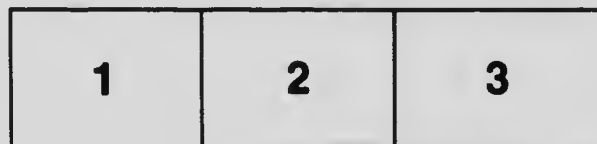
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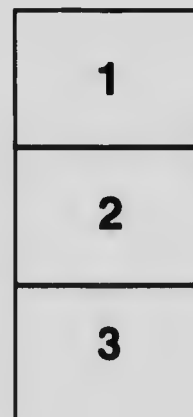
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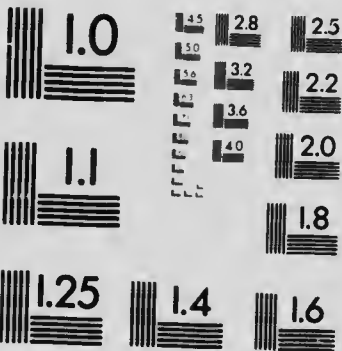
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PAPERS FROM THE DEPARTMENT OF
GEOLOGY AND MINERALOGY

No. 5. On Ferrierite, a New Zeolitic Mineral, from
British Columbia; with Notes on some
other Canadian Minerals

by

R. P. D. GRAHAM.

Reprinted from the Transactions of the Royal Society of
Canada, Section IV., 1918, pp. 185-201.

MONTREAL, 1919.

*On Ferrierite, a New Zeolitic Mineral, from British Columbia; with
Notes on some other Canadian Minerals*

By R. P. D. GRAHAM

Presented by Frank D. Adams, D.Sc., F.R.S.C.

(Read May Meeting, 1918)

FERRIERITE, A NEW ZEOLITIC MINERAL FROM THE NORTH SHORE OF
KAMLOOPS LAKE, BRITISH COLUMBIA

During the summer of 1917, Dr. W. F. Ferrier collected some specimens of a soft white mineral, in the form of spherical aggregates of radiated blades, and having much the appearance and associations of a zeolite. The mineral, however, presents certain features which led Dr. Ferrier to believe that it might be a new species, but being at that time engaged in field work for the Munition Resources Commission, he was, through lack of facilities, unable to proceed further with its identification. Specimens were accordingly sent to the University of Alberta, and a determination of the blow-pipe characters by Dr. J. A. Allan, together with a partial analysis made by Mr. Kelso, only tended to confirm Dr. Ferrier's surmise. More and better specimens were subsequently obtained, and, early in the present year, Dr. Ferrier, with the permission of the Commission, placed this material in the hands of the writer for examination. This examination has now been completed, and the result, detailed below, definitely establishes the mineral as a new species. The writer has great pleasure in naming the mineral *ferrierite*, in honour of Dr. Ferrier, the well known mineralogist and mining engineer, formerly of the Canadian Geological Survey.

PLACE AND MODE OF OCCURRENCE

The specimens were collected in a cut along the Canadian Northern Railway, about half a mile west of Mile Post 17, on the north shore of Kamloops Lake, British Columbia. The north shore of the lake is here underlain by rocks of the Kamloops Volcanic Group (lower Miocene), which have a widespread distribution throughout this district. This volcanic group consists mainly of surface lava flows, tuff beds, and agglomerate accumulations, but as a result

of erosion, it is now represented chiefly by the lava flows, which are predominantly basaltic. The basalt passes transitionally into vesicular and amygdaloidal types, the amygdules being in many places well banded but pale coloured chalcedony. Zeolites, a green chloritic mineral, quartz, and calcite (the latter intergrown with chalcedony) also fill vesicles.¹

In the railway cut where the ferrierite was found, the rock is a massive olivine-basalt. Where fresh, this rock is nearly black in colour, and fine grained, but with a distinctly porphyritic structure. A thin section of a very fresh specimen was examined and showed well developed phenocrysts of plagioclase feldspar, pale brownish-green pyroxene, and colourless olivine, the latter only very slightly altered to serpentine. A fair number of grains of magnetite are present, and all these minerals are distributed through a finely crystalline ground-mass, with no apparent tendency towards a fluidal arrangement.

Fractures traversing the basalt are filled with seams, or veins, of pale coloured, translucent chalcedony, and in the vicinity of these the rock is very much decomposed, soft, and crumbling. The seams vary from mere films to veins several inches in width, but they are usually quite narrow. The ferrierite occurs within the chalcedony, which completely or partially encloses the spherical aggregates of the mineral. Subsequently to the formation of the chalcedony and ferrierite, white coarsely crystalline calcite has been deposited in the veins. Many of the ferrierite aggregates are thus partially enclosed in calcite, and by dissolving the latter in dilute acid, their surfaces may be freed, when the outer ends of the crystals are found to exhibit terminal faces. In the best specimens collected, the spheres have a radius of three-eighths of an inch, but for the most part they are smaller than this.

In addition to the new mineral, Dr. Ferrier reports the occurrence at this locality of agate, and also chalcedony geodes lined with crystals of amethyst, as well as with ordinary quartz. Finely developed flat rhombohedral crystals of calcite are, in some cases, implanted on the quartz, and in one specimen crystals of the latter mineral are coated with tufts of minute rutile crystals. These geodes are sometimes over six inches in diameter. Some of the smaller ones, measuring two or three inches in diameter, are completely filled with coarsely crystalline calcite, with a comparatively narrow marginal zone of banded pale chalcedony, between which and the calcite there may be some quartz.

¹ See Summary Report, Geological Survey, 1912, p. 142: Geology of the Thompson River Valley below Kamloops Lake, B.C., by Chas. W. Drysdale.

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Radiated groups of ferrierite crystals are sometimes seen on the outer surface of such specimens, embedded in the chalcedony.

CRYSTALLOGRAPHY AND GENERAL PHYSICAL PROPERTIES

Individual crystals of ferrierite have the form of very thin blades, which are rectangular in outline, but isolated crystals of this type are seldom seen. In the specimens, these blades are stacked upon one another in nearly parallel position, after the manner of the leaves in a closed fan; a large number of such piles of slightly divergent blades radiate from a common centre, and give rise to the spherical aggregates. The true form of the latter, and the manner in which they are built up, becomes very evident when the spheres have a covering of calcite, and this is removed by solution in acid. It is then seen that the ferrierite does not, as a rule, form a continuous, solid sphere, but that spaces have been left between the variously inclined piles of blades, and have been filled by the subsequent deposition of calcite. The structure is no doubt similar when chalcedony forms the enclosing material. Here, cross sections of the spheres usually appear as complete circles of radiated ferrierite blades, but on closer examination white streaks of the silica may usually be seen between the blades, especially towards the circumference of the circle.

The optical study of the mineral proves it to be orthorhombic, and if the crystals are oriented as tabular parallel to $a(100)$, with elongation along the c -axis, the forms exhibited are the pinacoids, $a(100)$ and $b(010)$, and the macro-prism or dome $d(101)$. The angle $100:010$ is $90^\circ 00'$. The dome faces form the terminal planes of the blades, but, although they are often of fair size, they are always imperfect, and yield multiple reflections as a result of the parallel growth already referred to. Only two or three very thin blades were found, on which the dome face yielded a single, but faint, image, and the mean of the measurements made on these gave the angle $ad = 67^\circ 47'$, from which $dd' = 44^\circ 26'$. No twin crystals were observed, nor did the optical examination reveal any evidence of twinning.

The mineral has a perfect cleavage parallel to $a(100)$, and on this face the lustre is pearly; the lustre on $b(010)$ is bright vitreous, but on the c -axis it is duller, doubtless owing to their imperfect nature. Individual blades or thin cleavage plates are perfectly colourless and transparent, but in the crystal aggregates the mineral appears white; in some weathered specimens, it is stained reddish by iron oxide. The outer ends of the blades, near their contact with the enclosing chalcedony, are quite generally translucent and milky, while thin white streaks of chalcedony penetrate for a short distance between the blades, forming a narrow zone of the chalcedony, immedi-

ately bordering the spheres, is clouded and bluish as compared with that further distant. There seems to have been some reaction between the chalcedony and the ferrierite, and it is possible that at the time the crystals of the latter mineral were forming, the surrounding silica had not yet assumed the solid state, but was still in the gelatinous condition.

The mineral has a hardness of 3 to $3\frac{1}{2}$, and the specific gravity is 2.150.

OPTICAL CHARACTERS

The blades show straight extinction when lying flat, on $a(100)$, and also when they rest on $b(010)$ and on $c(001)$; in each case compensation takes place when the quartz wedge is inserted normal to the length, whence it appears that the a -axis = α , b -axis = β , c -axis = γ , and the axial plane lies in the direction of elongation of the blades. In convergent light it is seen that the obtuse bisectrix is normal to the blades, or coincides with the a -axis and therefore = α , and the birefringence, which is weak, is thus positive.

The refractive indices β and γ were determined by total reflection from $a(100)$, the crystal being immersed in methylene iodide, and the obtuse optic axial angle was measured in the same medium. The angle $2V$ calculated from the latter measurement, the indices β and γ , and the index α calculated from these values, are as follows:—

$$2V = 50^{\circ}25'; \alpha = 1.478, \beta = 1.479, \gamma = 1.482, \gamma - \alpha = 0.004.$$

It was necessary to employ very small plates for the determination of the refractive indices, because in the larger blades, the face $a(100)$ is never a perfect plane. It is believed, however, that the values given above are approximately correct.

CHEMICAL COMPOSITION

Heated in the flame of a bunsen burner, the mineral whitens, and thin splinters fuse to a blebby glass. Fusibility 3– $3\frac{1}{2}$. The flame is yellow, and observed with the hand spectroscope it shows only the sodium line. Heated in a closed tube, the mineral whitens and gives off much water, which is slightly acid. Insoluble, or only very slightly soluble, in hydrochloric acid.

In view of the danger of contamination with chalcedony, especial care was taken in selecting the material for analysis, and colourless and perfectly transparent blades only were used. The fusion was very pale bluish-green, indicating the presence of a trace of manganese. The analysis gave the following result:—

		Molecular ratio.	
SiO ₂	69.13	1.152	10.28
Al ₂ O ₃	11.44	.112	1.00
CaO.....	None		
MgO.....	2.92	.073	0.65
Na ₂ O.....	3.97	.064	0.61
K ₂ O.....	0.36	.004	
H ₂ O.....	13.05	.725	6.47
<hr/>			
100.87			

The water was fractionated as follows, heating at each temperature being continued for two hours:—

At	102°	130°	150°	175°	205°	260°	275°	Ignition
Loss %	1.85	1.55	0.50	1.00	1.60	0.68	0.16	5.71

The mineral commences to lose water at, or below, 100°, and continues to do so at a fairly uniform rate until a temperature of 205° is reached, when 6.5 per cent., or almost exactly one-half, of the water has been driven off. At 275° the additional loss has been less than 1 per cent., and the 5.71 per cent. of water still retained by the mineral corresponds to 0.317 molecules, or 2.83 molecules on the basis $\text{Al}_2\text{O}_3 = 1.00$.

Ferrierite thus has all the general characters of a zeolite; but it differs from all known zeolites in containing MgO in place of CaO, which is entirely absent from the mineral. In composition it is very closely related to mordenite and ptilolite, both of which have been shown by Clarke¹ to be simply representable by the general formula $\text{Al}_2(\text{Si}_2\text{O}_5)_n\text{R}'_4 + n\text{Aq.}$, where $\text{R}'_2 = \text{Ca}, \text{Na}_2, \text{K}_2, \text{H}_2$ and $n = 6$ or 3 .

In ferrierite, the molecular ratio $\text{Al}_2\text{O}_3 : \text{SiO}_2 = 1 : 10$, as required by this formula; the molecular ratio $\text{Al}_2\text{O}_3 : \text{MgO}$ is approximately $1 : \frac{2}{3}$, and the ratio $\text{Al}_2\text{O}_3 : (\text{Na}, \text{K})_2\text{O}$ approaches the same value. For exact correspondence with Clarke's formula, it would be necessary to assume that 1.35 per cent. of the water contained in the mineral is basic. Ferrierite might then be given the formula $\text{Al}_2(\text{Si}_2\text{O}_5)_5\text{R}'_4 + 6\text{H}_2\text{O}$, where $\text{R}'_2 = \text{Mg} : \text{Na}_2 : \text{H}_2 = 1 : 1 : 1$; the theoretical percentage composition calculated for this formula is as follows:—

¹*Am. Jour. Sci.*, 3rd Series, vol. 44, 1892, p. 101.

SiO ₂	67.42.....	10
Al ₂ O ₃	11.46.....	1
MgO.....	2.99.....	2
Na ₂ O.....	4.65.....	2
H ₂ O {	1.35.....	2
.....	12.13.....	6

100.00

It is true that, in arriving at the above formula for ferrierite, an entirely arbitrary assumption has been made with regard to the water content of the mineral; but, in general, the same criticism might be levelled at the formulae which have been assigned to practically all the zeolites. These minerals without exception commence to lose water at a relatively low temperature, and the percentage loss increases at a fairly uniform rate as the temperature is raised to 300°. Determinations which have been made of the loss of water at definite temperatures seldom go beyond this point, at which the minerals still retain several per cent of water. Moreover, with many zeolites, as for example chabazite, scolecite, thomsonite, brewsterite, etc., it has been found that after heating at this temperature the material regains its original weight when exposed for some time to a moist atmosphere. It is very probable that all these minerals continue to lose water at the same gradual and uniform rate at temperatures considerably higher than 300°, and that much of the water still retained by them at the latter temperature is water of crystallization. Levynite, for example, remains hygroscopic even after heating at 360°.

There is thus no reason for supposing that the whole of the 5.71 per cent of water which ferrierite retains at 275° is constitutional, or basic; on the other hand, a consideration of certain other related zeolites indicates that some portion of it may well be present in the mineral as water of constitution, and in the formula here suggested for ferrierite, 1.35 per cent of water is assumed to be so combined.

In the case of the ptilolite from Silver Cliff (Custer County, Colorado), Cross and Eakins¹ found that 3.10 per cent of the water were stable at 300°. In the theoretical composition assigned to this mineral by Clarke, a trifle less than two per cent of the water is basic, but this discrepancy is not considered an insuperable objection to the formula proposed.

Ferrierite is apparently not isomorphous with mordenite, which is monoclinic. Ptilolite has only been observed in capillary needles; these have parallel extinction, and a negative optical character².

¹ *Amer. Jour. Sci.*, 3rd. Series, Vol. 44, 1892, p. 96.

² Cross and Eakins, *op. cit.*

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FIGURE 1.



On left, Bismuthinite; on right, Molybdenite.

ON PHENACITE, AND A PSEUDOMORPH OF BISMUTHINITE AFTER MOLYBDENITE, FROM NORTHERN QUEBEC

Location and Mode of Occurrence of the specimens

The specimens described below came from the Height of Land Mining Company's property, on the west bank of Kewagama river, in the extreme north of Preissac township, northern Quebec. The locality is about fifteen miles south of the Trans-continental Railway (which here, for a short distance, follows the Height of Land), and fifty-two miles east of the Quebec-Ontario provincial boundary.

The property of the Height of Land Mining Company is situated on the western margin of an extensive granite (Laurentian) batholith. The peripheral zone of this mass, where it crosses the Kewagama river, is unusually pegmatitic in character, and the rock is traversed by a great number of quartz veins; these, as well as tongues of pegmatite, also appear cutting the neighbouring Keewatin schists. The quartz veins are themselves undoubtedly pegmatitic, and represent the last and most acid intrusions of the same magma which gave rise to the granite. Molybdenite and bismuthinite occur in the pegmatitic and aplitic facies of the granite, and, more especially, in the quartz veins. Both minerals are very erratic in their distribution, and bismuthinite is relatively much the less common. The bismuthinite usually occurs along fracture planes within the veins and filling cracks in other minerals, such as pyrite, and in some places it surrounds and encloses minute crystals of molybdenite. It thus appears to have been introduced later than the latter mineral, and this view receives support from the occurrence here of a pseudomorph of bismuthinite after molybdenite, which is described below.

Other minerals which have been met with in these quartz veins include the following:—beryl, fairly abundant in some of the veins, in greenish sub-translucent prismatic crystals, which may attain a diameter of three or four inches; phenacite, only observed in specimens from one vein and described below; fluorite, of a deep purple colour; pyrite, chalcopyrite, and sphalerite. Some of the veins show low values in gold.

Pseudomorph of Bismuthinite after Molybdenite

This interesting specimen was collected in 1907 by Mr. J. A. Dresser, who later presented it to the McGill University Mineral Collection. It is shown in Plate I, figure 1, which is reproduced from a photograph, and is about natural size.

As may be seen, the specimen consists of two apparently hexagonal crystals, about equal in size, of similar shape, and attached in parallel

position; one of these, however, (that on the right in the figure), is molybdenite, while the other is composed of bismuthinite. Neither individual has a very sharp crystal outline, but each presents the appearance of a hexagonal bi-pyramid with its apices deeply truncated by faces of the basal pinacoid, so that the habit is somewhat tabular.

In the molybdenite crystal, the pyramid faces are, as is usual, heavily striated parallel to the base; it would be more correct to say that the pyramid is formed by the free outer edges of superposed thin plates of molybdenite, which, being of continually decreasing diameter, give rise to the tapering above and below. Approximate measurement of the angles with the hand goniometer indicates that the pyramid is the form $o(10\bar{1}1)$. Instead of a flat basal plane, the upper surface of the crystal exhibits a concave rosette form, due to the manner in which the hexagonal plates, of smaller and variable size, overlap here, and also in part to a curvature of the plates. The crystal is coated in places with a little earthy yellow molybdate, but in general this is inconspicuous or absent.

The other individual (on the left in Fig. 1) shows the same combination of pyramid and basal pinacoid, and has similar angles; but in this case the base is an approximately flat surface. It is composed of very fine-granular bismuthinite, through which occasional specks of native bismuth, isolated or in small nests, are dispersed. Here and there, also, traces of the original molybdenite may be seen. The surface is largely coated with a thin deposit of greyish-white or yellowish-white material, which is, in part at least, bismuth carbonate.

The manner in which the replacement of the molybdenite by bismuthinite has progressed may be observed better on the under side of the specimen. Attached to the large molybdenite crystal are several smaller crystals of similar habit, which also are quite fresh and unaltered. Below the pseudomorphous individual, on the other hand, are some crystals which show partial alteration to bismuthinite. One of these has been broken across and shows in cross-section the curvilaminar structure resulting from the superposition of curved flakes. At one end of this crystal the molybdenite has been entirely replaced by bismuthinite, but the original structure is still very evident. The fine granular bismuthinite retains the form of the curved plates, and in some cases these are easily separable, owing to the presence of a thin film of oxide, or of molybdenite, between them. Even where the material is more compact, the original curvilaminar structure is plainly indicated by a streaky appearance, largely caused by the presence of narrow streaks of earthy grey oxidation products, in part bismuth carbonate. Another portion of the same crystal is still

composed almost entirely of unaltered molybdenite, with only an occasional layer replaced by the granular bismuthinite.

It can hardly be doubted that the whole specimen consisted originally of molybdenite alone, of which mineral two large crystals had grown in parallel position, united by a pyramid face, as shown diagrammatically in Plate I, figure 2, with several smaller crystals grouped irregularly upon them.

Although the association of bismuthinite with molybdenite is by no means uncommon, pseudomorphs of the one after the other have not hitherto been recorded. In the present occurrence, a study of the veins has shown that the bismuthinite was deposited later than the molybdenite, and it would seem that, where the exhalations or solutions carrying the former have encountered crystals of the latter, they have, under certain conditions, been able to effect a replacement of the molybdenite by bismuthinite.

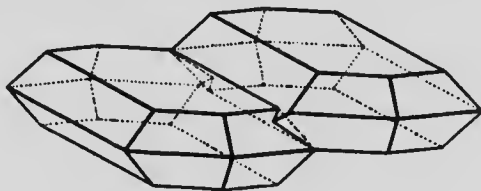


FIGURE 2.

In the particular case of the specimen described above, there remains the difficulty of accounting for the fact that only one half of it has been so affected, while the other half has undergone no change. It might be suggested that the individual plates of molybdenite, whose aggregation has built up the larger crystals, were less closely compacted in one case than in the other; or that the surroundings of the specimen within the vein were of such a character that, while one portion of it was freely exposed to the ascending bismuthinous fluids, the other was entirely protected from their influence.

The only other minerals present on the specimen are quartz and muscovite, both in small amount.

Phenacite

A specimen collected in 1910 by Dr. J. A. Bancroft from a pegmatitic quartz vein, near the northern end of the Height of Land Mining Company's property, proved on examination by the writer to be composed partly of phenacite. The quartz of the vein is of the

usual milky white variety, through which, in addition to the minerals mentioned above as generally occurring in these veins, there are distributed patches of dark green, massive or fine-granular chlorite.

The phenacite, in the specimen collected, is intimately associated with the latter mineral. For the most part it is massive, or exhibits an ill-defined prismatic habit. In appearance it closely resembles the quartz, than which, however, it is rather more colourless and transparent. The similarity to quartz is further increased by the hexagonal form and optically positive character, but the birefringence and high refractive index proved conclusively that the mineral could not be quartz. A few imperfectly terminated crystals were found, and from the measurement of these, the mineral was identified as phenacite. The following forms were observed on the crystals:—

$a(11\bar{2}0)$, $m(10\bar{1}0)$, $k(5\bar{1}40)$, $r(10\bar{1}1)$, $p(11\bar{2}3)$, $p_1(2\bar{1}13)$, $d(01\bar{1}2)$.

On one crystal, of which figure 3 is a drawing, there is, in addition to the above forms, a well-defined face lying between $r(10\bar{1}1)$ and

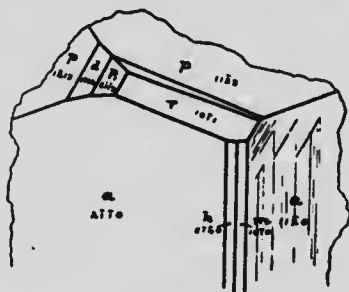


FIGURE 3.

$p(11\bar{2}3)$, but not quite in zone with them. This is vicinal, but very nearly coincident with $v(21\bar{3}4)$, as may be seen from a comparison of the measured and calculated angles:—

Angle	Measured	Calculated
$11\bar{2}0 : 21\bar{3}4 = a : v$	$64^\circ 13'$	$63^\circ 44'$
$2\bar{1}10 : 21\bar{3}4 = a : v$	$71^\circ 47'$	$72^\circ 50'$
$10\bar{1}1 : 21\bar{3}4 = r : v$	$13^\circ 41'$	$14^\circ 32'$

The prism is striated vertically, while on the face $a(11\bar{2}0)$ there are also striæ parallel to the edge ar .

The crystals have a diameter of about 2 mm., and only about the same length of prism, bearing the terminating forms, stands out freely from the massive matrix. The latter is itself largely phenacite, often showing an ill-defined, longitudinally striated prismatic form,

and also a fair prismatic cleavage, parallel to the predominant prism $a(11\bar{2}0)$. The free ends of the crystals are colourless and transparent, but the more massive material appears white, or is filled with inclusions of dark green chlorite.

The specific gravity, as determined in methylene iodide, is 2.944. The refractive indices, using the minimum deviation method and sodium light, were measured as

$$\epsilon = 1.673, \quad \omega = 1.656. \quad \epsilon - \omega = +0.017,$$

but the images obtained being somewhat faint, these values are only approximate.

Especial interest attaches to the phenacite from the fact that this is the first record of the occurrence of the mineral in Canada.

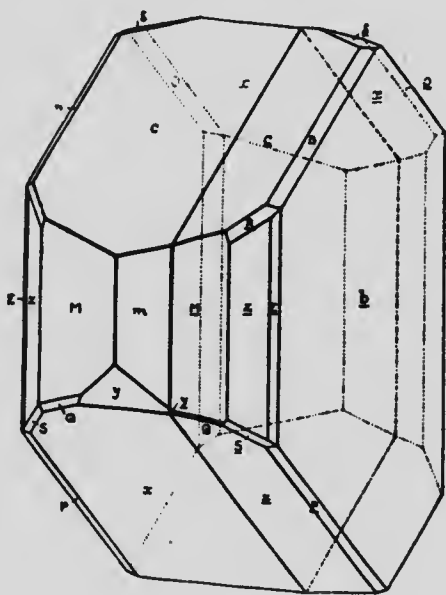


FIGURE 4.

NEW FORMS ON A CRYSTAL OF ALBITE FROM THE ASCOT MINE,
SHERBROOKE COUNTY, QUEBEC

A crystal of albite occurring on a specimen collected by Dr. Ferrier at the Ascot Mine, Sherbrooke County, Quebec, exhibits several forms which appear to be new for this mineral. The crystal, shown in Plate II, figure 4, has the usual prismatic albite habit, and is composed of two individuals twinned according to the *albite law*. The most prominent of the new forms occurs in the prism zone, where there

common to the zones $[MQx]$ and $[mQS]$, so that the symbols of these two forms are definitely fixed by the zone law.

The crystal on which the new forms were observed is colourless and transparent, and rather more than one-eighth of an inch in length. The other forms present are shown in the figure, which gives the approximate relative dimensions of all the forms occurring on the crystal. All the new forms appear on both halves of the twin.

The specific gravity, as determined by immersion in methylene iodide, is 2.605; this is the value found by Day for pure artificial albite, and it would indicate that the crystal is relatively free from lime.

The albite is associated with very pale brown dolomite, in simple rhombohedra. The specimen came from the Harvey vein of the Ascot Mine, Range VIII, Lot 8 (West half), Ascot Township, Sherbrooke County, Quebec.

THAUMASITE FROM THE CORPORATION QUARRY, MONTREAL

Some time ago the writer collected, at the Corporation Quarry, a specimen of crystalline limestone which was coated along a joint plane with a thin deposit of a soft white mineral, and a preliminary examination indicated that this was thaumasite. During a recent visit to the quarry, several larger specimens of better material were obtained, and it was possible to confirm the identification and make an analysis of the mineral.

The Corporation Quarry is situated immediately below the northwestern shoulder of Mount Royal, and it affords excellent exposures of the intrusive contact between the nepheline syenite, of which this side of the mountain is largely composed, and the Trenton limestone. The latter has been altered to a crystalline limestone, and both it and the nepheline syenite are traversed by a number of dykes, while all these rocks are intersected by joint planes.

The thaumasite occurs near one of these contacts, usually as a thin coating on narrow joint planes, which may be continuous through the syenite, limestone, and one or more dykes; but so far as observed, the mineral is mainly coating joint planes within the limestone. The thaumasite is white, with a dull silky lustre, and forms crusts made up of fibres with a feathery or somewhat radial arrangement; beneath this there may be a thin layer of more compact material, also thaumasite, which rests directly on the limestone or other rock. In one case a joint plane traversing the nepheline syenite had been first coated with crystals of calcite and upon these the thaumasite

rests as loosely compacted, and more or less freely developed, capillary crystals up to $\frac{1}{8}$ of an inch in length.

The best specimens were obtained from a fissure about 3 inches in width, which was completely filled with thaumasite in the form of mealy masses, somewhat loose in texture. These also are built up of capillary crystals, aggregated together with a tendency towards a feathery arrangement, and the specimens show a somewhat fibrous structure when broken. The material for analysis was selected from these specimens, and it was found to be remarkably pure, only 0.3 per cent. remaining undissolved in cold dilute hydrochloric acid. The analysis yielded the following result:—

	Theoretical composition	Corporation Quarry	Molecular ratio		
SiO ₂	9.64	9.38	.156	0.96	1
SO ₃	12.86	13.07	.163	1.01	1
CO ₂	7.08	6.71	.153	0.95	1
CaO	27.01	27.32	.488	3.02	3
H ₂ O	43.41	43.69	2.427	15.00	15
	100.00	100.17			

The ratios agree fairly closely with the established formula, 3CaO. SiO₂. SO₃. CO₂. 15H₂O. Both the silica and the carbon dioxide are a little low. Three determinations of the carbon dioxide gave 6.66, 6.71, and 6.71 per cent. The water was determined by the Penfield direct method.

The specific gravity was determined as 1.877 by the pycnometer method, and 1.879 using Thoulet solution. This agrees with the value usually assigned to thaumasite, but is higher than that found by Schaller for the Utah material (Sp. G. = 1.84). The remaining physical properties, and the optical characters, so far as they could be determined, are as usual for thaumasite, and call for no comment.

Thaumasite has not previously been recorded from Canada; indeed, this peculiarly constituted mineral appears to be of somewhat rare occurrence, having been noted only at one or two localities in Sweden and the United States. It was first described in 1878 by Baron von Nordenskiöld,¹ from the copper mines of Areskuta, Jemtland, Sweden, and it has since been found at two other neighbouring localities in that country. In the United States, the occurrence of the mineral at Berger's Quarry, West Paterson, New Jersey, was described

¹Compt. Rend., vol. 87, 1878, p. 313.

by S. L. Penfield and J. H. Pratt¹ in 1896, and E. T. Wherry² states that it occurs in considerable amount also at another quarry (Francisco Bros.) at Great Notch, 3 miles southwest of Paterson. More recently, W. T. Schaller³ has described thaumasite from a second locality in the United States, Beaver County, Utah.

SAPONITE FROM THE CANADIAN NORTHERN RAILWAY TUNNEL, MONTREAL

When first collected, this substance is somewhat translucent, soft, and quite plastic, with very much the consistency and appearance of candle grease. If kept immersed in water, the material retains its original character for some time. Gradually it becomes more opaque and rather harder. After long exposure to the air, also, it turns white and opaque, and ultimately crumbles to powder, apparently through loss of moisture. This dry material is soft, has a somewhat soapy feel when rubbed between the fingers, and does not adhere to the tongue. Moistened with water, it forms a clay-like paste.

Some of this material, which had been exposed to the atmosphere for about a year, was analysed, with the following result:—

Clarke's formula		C.N.R. Tunnel Montreal	Molecular ratio	
47.24	SiO ₂	46.45	774	1.00
	Al ₂ O ₃	3.32	132	
	Fe ₂ O ₃	42	35 × 3 = .105	
	FeO	72		.763
31.50	MgO	5.91	168	0.99
14.17	H ₂ O-100	14.48	105	1.04
7.09	H ₂ O+100	8.13	8	0.58
100.00		99.43		

The water is, in part at least, very loosely held. After heating to 100° C, there was a loss in weight of 8.5 per cent, and thereafter there was a gradually increasing loss at higher temperatures, until at 100° it amounted to 14.48%. Above this temperature, the mineral still continued to lose weight at a fairly regular rate, as follows:—

Temperature.....	120°	140°	160°	180°	205°
Total loss %.....	15.03	15.46	16.07	16.53	16.89

¹*Am. Jour. Sci.*, 4th ser., vol. 1, 1896, p. 229.

²Quoted by Schaller, *op. cit.*

³Mineralogical Notes, Series 2, U.S. Geol. Survey, Bulletin 509, 1912, p. 110.

There was no change in the appearance of the material after it had been heated to this temperature. It was placed, together with a dish containing water, under a bell jar, and allowed to remain for a day, when it was found to have regained very nearly its original weight (all but 0.3 per cent.). This material was then ignited; almost immediately it began to darken in colour, and soon the entire mass appeared nearly black, but with further heating the mineral became white again, and remained so on cooling. The total loss in weight was 22.61 per cent. From the change in colour it is evident that this loss is not entirely due to the water expelled, but the cause of the blackening was not determined; it is apparently a characteristic feature of all saponite. A direct determination of the water by the Penfield method gave 20.42 per cent., but this is probably low, for the last traces of water appear to be very tenaciously held, and by the ignition method it is only after very prolonged heating that a constant weight is attained. After complete dehydration in this way, the substance does not re-absorb water when exposed to a moist atmosphere.

The mineral is essentially a hydrous silicate of magnesium, containing also aluminium, and although the analysis shows rather less of the latter constituent than is usual in the recorded analyses of saponite, the mineral is best referred to this species, which it further closely resembles in its general physical and blowpipe characters.

The recorded analyses of saponite vary between very wide limits for all the principal constituents, and this is no doubt to be explained, in part at least, on the assumption that the material analysed has in most cases been impure, or has consisted of a mixture of two or more substances. However, the analyses without exception show alumina to be present, and in most cases ferric oxide also, these two sesquioxides averaging more than 10 per cent., and even amounting to as much as 20 per cent. on occasion. Generally speaking, the sesquioxide and magnesia contents vary more or less inversely. The mineral appears, in every case, to lose about two-thirds of its water content at 100°C.

It may be doubted whether saponite, considered as a hydrous silicate of magnesium and aluminium, should be regarded as a definite species. Many analyses would approximate very closely to mixtures in varying proportions of, say, deweylite and kaolin. Clarke¹ suggests that "saponite is perhaps normally $H_4(MgOH)_2Si_2O_7$, although the analyses all show admixtures of some aluminous compound." The percentage composition calculated for Clarke's formula is given in the first column of the table above. It is perhaps a curious chance that the Montreal material gives almost exactly the ratios required by this

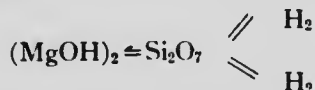
¹ The constitution of the Natural Silicates, U. S. Geological Survey, Bulletin 588, 1914, p. 109.

formula, assuming Al_2O_3 equivalent to 3MgO , i.e., that the substance is a mixture of the compound $6\text{MgO} \cdot 6\text{SiO}_2 \cdot 9\text{H}_2\text{O}$ with a small amount of the corresponding compound $2\text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2 \cdot 9\text{H}_2\text{O}$.

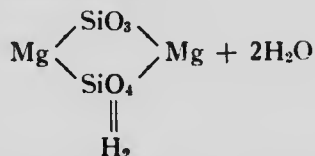
If Clarke's formula really expresses the true composition of saponite, it would seem better to write it in the form $(\text{MgOH})_2 \cdot \text{Si}_2\text{O}_5 + 2\text{H}_2\text{O}$, or $\text{H}_2\text{Mg}_2\text{Si}_2\text{O}_7 + 2\text{H}_2\text{O}$, seeing that two-thirds of the water, representing two molecules, are given off at a temperature below 100°C , and moreover are again absorbed by the material when it is exposed to a moist atmosphere at the ordinary temperature.

According to this view, saponite would be comparable with picrosmine, $\text{H}_2\text{Mg}_2\text{Si}_2\text{O}_7$, differing from it only in containing two additional molecules of water, which are held very loosely.

Little is known concerning the actual constitution of saponite. Clarke favours the view that the mineral is best represented by the orthodisilicate formula



To indicate that two molecules of water are very loosely held, the formula might still be written as an orthodisilicate, $\text{H}_2\text{Mg}_2\text{Si}_2\text{O}_7 \cdot 2\text{H}_2\text{O}$; or it might be represented as



which is the constitution ascribed by Clarke to picrosmine. Other constitutional formulæ, as for example the metadisilicate $(\text{MgOH})_2 \cdot \text{Si}_2\text{O}_5 + 2\text{H}_2\text{O}$, might of course be suggested for saponite, but in the present state of our knowledge concerning the genesis of the mineral, and especially in view of the existing uncertainty even of its correct empirical formula, it is not possible to confidently assign any particular one of these to the mineral.

The saponite described above was collected by Dr. J. A. Bancroft near the western end of the Canadian Northern Railway tunnel, immediately beneath the Corporation Quarry. This tunnel, which has been recently completed, passes from east to west under Mount Royal, and below the quarry it traverses the intrusive contact between the nepheline syenite and Trenton limestone. It is here that the saponite occurs, as a deposit on corroded crystals of calcite which coat fissures and cavities in the rock.

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