ON BABINGTONITE

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SUMMARY

Babingtonite from four new localities, all in Massachusetts, is described. Four new chemical analyses show an extraordinarily constant composition and lead to the formula $Ca_2Fe''Fe'''Si_5O_{14}(OH)$. The form and optical and other physical characters are shown to be essentially identical in all occurrences. Reasons are given for regarding babingtonite as not belonging either to the pyroxene group, the "triclinic pyroxene" group, or the feldspar group of minerals in all of which it has been at one time or another classified. Rather it is to be considered as standing quite alone and without near relatives. Its paragenesis is discussed and it is shown to be characteristically a low temperature hydrothermal mineral.

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The study of some new or hitherto undescribed occurrences of babingtonite has once more brought up the question of the place in the mineral classification of this rather uncommon mineral. In the following pages it is proposed to give an account of the results of this investigation.

NEW OCCURRENCES IN MASSACHUSETTS

BABINGTONITE FROM WINCHESTER HIGHLANDS, MASS. Winchester Highlands lies a few miles north of Cambridge on the border of the Boston Basin. A large quarry for road metal has been operated there for some years at the base of Blueberry Mountain and in it a number of interesting mineral deposits occur. The principal rock quarried is a granodiorite together with the quartzite into which it has been intruded. Cutting the diorite are lenselike intrusions of granite pegmatite and a later system of narrow veins cutting both diorite and pegmatite. The pegmatite is of an

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unusual type with much original epidote and such rare-earth minerals as allanite and thorite (1).

The veins are generally but a few inches wide, often mere seams, and have no great linear extent. They are for the most part wholly filled with calcite but some of them show a variety of earlier minerals when the calcite has been removed by weathering or by solution in acid. These include prehnite, epidote, babingtonite, albite, quartz, hornblende (a fibrous variety), several zeolites and sulphides in small amount.

Babingtonite is sometimes the first mineral to form, attached directly to the vein wall; where prehnite is present babingtonite rests upon that and may be followed by a later generation of prehnite and by the zeolites heulandite and chabazite and always by calcite. The crystals are rarely more than a few millimeters in dimension, often doubly terminated, and are brilliant black in color. The prism zone is dominant and by its prominence and the striations on some of its faces may always be recognized. A number of crystals were measured and were found to conform closely in habit and angles to the babingtonite crystals from Somerville, described by Palache and Fraprie (2).

The forms observed were $c(001)$, $b(010)$, $a(100)$, $h(110)$, $g(2\bar{1}0)$, $f(3\bar{2}0)$, $k(1\bar{1}0)$, $o(011)$, $s(0\bar{1}1)$, $d(101)$, $n(\bar{1}01)$, $p(111)$, $q(\bar{1}11)$ and the new form $r(1\bar{1}1)$. $q(\bar{1}11)$ was first observed by Watanabé (3) on the Japanese babingtonite.

	Calculated		Observed		Number of
	ϕ	ρ	ϕ	ρ	Observations
$q(\bar{1}11)$	$-34°\ 35'$	$40°\ 22'$	$34°\ 16'$	$40°\ 15'$	3
$r(1\bar{1}1)$	$142\ 07$	$45\ 03\frac{1}{2}$	$141\ 20$	$45\ 07$	1

Figures* 1 and 2 show the new form and typical habits.

The optical characteristics were identical with those stated for the mineral by Washington and Merwin (5).

The chemical analysis and formula will be discussed on a later page.

BABINGTONITE FROM HOLYOKE, MASS. This locality was first discovered within a year or two and was brought to the writer's attention by Dr. H. O. Hastings of Holyoke who generously donated to the Museum his finest specimens and conducted us to the locality where an abundance of material was collected. It occurs

* These and the following crystal figures were drawn by L. W. Lewis and Edgar Mendelsohn.

in a quarry opened recently in the diabase at the foot of Mt. Tom, a few hundred yards from the foot of the incline railway which runs to the top of that mountain. It occurs with prehnite and calcite in gash veins traversing the diabase. Openings in the vein are coated with masses of the brilliant black crystals which are grouped in radiated masses or implanted singly on prehnite surfaces. Single crystals reach a length of 3 cm. and surfaces of a square foot or more are wholly covered by it in splendent groups. In abundance and beauty it far surpasses any previously described occurrence of babingtonite.

The crystals are of simple form and poorly suited for crystal measurement as they are deeply striated and are generally in subparallel aggregates so that the crystal faces give multiple reflexions. The forms of the prism zone are dominant, especially the prisms $f(3\bar{2}0)$ and $g(2\bar{1}0)$. Other forms observed as shown in the figure are: $a(100)$ $b(010)$ $h(110)$ and $k(1\bar{1}0)$. The termination is either by the base, $c(001)$, alone or with one or both of the forms $o(011)$ and $d(101)$. Figure 3 shows a typical habit.

The physical and optical characters of this babingtonite agree so closely with those of Arendal that they may be said to be identical. The analysis is discussed below.

A peculiar alteration is shown by some specimens of the Holyoke babingtonite. A mass of parallel fibres of silvery white color begins to grow outward from the surface of a babingtonite crystal. The axis of the bundle of fibres does not have, so far as could be observed, any particular orientation with respect to the underlying crystal but it is constant for all the fibres on any one crystal. In a few cases these fibres were seen to be embedded in a later growth of calcite and this halted the process of their formation so that the babingtonite is not visibly destroyed. Generally, however, the fibrous growth penetrates the crystal from both sides and invades it almost to the centre leaving only a narrow black band of unaltered material from which the fibres seem to spring. The fibres in turn change from the original silvery-white form to brown and then to rusty limonitic phases. Mr. Berman made an optical examination of the fibres on the Federof stage and established their probable nature. They appear to be a pyroxene, probably augite; the fibres are excessively fine however, and yielded no characteristic cross sections or cleavage.

Refractive indices

$$\left.\begin{array}{l}\alpha=1.700\\\beta=1.710\\\gamma=1.725\end{array}\right\}\pm.003$$

$Y=b?$ $Z\wedge c=43°$

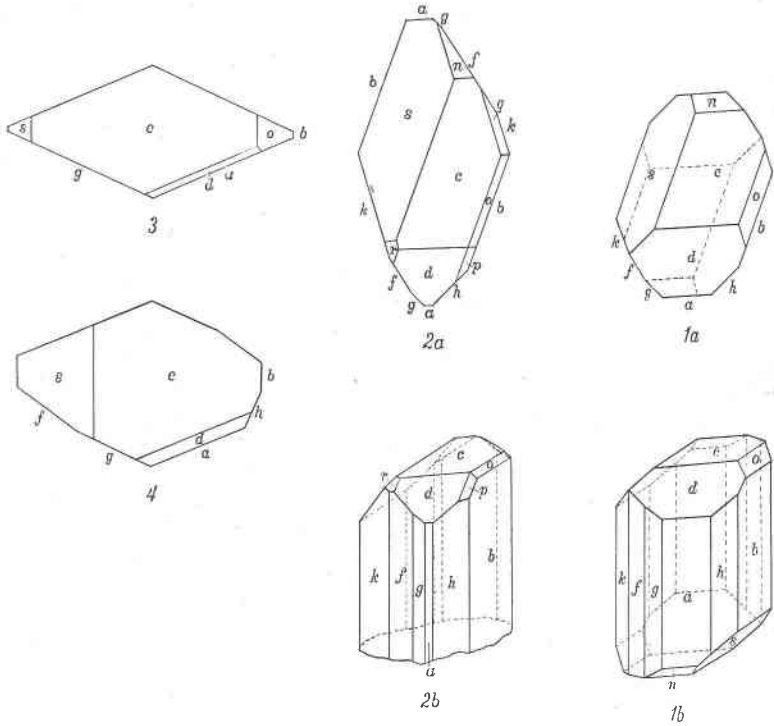$Bx\ (+).$ $2V=50°\pm2°$

The calcite associated with this babingtonite is in part in large brownish rhombohedrons, too rough for measurement but apparently near the negative rhombohedron $(02\bar{2}1)$; in part in slender (later) crystals with scalenohedral termination. Chabazite was noted in a few small rhombohedral crystals. Natrolite forms spheroids or rosettes of slender glassy needles in a few specimens. Quartz, white or amethystine, is sparingly present and a few minute pyrite crystals were seen in one specimen. Datolite was present in one specimen only.

BABINGTONITE FROM DEERFIELD, MASSACHUSETTS. In his description of the Deerfield Dike and its minerals, Emerson (4) mentions the occurrence of crystals of black axinite. The writer long since secured specimens of this supposed axinite and identified it as babingtonite but this determination has not been published. The vein specimen was freed from calcite with acid and revealed very rough and imperfect crystals of babingtonite resting on or embedded in prehnite. The forms $a(100)$, $b(010)$, $g(2\bar{1}0)$, $d(101)$, and $o(011)$ were identified on minute crystals of the habit of figure 3. Sufficient material was obtained from one of the specimens for a chemical analysis as shown on a later page.

BABINGTONITE FROM UXBRIDGE, MASSACHUSETTS. A small quarry was opened in Uxbridge, Mass. many years since, in gneiss. Cutting the gneiss were small gash veins of granite pegmatite from the cavities of which a small collection of crystallized minerals was made. The minerals comprise microcline, albite in pericline habit, adularia, epidote, biotite altered to chlorite, quartz, heulandite, prehnite, pyrite and babingtontite.

The babingtonite crystals are not numerous and were too much altered to permit of analysis. The crystals which reach a diameter of four or five millimeters are simple, showing the forms $c(001)$, $b(010)$, $a(100)$, $h(110)$, $g(2\bar{1}0)$, $f(3\bar{2}0)$, $s(0\bar{1}1)$, $o(011)$ and $d(101)$ as shown in figure 4. The occurrence is chiefly interesting as adding one more to the very numerous localities of this mineral in Massachusetts. An additional interest attaches to the Alpine habit of the veins and constituent minerals. The gneiss is a "pencil gneiss" showing pronounced linear structure. The pegmatite veins fill ten-

PLATE I

Crystals of Babingtonite from Massachusetts Localities.

Figs. 1a and 1b. Babingtonite from Winchester Highlands. Plan and clinographic projection of a doubly terminated crystal showing the forms $c(001)$, $b(010)$, $a(100)$, $h(110)$, $g(2\bar{1}0)$, $f(3\bar{2}0)$, $k(1\bar{1}0)$, $o(011)$, $s(0\bar{1}1)$, $d(101)$, $n(\bar{1}01)$.

Figs. 2a and 2b. Babingtonite from Winchester Highlands. Plan and clinographic projection of a crystal showing the forms of figure 1 and in addition $p(111)$, $q(\bar{1}11)$ and $r(1\bar{1}1)$.

Fig. 3. Babingtonite from Holyoke. Plan of a prismatic crystal showing the forms $c(001)$, $b(010)$, $a(100)$, $g(2\bar{1}0)$, $o(011)$, $s(0\bar{1}1)$, and $d(101)$.

Fig. 4. Babingtonite from Uxbridge. Plan of a crystal showing the forms $c(001)$, $b(010)$, $a(100)$, $h(110)$, $g(2\bar{1}0)$, $f(3\bar{2}0)$, $s(0\bar{1}1)$, and $d(101)$.
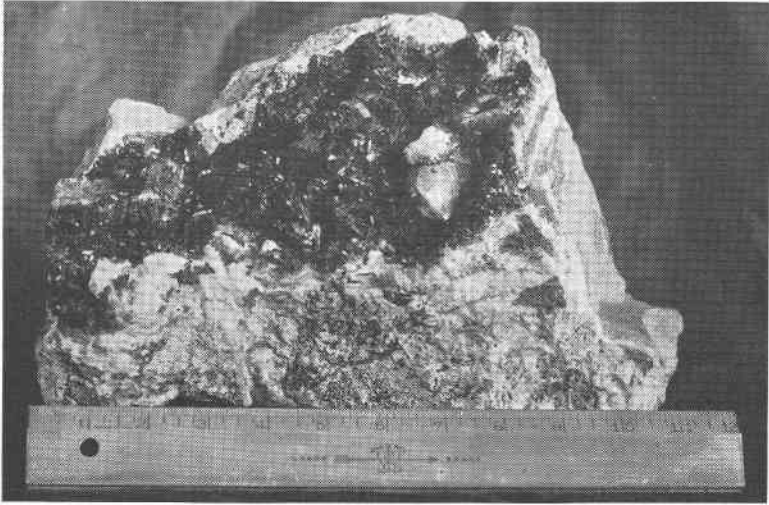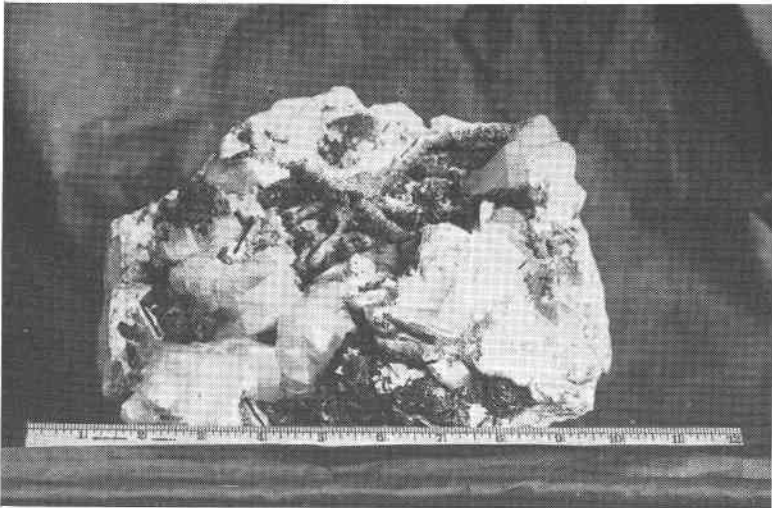
PLATE II

FIG. 5.

FIG. 6.

Photographs of Babingtonite from Holyoke, Mass.

The Babingtonite, black, rests on prehnite. Calcite crystals are later. The black linear markings in figure 6 are hollow prehnite casts of a mineral, probably anhydrite, now wholly removed by solution. Scale of inches.

sional cracks normal to the gneissic structure. The feldspars include adularia and pericline, both Alpine habits of this group of minerals. And the whole appearance of the small cavities strikingly recalls that of many Swiss "crevice" deposits.

CHEMICAL COMPOSITION OF BABINGTONITE

The three following analyses were made by Mr. Gonyer on abundant samples of very pure material prepared by Mr. Berman and Mr. Mendelsohn. Their identical nature can only be described as astonishing. With them is a new analysis by the same chemist of the Somerville babingtonite, correcting the figures obtained by Fraprie (2); and lastly the only other reliable modern analysis of the mineral from Arendal.

1. Babingtonite from Winchester Highlands analyzed by F. A. Gonyer
2. Babingtonite from Holyoke analyzed by F. A. Gonyer
3. Babingtonite from Deerfield analyzed by F. A. Gonyer
4. Babingtonite from Somerville, Mass., analyzed by F. A. Gonyer
5. Babingtonite from Arendal, analyzed by Washington and Merwin (5)
6. Babingtonite calculated from formula $Ca_2Fe''Fe''' Si_5O_{14} (OH)$

	1.	2.	3.	4.	5.	6.
SiO_2	52.46	52.44	52.40	52.12	52.80	52.41
TiO_2	—	none	—	0.31	0.29	—
Al_2O_3	0.19	0.23	none	0.08	2.41	—
Fe_2O_3	14.74	14.43	14.40	13.56	13.17	13.93
FeO	9.32	10.12	10.09	10.78	7.68	12.52
MnO	1.21	1.03	1.13	0.76	1.89	—
MgO	0.95	0.65	0.47	0.60	0.92	—
CaO	19.73	19.67	19.71	20.44	19.19	19.57
Na_2O	0.14	0.08	0.21	0.09	0.48	—
K_2O		none				
H_2O	1.21	1.27	1.23	1.33	0.91	1.57
	99.95	99.82	99.64	100.07	99.74	100.00
Sp. Gr.*	3.368	3.369	3.340	3.342	3.359	

* Determined by Mr. Berman with the pycnometer.

The five analyses show essential identity in the composition of these samples of the mineral from widely separated localities and of various origins. They all lead to the same formula $Ca_2Fe''Fe'''$ $Si_5O_{14}(OH)$. The ratio of ferrous iron to ferric iron is constant and in the proportion of 1:1. When it was found that the babingtonite from Somerville, analyzed by Fraprie (2), was exceptional in having considerable alumina and in having more ferric iron than ferrous, new material was isolated and analyzed with the result shown in

Column 4 of the Table. It appears that Fraprie's analysis was in error and that in this occurrence also the usual proportion of iron oxides is present.

This formula differs essentially from that of any member of the pyroxene group in the ratio of bases to silica. Here it is 4 to 5, in all pyroxenes 4 to 4. In view of this fact and other arguments, summarized best by Washington and Merwin (5) it seems necessary to remove babingtonite from the pyroxene group notwithstanding the possibility of so orientating the crystals that a form similarity exists. In the same way the attempt by Hillebrand (6) to draw a parallelism with anorthite, considering babingtonite as an iron-anorthite, must be considered simply as bringing out an interesting coincidence of certain angles, not of any real significance in the nature of the mineral.

Gossner and Mussgung (7) have also considered this interpretation of babingtonite in the light of their measurements by x-ray study of the dimensions of a unit cell. Although an orientation is adopted by them differing from that here used (Dauber) they employ the same pinacoidal body and the formula Ca Fe $Si_2O_6 \cdot SiO_2$. They calculate four molecules in the unit cell. Our formula yields by the same calculation two molecules in the unit cell. Their effort to bring out an analogy between feldspar and babingtonite is unsuccessful. They revert to the pyroxene-like formula above given which is that of a pyroxene which has a molecule of silica built into it—a most unsatisfactory conclusion. Neither do they consider the hydroxyl always present. It seems safe to conclude that babingtonite can not in any proper sense be regarded as either a pyroxene or a feldspar.

Nor does it appear to belong to the group of so-called "triclinic pyroxenes." These all conform to the pyroxene ratio with bases to silica equal 1 to 1, and have close optical relations as shown by the recent work of Sundius (8). They have also common cleavage directions. If babingtonite is orientated to bring out similarity of angles, its cleavage is not similar to other members of the group and its optical orientation is quite unrelated. Sundius draws wollastonite into this group and Warren and Biscoe (9) show that wollastonite, despite its apparent monoclinic symmetry, is really triclinic and has a structure unrelated to the pyroxenes. Their study confirms that of Sundius in placing wollastonite in the "triclinic pyroxene" group which is not closely related to the pyroxene group in struc-

ture. The sharper classification of isomorphous groups now possible with the aid of structure analysis would seem to lead away from the older tendency to force into a single series minerals which both in form and composition are really fundamentally different. As far as babingtonite is concerned, it can not be said to have any group relationship as the facts now stand.

PHYSICAL CHARACTERS

The crystals of all known occurrences of babingtonite show strikingly little variation. The forms are not numerous and the common ones are the same everywhere. The only variable element is in habit, which varies from a dominant prismatic development, to one of tabular form parallel to the basal pinacoid. This is most pronounced in babingtonite from Baveno, less so in that from Uxbridge. As these are both pegmatite occurrences it is safe to say that the unusual habit is a function of the different paragenetic conditions.

The optical constants of babingtonite are as similar in all known occurrences as is the chemical composition, strengthening the impression that this is a strongly individual mineral and not a member of a variable isomorphous series.

PARAGENESIS

In Table I are collected the facts regarding the known authentic* occurrences of babingtonite both as to geologic character and associated minerals. It will be seen that on the whole the accompanying minerals are very similar notwithstanding a considerable variety of origin. Babingtonite has been found in iron skarns, in granite pegmatites and in hydrothermal veins, especially those traversing diabase. In all of these occurrences but one, the contact ores of Japan,

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* Certain supposed occurrences of babingtonite are here purposely omitted. That from Devonshire, England, whose analysis is given by Dana, SYSTEM 1892, p. 382, appears when critically examined to be a pyroxene. The original description by Forbes (*Phil. Mag.*, **37**, 328, 1869) gives no physical characters and the occurrence, stated as a large mass of material, so pure as to have been mined as an iron ore, recalls rather a contact deposit of pyroxene than any known babingtonite deposit. The Scotch occurrence described by Heddle (*Min. Mag.*, **5**, 147, 1883) in a granite pegmatite is also inadequately described but from the analysis appears to be a pyroxene. The "babingtonite-like" mineral from Broken Hill Mine, New South Wales, described by Stillwell (in Andrews', E. C., Geology of Broken Hill District, Appendix II, p. 386) is certainly, from the analysis and optical characters, a lime-rich rhodonite.

babingtonite is a late mineral in the sequence, and often the last to form with the exception of calcite. Epidote, prehnite and zeolites are characteristic associates, one or both found in almost every deposit. It is essentially a low temperature, hydrothermal mineral, judged by its paragenetic history. And here again it may be said to show a character essentially opposed to that of any typical pyroxene.

TABLE I

PARAGENESIS OF BABINGTONITE

Locality	Type of Deposit	Associated Minerals
Arendal, Norway	Contact Iron Skarn	Hornblende, garnet, epidote, oligoclase, albite, calcite.
Nassau, Germany	Contact Diabase and slate	Ilvaite, beudantite, jasper, calcite.
Yakubi Mine, Japan	Contact of granodiorite with slate and limestone	Hedenbergite, garnet, magnetite, sphalerite, chalcopyrite, quartz, calcite, ilvaite?
Baveno, Italy	Pegmatite Granite	Microcline, albite, quartz, epidote, tourmaline, zeolites, calcite, hematite.
Uxbridge, Mass.	Pegmatite Granite	Microcline, adularia, epidote, biotite, hornblende, quartz, heulandite, pyrite.
Athol, Mass.	Veins in chloritic gneiss	Epidote, prehnite, pyrite
Buckland, Mass.	Veins in gneiss	Epidote, natrolite, chabazite, quartz, calcite.
Paterson, N. J.	Cavities in amygdaloidal diabase	Prehnite, quartz, calcite, datolite, zeolites.
Winchester Highlands, Mass.	Veins in diorite and granite pegmatite	Prehnite, epidote, albite, quartz, hornblende, zeolites, calcite.
Somerville, Mass.	Veins in diabase	Prehnite, quartz, epidote, chlorite, pyrite, chabazite, calcite.
Holyoke, Mass.	Veins in diabase	Prehnite, quartz, calcite, datolite, chabazite, natrolite, pyrite.
Deerfield, Mass.	Veins in diabase	Prehnite, chlorite, calcite, datolite.

BIBLIOGRAPHY

1. Dr. A. C. Lane has described his experiments on the radioactivity of this rock and its probable age in *Ann. Rept. Nat. Res. Coun.*, **1927–28**, Appendix F, 507.

2. Palache and Fraprie, Babingtonite from Somerville, Mass.: *Am. Acad. Arts & Sci. Proc.*, **38**, 383, 1902.

    Numerous errors in form symbols appear in this paper as follows:

    Page 387 in list of forms by various authors.

    Col. 2 fourth line from bottom (221) should read (22$\bar{1}$)

    Col. 2 last line (221) should read (2$\bar{2}$1)

    Col. 5 fourth line from bottom (551) should read (5$\bar{5}$1)

    Col. 6 first line (011) should read (0$\bar{1}$1)

    Page 389, Table II

    Col. 1 f(320) should read f(3$\bar{2}$0)

    k(110) should read k(1$\bar{1}$0)

    s(011) should read s(011)

3. Watanabé, M. On the Babingtonite from the contact metamorphic deposits of the Yakuki Mine, Japan: *Am. J. Sc.*, **4**, 159, 1922.

    In the table of angles of new forms described in this paper, p. 160 there are several errors as follows:

	ϕ	ρ		ϕ	ρ
$j\bar{1}$02 read	$-127°08'$	$14°37\frac{1}{2}°$	instead of	$-127°07'$	$14°39'$
$l\bar{2}$01 read	$-115\ 34\frac{1}{2}$	48 50	instead of	$-115\ 26$	49 59
$q\bar{1}$11 read	$-\ 34\ 35$	40 22	instead of	$-\ 34\ 17$	40 25

4. Emerson, B. K., The Deerfield Dike and its Minerals: *Am. J. Sc.*, **24**, 350, 1882 *U. S. G. S. Bull.* **126**, 31, 1894.

5. Washington, H. S. and Merwin, H. E., On Babingtonite: *Am. Min.*, **8**, 215, 1923.

6. Hillebrand, S., Ueber Aegirin und Babingtonit: *Tsch. Min. Mitth.*, **32**, 256, 1913.

7. Gossner, B. und Mussgnug, F., Ueber die systematische Stellung von Neptunit und Babingtonit: *Centb. für Min.*, A, **1928**, 274.

8. Sundius, N., On the triclinic manganiferous pyroxenes: *Am. Min.*, **16**, 411–429, 488–518, 1931.

9. Warren, B. E. and Biscoe, J., The crystal structure of the monoclinic pyroxenes: *Zeit. für Kryst.*, **80**, 391, 1931.