JOHANNSENITE, A NEW MANGANESE PYROXENE*

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Introduction

At the December, 1932, meeting of the Mineralogical Society of America, at Cambridge, Mass., the writer presented a short paper on a new manganese pyroxene. Since then the same mineral has been found to occur at several additional localities, and abundant material from one of these localities, namely, Puebla, Mexico, having been obtained, a more complete study of the mineral has been made. As the publication of the full report may be delayed for some time, it seems desirable to present, as an extended abstract, the data upon which the new mineral is established.

Johannsenite, named in honor of Professor Albert Johannsen of the University of Chicago, is the manganese analogue of the monoclinic pyroxenes diopside and hedenbergite, with the formula $MnO \cdot CaO \cdot 2SiO_2$, containing theoretically 28.68 per cent of MnO. X-ray powder photographs show that it has the same structure as diopside and hedenbergite.

Occurrence

The new mineral has been determined to occur at the following localities: Bohemia mining district, Lane County, Oregon; at the Empire Zinc Company's mine near Hanover, New Mexico; Franklin, New Jersey; near Schio, Venetia, Italy; Campiglia, Tuscany, Italy; Tetela de Ocampo, Puebla, Mexico; Pachuca, Hidalgo, Mexico; and probably at Rezbanya, Hungary; Elba; and Algeria.

Johannsenite forms columnar, radiating, and spherulitic aggregates of fibers and prisms, generally of a clove-brown, grayish, or greenish color, and in appearance resembles some grayish diopside and light colored hedenbergite. The presence of black stains of oxide of manganese however is indicative of the presence of manganese. The columnar and radiating prisms from Venetia, Italy, are several inches long and the greenish spherulites from Puebla, Mexico, are an inch and a half thick (Fig. 1). The brown spherulites and masses of radiating prisms of johannsenite from Oregon rarely exceed a quarter of an inch in size. The minute brown crystals from Franklin, New Jersey, are embedded in bustamite.

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At all of the occurrences except Franklin, New Jersey, some of the johannsenite is in places changed to rhodonite and at Puebla, Mexico, the released calcium silicate has been redeposited as xonotlite (the white area in Fig. 1).

The change from johannsenite to rhodonite has taken place in one of three ways. (1) The rhodonite forms irregularly shaped masses em-
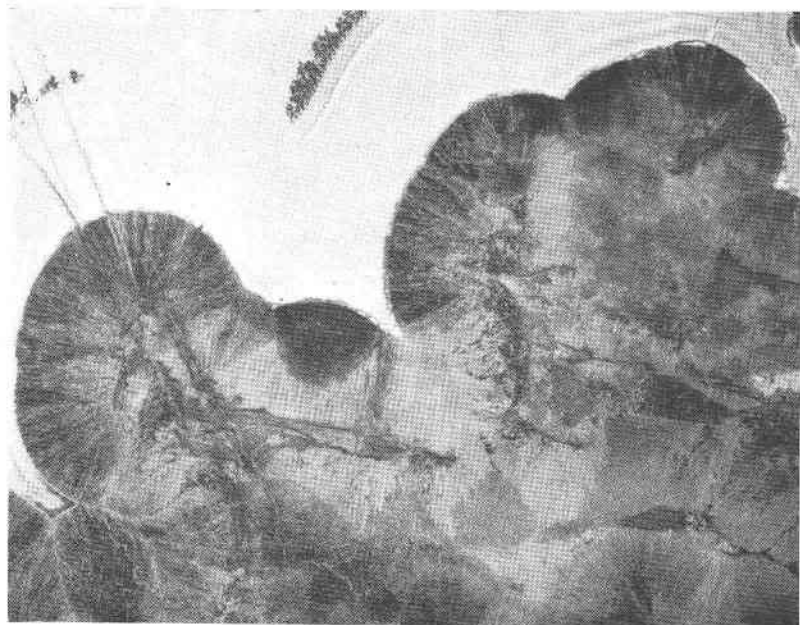

Fig. 1. Greenish spherulites of johannsenite from Tetela de Ocampo, Puebla, Mexico. The white area is xonotlite with dendrites of oxide of manganese. Natural size.

bedded in the johannsenite. Under crossed nicols the rhodonite shows a moiré effect due to wavy extinction bands. The prismatic structure of the original johannsenite has completely disappeared. All stages of the change, from a little rhodonite to abundant rhodonite with only a little residual johannsenite, can be seen in thin sections. This type of alteration is very abundant in the material from Puebla, Mexico, and to a lesser extent in that from Oregon, New Mexico, and Venetia, Italy.

(2) A pseudomorphic change; the prisms of johannsenite retain

their shape and yield compact columnar rhodonite with, however, the continuity of the long prisms of original johannsenite broken.

(3) Development of euhedral cystals of rhodonite at the ends of the prisms of altered johannsenite.

In one specimen from Puebla, Mexico, the development of massive pink rhodonite embedded in the brownish and grayish johannsenite and as a pink border along the ends of the johannsenite prisms is very well shown. Some specimens from both Oregon and New Mexico have altered to impure black oxide of manganese, and in one thin section of the material from Mexico, long prisms of johannsenite have been replaced by calcite. Like many silicates of manganese, johannsenite is prone to incipient alteration, and oxidation, hydration, and carbonatization products are common.

In Oregon, johannsenite occurs in a quartz vein in rhyolite and at Puebla, Mexico, it is reported to be in a calcite vein in rhyolite. At the other localities it is a product of contact metamorphism of a limestone. Quartz, calcite, and rhodonite are the most abundant associated minerals. Characteristic metallic associates are magnetite, pyrite, sphalerite, galena, and chalcopyrite.

PROPERTIES

The cleavage is good parallel to the prism $m\{110\}$. Other planes of separation, as observed under the microscope, are parallel to $c\{001\}$, $a\{100\}$, and $b\{010\}$. The density of pure johannsenite, free from magnesium and iron, has been calculated as about 3.6, but owing to partial alteration and the presence of impurities (chiefly calcite and quartz), massive pieces of the mineral yield lower values, ranging from 3.2 to 3.5. The powdered material from Puebla, Mexico, (analysis no. 2) has a density of 3.53.

The optical axial plane is parallel to $b\{010\}$, and extinction is $48° \pm$; optically positive, 2V about 70°, dispersion $r > v$. Polysynthetic twinning lamellae are common. The indices of refraction for pure $MnO \cdot CaO \cdot 2SiO_2$ are: $\alpha = 1.710$, $\beta = 1.719$, $\gamma = 1.738$, calculated from the measured values on material whose composition is known, and correcting for the presence of isomorphous diopside and hedenbergite.

The measured indices of refraction, together with the component composition as deduced from the chemical analyses, are shown in Table 1. On account of the compensating effect of magnesium and iron, the measured indices of several of the samples are nearly the same as those of the magnesium- and iron-free pure $MnO \cdot CaO \cdot 2SiO_2$.

TABLE 1. MEASURED INDICES OF REFRACTION OF JOHANNSENITES WITH THEIR
COMPONENT COMPOSITION

	Locality	Measured			Component composition $J=MnO \cdot CaO \cdot 2SiO_2$ $D=MgO \cdot CaO \cdot 2SiO_2$ $H=FeO \cdot CaO \cdot 2SiO_2$ $Z=ZnO \cdot CaO \cdot 2SiO_2$			
		α	β	γ	J	D	H	Z
1	Venetia, Italy	1.710	1.719	1.738	97	1	2	0
2	Puebla, Mexico	1.709	1.718	1.737	95	3	2	0
3	Puebla, Mexico	1.710	1.719	1.738	95	2	3	0
3a	Tuscany, Italy	1.709	1.717	1.735	86	9	5	0
4	Hanover, New Mexico	1.713	1.721	1.740	81	3	16	0
5	Oregon	1.709	1.718	1.736	76	12	12	0
6	Venetia, Italy	1.708	1.718	1.737	72	14	14	0
7	New Jersey	1.697	1.706	1.725	51	32	9	8

REFERENCES

1. Roebling collection, U. S. Nat. Mus., Cat. no. R3118. Analysis no. 1.
2. From specimen illustrated in Fig. 1. U. S. Nat. Mus., Cat. no. 97484. Analysis no. 2.
3. From a different specimen containing considerable rhodonite. Analysis no. 3.
3a. Material from Harvard University. Component composition approximate, based on an old analysis.
4. Collected by A. C. Spencer. Analysis no. 4.
5. Collected by J. T. Pardee. Analysis no. 5.
6. Collected by D. F. Hewett. Analysis no. 6.
7. Furnished by L. H. Bauer. Minute brown crystals embedded in bustamite. Crystals hand picked by Miss J. J. Glass. Analysis no. 7.

Johannsenite fuses readily (about 4) before the blowpipe flame to a non-magnetic glassy bead whose color depends on the quantity of iron present. The purest mineral (nos. 1 and 2) fuses to an amber colored translucent bead; if several per cent of iron is present (nos. 4, 5 and 6) the bead is darker brown and more opaque. Hedenbergite fuses to a black, opaque, magnetic bead. All the samples analyzed yield a little water when heated in a closed tube and show a slight effervescence when treated with HCl, due to the presence of impurities and slight alteration. The powdered mineral is completely decomposed by evaporation with HCl, if nearly pure $MnO \cdot CaO \cdot 2SiO_2$.

ANALYSES

All the samples analyzed, except that from Franklin, New Jersey, contained some rhodonite. Pure johannsenite should contain 22.69 per cent of CaO and as no rhodonite contains more than about 11 per cent of CaO, the presence of admixed rhodonite in the samples analyzed will lower the percentage of CaO. In addition to rhodonite, small quantities of quartz, calcite, sphalerite, and undetermined oxidation, hydration, and carbonatization products were present.

Seven analyses of johannsenite have been made. They are listed in Table 2 in the order of decreasing content of pure $MnO \cdot CaO \cdot 2SiO_2$. These analyses have been recalculated (Table 3) deducting impurities other than quartz and rhodonite, except for analysis no. 3 in which about 18 per cent of rhodonite was deducted. The CO_2 was deducted as calcite except for analysis no. 5 in which the CO_2 was equally distributed between Ca and Mn. The H_2O, Al_2O_3, Fe_2O_3, and ZnS were deducted as such.

The slightly high ratios of SiO_2 in Table 4 are ascribed to admixed quartz and the slightly low ratios of CaO to admixed rhodonite.

TABLE 2. ANALYSES OF JOHANNSENITE

No.	1	2	3	4	5	6	7
Locality	Venetia, Italy	Puebla, Mexico	Puebla, Mexico	New Mexico	Oregon	Venetia, Italy	New Jersey
Analyst	Schaller	Steiger	Schaller	Schaller	Schaller Richardson	Schaller	Fairchild
SiO_2	48.16	47.62	50.24	48.15	42.84	47.62	50.30
MnO	27.82	27.47	29.94	21.37	23.61	21.15	14.85
MgO	0.23	0.53	0.26	0.48	2.06	2.74	6.19
FeO	0.50	0.70	0.88	4.28	3.20	4.31	2.59
ZnO	—	—	—	—	—	—	3.27
CaO	20.56	22.18	18.16	20.88	20.99	20.15	22.97
Al_2O_3	—	0.91	0.32	0.31	—	0.81	—
Fe_2O_3	—	0.04	0.25	1.58	0.59	0.62	—
CO_2	1.02	0.24	—	1.39	3.86	2.07	—
H_2O-	0.55	0.09	0.15	0.24	0.58	0.19	—
H_2O+	0.58	0.40	0.49	0.96	1.57	0.25	—
ZnS	0.34	—	—	0.17	0.77	0.25	—
MnO_2	0.11	—	—	—	—	—	—
	99.87	100.18	100.69	99.81	100.07	100.16	100.17

TABLE 3. RECALCULATED ANALYSES OF JOHANNSENITE

	1	2	3	4	5	6	7
SiO_2	50.18	48.29	51.27	51.56	49.17	51.02	50.58
MnO	28.99	28.09	26.83	22.89	23.52	22.66	15.28
MgO	0.24	0.54	0.32	0.51	2.37	2.94	6.37
FeO	0.52	0.72	1.07	4.59	3.67	4.62	2.67
ZnO	—	—	—	—	—	—	2.56
CaO	20.07	22.36	20.51	20.45	21.27	18.76	22.54
	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE 4. RATIOS OF RECALCULATED ANALYSES OF JOHANNSENITE

	1	2	3	4	5	6	7
SiO_2	2.07	1.98	2.11	2.11	2.00	2.07	2.00
(Mn, Mg, Fe, Zn)O	1.04	1.03	0.99	0.99	1.08	1.11	1.05
CaO	0.89	0.98	0.90	0.90	0.92	0.82	0.95

TABLE 5. MINERALOGICAL IDENTITY OF "HIGH LIME RHODONITES" LISTED IN
STANDARD REFERENCE BOOKS

No.	Dana	Hintze	Doel-ter	Locality	Per cent CaO	Mineral
1	—	VII	1	Italy	13.23	Mixture of rhodonite and johannsenite
2	11	XXVII	—	Mexico	16.45	Mixture of rhodonite and johannsenite
3	—	XXVI	5	Mexico	14.57	Mixture of rhodonite and johannsenite
4	10	XXVIII	—	Mexico	9.60	May have been all rhodonite but probably contained some johannsenite
5	—	VIII	3	Italy	18.72	Mixture of johannsenite and rhodonite
6	13	IV	—	Hungary	21.02	Johannsenite and a little rhodonite
7	—	XXII	—	New Jersey	18.00	Bustamite
8	12	X	2	Sweden	18.16	Bustamite

The standard reference books contain six analyses of johannsenite, or probably more accurately of mixtures of johannsenite and rhodonite, as the low percentages of CaO indicate that considerable rhodonite must have been present in the material analyzed. These six analyses are listed in the standard text books under rhodonite, generally as bustamite. They include analyses of material from (1) Monte Civilla, Vicentia, Italy (Pisani, 1886); (2, 3, and 4) three analyses, Puebla, Mexico (Ebelmen, 1845; Dumas, 1826; and Rammelsberg, 1866); (5) Campiglia, Tuscany, Italy (von Rath, 1868); and (6) Rez-

banya, Hungary (Sipöcz, 1873). The references and mineralogical interpretations of these six analyses are shown below in Table 5 together with two other analyses (7 and 8) of "high-lime rhodonites," which are bustamites.

RELATION TO OTHER ANHYDROUS SILICATES OF MANGANESE

Isomorphous mixtures of johannsenite and hedenbergite, known as manganhedenbergites, are not rare. Small quantities of the diopside constituent are usually present. Schefferite is dominantly diopside with Mn, Fe, and Zn substituting for part of the Mg, and CaO-free components of the $RO \cdot SiO_2$ type are present to a small extent. In jeffersonite, no component of the $RO \cdot CaO \cdot 2SiO_2$ (R = Mn, Mg, Fe, Zn) type is dominant.

The bustamites have a different structure. They are of the wollastonite type, and are a homogeneous solid solution of $CaO \cdot SiO_2$ (wollastonite) with $MnO \cdot SiO_2$. Optical data have been obtained for examples with percentages of MnO ranging from a few per cent, through 6, 7, 25, 28 per cent to a maximum of 33 per cent of MnO, or 61 per cent of $MnO \cdot SiO_2$. Those bustamites in which the ratio of MnO to CaO is close to 1:1, represent a dimorphous form of $MnO \cdot CaO \cdot 2SiO_2$, whose optical properties are very different from those of johannsenite as shown in Table 6.

TABLE 6. OPTICAL PROPERTIES OF THE DIMORPHOUS FORMS OF $MnO \cdot CaO \cdot 2SiO_2$

	Johannsenite $MnO \cdot CaO \cdot 2SiO_2$	Bustamite $(Mn, Ca)O \cdot SiO_2$ $MnO:CaO = 1:1$
System	Monoclinic	Triclinic
α	1.710	1.671
β	1.719	1.685
γ	1.738	1.687
B	0.028	0.016
Sign	Positive	Negative
Ext.	48°±	<15°
2V	70°	40–44°

Bustamite with a 1:1 ratio of MnO and CaO, is the high-temperature modification, johannsenite the low-temperature form, with the transition temperature about 830°C. Johannsenite, on ignition, inverts to bustamite.

The name bustamite was given in 1826 by Brongniart to the material from Puebla, Mexico, now known to be a mixture of johannsenite and rhodonite. Since 1922, however, the term bustamite has been applied to

a different and distinct mineral whose optical properties were first determined by Larsen and Shannon[1] and their reallocation of the name bustamite has been followed by all subsequent writers on these minerals.

Rhodonite is different from both johannsenite and bustamite. A compilation of all analyses of authenticated rhodonites shows that the maximum content of CaO is about 11 per cent, which may be represented by the formula $3MnO \cdot CaO \cdot 4SiO_2$. The content of CaO in rhodonites ranges down to a minimum of 1.31 per cent. Any so-called rhodonite with a greater percentage of CaO than about 11 per cent is probably not rhodonite but some other mineral, probably either johannsenite or bustamite. All rhodonites are optically positive with a large axial angle. Synthetic products which have been referred to rhodonite in the past should more correctly be referred to pyroxmangite, which is a triclinic mineral of the same general type of formula, namely, $RO \cdot SiO_2$, with R essentially Mn and Fe.

Plotting the variation of indices of refraction with percentages of CaO for these minerals on one diagram shows that johannsenite, bustamite, rhodonite, and pyroxmangite are distinct minerals and do not form a continuous series between any two or more of them, even though they are very similar in composition.

Rhodonite: Essentially $MnO \cdot SiO_2$ with $FeO \cdot SiO_2$ and $CaO \cdot SiO_2$ and minor quantities of $MgO \cdot SiO_2$ and $ZnO \cdot SiO_2$.

Bustamite: Essentially $MnO \cdot SiO_2$ with $CaO \cdot SiO_2$ and minor quantities of $FeO \cdot SiO_2$, $MgO \cdot SiO_2$, and $ZnO \cdot SiO_2$.

Pyroxmangite: Essentially $MnO \cdot SiO_2$ with $FeO \cdot SiO_2$ and minor quantities of $CaO \cdot SiO_2$ and $MgO \cdot SiO_2$.

Johannsenite: Essentially $MnO \cdot CaO \cdot 2SiO_2$ with minor quantities of $MgO \cdot CaO \cdot 2SiO_2$ and $FeO \cdot CaO \cdot 2SiO_2$.

[1] Larsen, E. S., and Shannon, E. V., Bustamite from Franklin Furnace, New Jersey: *Am. Mineral.*, vol. **7**, pp. 95–100, 1922.