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PYROXMANGITE, NEW LOCALITY: IDENTITY OF SOBRALITE AND PYROXMANGITE

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1. SUMMARY

The discovery of a new locality for pyroxmangite provided material for a rather complete study of this little-known triclinic manganese and iron pyroxene, and established Idaho as a second occurrence of the mineral in America. Physical, optical, chemical, and *x*-ray properties of the new mineral show close agreement with those of the mineral from the original locality at Iva, South Carolina. The indices of refraction are slightly lower in the Idaho material, due probably to a correspondingly lower iron content. A careful study of the mineral from Sweden, called sobralite, revealed its identity with pyroxmangite, a name which has four years' priority over sobralite. A comparative study of pyroxmangite with rhodonite (both iron-rich and iron-poor varieties) shows distinct differences in the birefringence and axial angle. *X*-ray patterns indicate a structural difference between the two minerals that, in the light of our present knowledge, justifies the retention of both mineral species. A complete structural analysis, however, may be necessary to establish the definite relationship of pyroxmangite to rhodonite.

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[1] Published by permission of the Secretary of the Smithsonian Institution and the Director of the U. S. Geological Survey.

2. INTRODUCTION

The triclinic iron-manganese silicate, pyroxmangite, from South Carolina, was described in 1913 by Ford and Bradley,[2] and in the intervening period of 22 years has not been reported by this name from any other locality, nor has it been restudied. Although the analysis yielded the same simple metasilicate formula as that of rhodonite, namely, $RSiO_3$ with R chiefly Fe and Mn, and while many of its properties were similar to those of rhodonite, it was held to be an independent species largely because of the much smaller optical angle and its positive optical sign, in contrast to that of rhodonite which generally had been regarded as being negative.

Four years after the published description of pyroxmangite, Palmgren[3] gave the name sobralite to a similar triclinic manganese-iron silicate from Sweden, differing, apparently, from pyroxmangite, only in optical orientation. Both pyroxmangite and sobralite, while having the same metasilicate formula of rhodonite, differ from it chemically in containing from 20 to 28 per cent of FeO, which is a much higher iron content than is reached by any of the known rhodonites, even in the so-called iron-rhodonites. Earlier descriptions of these manganese-iron silicates from Sweden, antedating the publication of the paper on pyroxmangite, apparently confused iron-rich rhodonites with what was later called sobralite. In a recent paper Sundius[4] has greatly clarified the relation of these and other related triclinic manganese silicates.

The pyroxmangite described in this paper was submitted to the United States National Muesum for identification in the summer of 1933 by Mr. E. W. Mortensen of Homedale, Idaho, and shortly after, an additional sample was received from Mr. D. J. Sullivan of Homedale, Idaho, through Dr. George R. Mansfield of the U. S. Geological Survey. It has not been possible to obtain the exact locality of this pyroxmangite. It was first reported as coming from near Homedale and later from near Boise, Ada County, Idaho.

A preliminary examination of the mineral (by E. P. H.) showed that it was a silicate of manganese and ferrous iron, and that it had the general physical and optical properties of pyroxmangite. The minerals associated with it are the black alteration product, skemmatite?, spessartite-almandite garnet ($n=1.799$), granular magnetite, and a small quan-

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[2] Ford, W. E., and Bradley, W. M., Pyroxmangite, a new member of the pyroxene group and its alteration product, skemmatite: *Am. Jour. Sci.*, 4th ser., vol. **36,** pp. 169–174, 1913.

[3] Palmgren, John, Die eulysite von Sodermanland (Sobralit): *Bull. Geol. Inst. Upsula*, vol. **14,** p. 173, 1917.

[4] Sundius, Nils, On the triclinic manganiferous pyroxenes: *Am. Mineral.*, vol. **16,** nos. 10 and 11, pp. 411–429, 488–518, 1931.

tity of orthoclase which occurs along the edges of some of the cleavage pieces of the pyroxmangite.

The discovery of pyroxmangite in Idaho establishes a second occurrence of this mineral in America, and the quantity of material available from this new locality is sufficient to permit an extensive study of its properties. As the optical properties of pyroxmangite from the original locality at Iva, South Carolina, had not been fully determined, this material was restudied. Samples of sobralite from Sweden were obtained from the Roebling collection in the U. S. National Museum, and also from Dr. Nils Sundius of Stockholm, Sweden, and a study of its properties showed it to be identical with the earlier described pyroxmangite.

The writers are greatly indebted to Mr. George L. English, for generously presenting to the U. S. National Museum all of the remaining specimens of pyroxmangite from Iva, South Carolina, which were used in the comparative study; to Dr. Nils Sundius of the Geological Survey of Sweden, for samples of sobralite and for additional information concerning the correction of some published data; to Dr. George Tunell and Mr. C. J. Ksanda of the Geophysical Laboratory, Carnegie Institution of Washington, D. C., for *x*-ray powder photographs and for their discussion of the relation of pyroxmangite to rhodonite. In addition, we are deeply indebted to Dr. James Gilluly of the U. S. Geological Survey, for measurements of the optical orientation of pyroxmangite and sobralite; and to Dr. W. T. Schaller of the U. S. Geological Survey, with whom the authors have had frequent consultations.

3. Description of Mineral

Physical Properties

The pyroxmangite from Idaho occurs in cleavage pieces, of which the largest measures about 2½ inches (6.4 cm.) long, 1½ inches (3.8 cm.) wide, and 1 inch (2.5 cm.) thick. When cleaved, the thicker fragments assume forms of short, nearly rectangular prisms, and resemble dull-black blocks.

Like the pyroxmangite from South Carolina, specimens from Idaho are dark brown to black, and have what appears to be a dull sub-metallic luster, due to the prevalence of a film of alteration material. The black opaque coating which has covered the outside and penetrated the small cracks and fractures has produced thereby a false color. After the dark stains have been removed by acid the true color of pyroxmangite is shown to be a pale pink tinged with lilac, while the luster is pearly to vitreous.

Dr. W. T. Schaller of the U. S. Geological Survey kindly made the following goniometric observations and measurements on the cleavages and cleavage angles of pyroxmangite.

"The pyroxmangite from Idaho shows two prominent cleavages, one more perfect than the other, after the prisms m(110 and $M(\bar{1}10)$. Two additional cleavages can be observed on inspection with a hand lens, and a fifth cleavage was observed while measuring the cleavage angles on the goniometer. The two best cleavages tend to break the mineral into short nearly rectangular prisms and, like the mineral from South Carolina, yield shining faces readily seen on the hand specimen. In order of perfection the five cleavages are:

$m(110)$.—This is a good cleavage, and while the faces are not uniformly a single cleavage surface but an aggregate of many small faces, the best surfaces yield single reflections on the goniometer over a considerable area.

$M(\bar{1}10)$.—The second best cleavage, while good, is not as perfect as the cleavage parallel to $m(110)$, and the surfaces generally give multiple reflections on the goniometer. The prismatic cleavage angle is nearly the same as that for the mineral from South Carolina.

$b(010)$.—This cleavage is the "parting" mentioned by Ford and Bradley[5] and has also been noted on the mineral from Sweden. It is much poorer than the prismatic cleavages but is seen repeatedly and was measured on the goniometer. Transverse cracks bisecting the first two cleavages can be observed on some fragments of the mineral when examined with a hand lens.

$c(001)$.—The basal cleavage is not reported on the mineral from South Carolina but can readily be developed on the mineral from Idaho. On the goniometer, a single bright reflection somewhat blurred, is obtained if the cleavage fragment is not too large. The basal cleavage is seen on the cleavage faces of $m(110)$ and $M(\bar{1}10)$ as transverse, straight-line fractures and is commonly present on crushed fragments when observed under the microscope. Under these conditions it was seen also on fragments from both South Carolina and from Sweden.

$a(100)$.—This very poor cleavage was observed only once on the goniometer. It must be considered doubtful but it is mentioned chiefly because it is recorded by Palache[6] as a parting on rhodonite.

The average angular values obtained on these cleavages are shown in Table 1, to which are added the similar values previously obtained. All measurements, except those for the angle between the two best cleavages, $m(110)$ and $M(\bar{1}10)$, are poor and not of great accuracy.

The average of several good measurements of the angles $m(110)$

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[5] Ford, W. E., and Bradley, W. M., *op. cit.*, p. 169.

[6] Palache, Charles, The minerals of Franklin Furnace and Sterling Hill, Sussex County, New Jersey: *U. S. Geol. Survey, Prof. Paper* **180,** p. 67, 1935.

TABLE 1. CLEAVAGE ANGLES OF PYROXMANGITE

	Idaho	South Carolina	Sweden
$m(110)\wedge M(1\bar{1}0)$	91°44′	91°50′	91°54′
$b(010)\wedge m(110)$	45 22	45 14	46 —
$b(010)\wedge M(1\bar{1}0)$	43 18	42 56	46 —
$b(010)\wedge a(100)$	96 —	— —	— —
$c(001)\wedge m(110)$	67 —	— —	— —
$c(001)\wedge M(1\bar{1}0)$	84 —	— —	— —
$c(001)\wedge c$-axis[a]	65 —	63 —	63–64

[a] Measured on cleavage faces of *m*(110).

$\wedge M(1\bar{1}0)$, on the pyroxmangite from South Carolina, gave the same value as that found by Ford, namely, 91° 50′. The angle of the Idaho mineral (91° 44′) differs but a few minutes."

The closely-spaced traces of the prismatic cleavage are well developed on some specimens and simulate polysynthetic twinning. The fracture is uneven to hackly. The hardness is 5.5. The specific gravity was determined on a Joly balance as 3.66. The cleavage fragments used in making this determination had been treated with acid to remove the dark stain. The true specific gravity may be slightly higher.

Optical Properties

The mineral when free from manganese oxide and viewed in transmitted light is colorless and nonpleochroic.

The indices of refraction of the pyroxmangite from Idaho are: $\alpha=1.737$ $\beta=1.740$, $\gamma=1.754$; ± 0.001. $\mathrm{B}=0.017$. The axial angle, 2 V, is approximately 39°. Dispersion is moderate $r>v$. Optically positive. These indices of refraction are slightly lower than those for the pyroxmangite from South Carolina, but almost identical with those for the sobralite (pyroxmangite) from V. Silvberg. (See table 4.)

Two good prismatic cleavages and a third transverse (basal) cleavage, that makes an angle of 65° with the *c*-axis on the *m*(110) cleavage, were frequently observed on crushed fragments under the microscope. These observations were later confirmed by goniometric methods. The extinction angle on $m(110)=31°$.

The optical orientation of the mineral is given in detail in the section devoted to the discussion of the relation of sobralite from Sweden to pyroxmangite. It will suffice here to say that allowing for a slight variation in chemical composition, and for errors of adjustment and measurement, there is no essential difference between the optical orientations of pyroxmangite from Idaho and South Carolina, and the mineral from Sweden (sobralite).

In the pyroxmangite from Idaho the axial plane makes an angle of about 45° to $m(110)$ and 89° to $M(1\bar{1}0)$.

Chemical Composition

The mineral fuses with difficulty to a black magnetic bead when heated in the blow pipe flame. The unaltered material is not attacked by acids. According to Schaller[7] rhodonite is partially decomposed (about 10 per cent) by HCl.

The sample analyzed was carefully prepared, first by crushing and screening to remove all fine powder, then by treating it with sulphurous acid to remove the dark stains. After washing with water and drying in air the material was hand picked and only the grains with a bright luster were selected for the analysis.

TABLE 2. ANALYSIS AND RATIOS OF PYROXMANGITE FROM IDAHO
[E. P. Henderson, analyst]

	Analysis	Ratios		
SiO_2	45.47	.7566	.7566	1.00
MnO	27.06	.3815	.7629[a]	1.01
FeO	20.91	.2910		
CaO	2.62	.0467		
MgO	2.14	.0531		
Fe_2O_3	1.50	.0094	.0094	
H_2O	0.32			
	100.02			

[a] After deduction of .0094 FeO corresponding to .0094 Fe_2O_3 for magnetite.

The sample analyzed contained, as its only impurity, specks of disseminated magnetite, amounting to 2.18 per cent, if all the Fe_2O_3 be regarded as belonging to magnetite. In the calculated ratios, shown with the analysis, a corresponding deduction of 0.68 per cent of FeO is made.

The ratios conform closely to the metasilicate formula $RO \cdot SiO_2$ or $RSiO_3$ with R essentially Mn and Fe, and a little Mg and Ca. The formula for pyroxmangite from Idaho can then be written: $(Mn, Fe)SiO_3$. Its ratio of MnO:FeO (after allowing for magnetite) is 0.3815:0.2816, or about 4:3.

In the pyroxmangite from South Carolina, however, iron oxide slightly dominates over manganese oxide.

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[7] Personal communication.

The calculated weight percentages of the four components in the pyroxmangite from Idaho are as follows:

$MnSiO_3$	51.0
$FeSiO_3$	38.0
$MgSiO_3$	5.4
$CaSiO_3$	5.6
	100.0

Alteration

The alteration product of the Idaho pyroxmangite is similar in appearance to that of the South Carolina material, which was described by Ford and Bradley[8] and named skemmatite. Although the brown to black alteration product on the Idaho material is developed to a less extent than on the South Carolina material, it covers the specimens and penetrates the small fractures throughout the mass, and is a conspicuous and characteristic associated material of the pyroxmangite from both localities. This altered material can be removed readily by treatment with hydrochloric or sulphurous acid.

It was found that the Fe_2O_3: MnO_2 ratios in the altered product on the Idaho material are not very close to the values reported on the S. Carolina mineral. There is not enough of the altered product on the Idaho specimens of pyroxmangite to satisfactorily determine the composition of skemmatite. The results are, on the other hand, close enough to somewhat strengthen the status of this mineral. However, when and if specimens are obtained which will permit a study of the composition of skemmatite, an investigation will be made.

4. PYROXMANGITE FROM IVA, SOUTH CAROLINA

The optical properties of the pyroxmangite from South Carolina were only partially determined by Ford and Bradley[9] who gave the mean index as 1.75 or 1.76; the optical angle as 30°; positive sign. Because of the lack of crystal faces the exact orientation of the cleavage pieces was impossible, therefore the position of the extinction direction was regarded as uncertain.

The physical and optical properties of pyroxmangite from Idaho and from Iva, South Carolina, are very similar. The indices of refraction are slightly lower in the mineral from Idaho, corresponding to a smaller percentage of FeO. The tabulation of the properties and composition of the mineral from Iva, South Carolina, is shown in Tables 4 and 7,

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[8] Ford, W. E., and Bradley, W. M., *op. cit.*, p. 174.

[9] Ford, W. E., and Bradley, W. M., *op. cit.*, pp. 170–171.

which also include similar data for the pyroxmangite (sobralite) from the two localities in Sweden. These values show the essential identity of the mineral from Idaho with that from the original locality of pyroxmangite in South Carolina.

5. IDENTITY OF SOBRALITE WITH PYROXMANGITE

Four years after the description of pyroxmangite was published, the mineral called sobralite was announced. (For convenience of reference pyroxmangite from Sweden is referred to as sobralite in this paper.) Sobralite has been found in two neighboring localities in Sweden, namely, Vester Silvberg and Tunaberg. V. Silvberg is the name of a mining district in the southern part of the province of Dalecarlia, central Sweden. The same district is also named Stollbery after the principal mining camp. Tunaberg is located in the province of Södermanland, SW of Stockholm (more exactly located about 14 km. SSW of Nykoping).

Pyroxmangite and the mineral called sobralite are so closely related in their chemical composition and in their optical properties that the study of pyroxmangite naturally involved the study of sobralite. The mineral sobralite was named by Palmgren[10] when making a study of the eulysite of Södermanland, Sweden. This mineral was studied optically by Sobral, who described it as being a triclinic pyroxene, optically positive, colorless, and without noticeable pleochroism in thin sections. Palmgren gave to this "hitherto unknown variety of pyroxene" the name sobralite, in honor of his former teacher, Doctor José M. Sobral of Buenos Aires.

Later Sobral[11] added the following descriptions:

"The mineral is triclinic. The crystals are anhedral. Twinning does not appear. The cleavages on 110 and $1\bar{1}0$ are commonly rather indistinct; interrupted cleavage cracks bisecting the prismatic cleavages also exist. Thin sections of more than 0.05 mm. thickness are not pleochroic. In the case of very low magnification the mineral shows a faint lilac color. The sign is positive (+). $2V=41.1°$; $r>v$ strong, but weaker than in the case of iron rhodonite. $\beta-\alpha=0.0025$; $\gamma-\beta=0.0175$; $\gamma-\alpha=0.0200$. The mean index is about 1.74."

Sobral mentions as the associated minerals, diopside, a triclinic pyroxene, olivine, and spessartite.

Sundius[12] has discussed the investigations of Sobral and Palmgren, and was able to obtain some of the material on which Sobral had worked and from this material prepared a sample for a new analysis (No. 4, Table 7).

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[10] Palmgren, J., *Bull. Geol. Inst. Upsula*, vol. **14,** p. 173, 1917.

[11] Sobral, José M., Optical investigation of the new pyroxene sobralite: *Bull. Geol. Inst. Upsula*, vol. **18,** p. 47, 1921.

[12] Sundius, Nils, *op. cit.*, pp. 502–507.

Palmgren, Sobral, and Sundius, all recognized the similarity of sobralite and pyroxmangite, but the information on the optical properties and orientation of pyroxmangite, as described by Ford and Bradley, was apparently too incomplete to establish identity.

A mineral designated as an iron-rich rhodonite from Vester Silvberg, Sweden, was described by Weibull[13] in 1884. Sundius secured two thin sections made from the specimen collected by Weibull, and after examining them reported that the "iron-rhodonite" had the same optical properties as the sobralite from Tunaberg. On the basis of both optical and chemical similarity to sobralite, Sundius called the "iron-rhodonite" analyzed by Weibull, sobralite. No. 3, Table 7, shows the analysis made by Weibull.

The sobralite specimen from Södermanland, Sweden, in the U. S. National Museum Collection (R-3128), was studied by the authors of this paper, and the optical properties of the sobralite and of the minerals found intimately associated with it, are given below. The minerals were separated by heavy solution and studied in grains mounted in immersion oils and melts. A thin section was also cut from this same specimen and examined optically.

About three-fourths of the specimen is composed of sobralite and a monoclinic pyroxene, the latter predominating. The sobralite is triclinic, optically positive, $2V=40°$. Indices of refraction are, $\alpha=1.726$, $\beta=1.728$, $\gamma=1.744$. $B=0.018$. The pyroxene is related optically to schefferite. It is optically positive, 2V large, with indices of refraction: $\alpha=1.701$, $\beta=1.705$ $\gamma=1.730$. $B=0.029$.

About one-fifth of the sample is composed of spessartite, $n=1.798$. The remaining fraction of the sample consists of knebelite, optically negative, $2V=60°$, indices of refraction: $\alpha=1.805$, $\beta=$n.d., $\gamma=1.845$; bustamite, optically negative, $2V=60°$, indices of refraction: $\alpha=1.660$, $\beta=1.670$, $\gamma=1.674$; and apatite, optically negative, indices of refraction: $\epsilon=1.63$, $\omega=1.64$.

The properties of the sobralite (U.S.N.M. No. R-3128) and its associated minerals agree very well with those described by Palmgren and by Weibull.

Sundius kindly contributed a sample and thin section of the sobralite from Vester Silvberg on which he had made his studies.[14] This specimen was also examined optically and the values found by the authors are: Optically positive, $2V=41°$, dispersion $r>v$, indices of refraction: $\alpha=1.737$, $\beta=1.740$, $\gamma=1.755$, $B=0.018$. These values all agree within the limits of error of measurement with those reported by Sundius. The

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[13] Weibull, M., *Kungl. Vet. Akad. Overs.*, no. 9, p. 29, 1884.

[14] Sundius, N., *op. cit.*, pp. 502–505, 518.

optical properties of the sobralite from Vester Silbverg coincide also within the limits of error of measurement with those of the pyroxmangite from Idaho.

The properties of pyroxmangite and sobralite from the different localities are summarized in Table 4. It can easily be seen that the properties of all of these minerals are essentially identical. The minor variations, as in the absolute values of the indices of refraction, are due to the varying ratios of MnO and FeO, and in some measure to the variations in CaO and MgO.

TABLE 4. PROPERTIES OF PYROXMANGITE AND OF SOBRALITE, SHOWING THEIR IDENTITY

Mineral	Pyroxmangite		Sobralite from Sweden				
Locality	Idaho	South Carolina	V. Silvberg		Tunaberg (Södermanland)		
Data by	Glass	Glass	Sundius	Glass	Glass	Sobral	Sundius
System	Tricl.	Tricl.	Tricl.	Tricl.	Tricl.	Tricl.	Tricl.
Cleavage	m, M, b, c	m, M, b, c	m, M, c	m, M, b, c	m, M, b, c	m, M, b	m, M
$m:M$	91°44′	91°50′	92°12′	—	—	91°54′	92°
$m:b$	45°22′	45°14′	—	—	—	46°	—
$M:b$	43°18′	42°56′	—	—	—	46°	—
$\overset{\vert}{c}:c$[a]	65°[a]	63°[a]	About 70°[b]	64°[a]	63°[a]	—	—
α	1.737	1.748	1.738	1.737	1.726	—	—
β	1.740	1.750	1.740	1.740	1.728	1.74[c]	—
γ	1.754	1.764	1.755	1.755	1.744	—	—
$\gamma-\alpha$	.017	.016	.017	.018	.018	.020	.018
$\gamma-\beta$	.014	.014	.015	.015	.016	.017	.015
$\beta-\alpha$	.003	.002	.002	.003	.002	.003	.003
Sign	+	+	+	+	+	+	+
2 V	39°	37°	42°	41°	40°	41°	41°
Disp.	$r>v$	$r>v$	—	$r>v$	$r>v$	$r>v$	—

[a] As measured on the cleavage after $m(110)$.

[b] Given by Weibull as angle between (001) and prismatic cleavage. Also noted by Sundius.

[c] Mean index of refraction.

The optical orientations of the mineral from Idaho, and for comparison, also from Iva, South Carolina, and from V. Silvberg, Sweden, were kindly determined by Dr. James Gilluly of the U. S. Geological Survey, using the Fedorov universal stage. Dr. Gilluly reports as follows.

"The optical orientations of the mineral from V. Silvberg, Sweden, Idaho, and South Carolina, were determined in thin sections using the universal stage, with the prismatic cleavages *m*(110) and *M*($1\bar{1}0$) as reference planes. Owing to twinning and slight displacements in parts of even small cleavage fragments, the material examined was not satisfactory for accurate measurements. This was especially true for the pyroxmangite from South Carolina, which showed commonly only one prismatic cleavage and a second cleavage considered as parallel to the base *c*(001). The second prismatic cleavage however was observed frequently enough to make the control of orientation seem reasonably good.

"The accompanying stereographic projection (Fig. 1) embodies the results of the measurements. Only one cleavage fragment from each locality was measured and no color filters were used. The measurements of the positions of α, β, and γ for the mineral from the three localities cannot be considered accurate within less than 10 degrees. Nevertheless, they suffice to establish the close similarity in optical orientation of the three specimens. The coordinates measured are given in Table 5, to which have been added the more accurate determinations of Sundius[15] on the sobralite from V. Silvberg (analysis No. 4 in Table 7) and from Tunaberg (not analyzed).

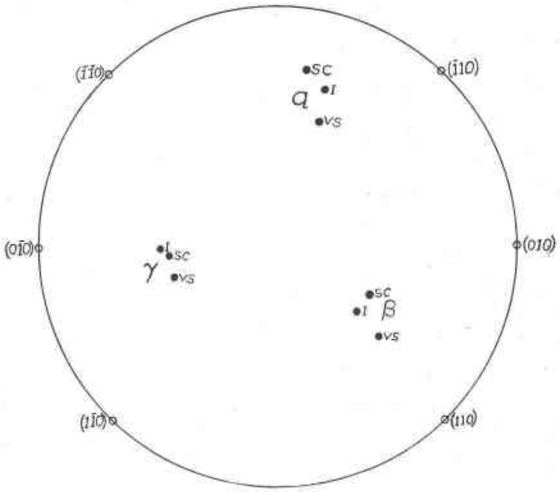

FIG. 1. Stereographic projection of positions of the three principal optical directions α, β, and γ for the three occurrences of pyroxmangite. VS = V. Silvberg, Sweden (sobralite), I = Idaho, SC = South Carolina.

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[15] Sundius, N., *op. cit.*, pp. 505, 507, 1931.

TABLE 5. COORDINATES OF THE OPTICAL DIRECTIONS α, β AND γ IN PYROXMANGITE AND IN SOBRALITE

ϕ (Measured from $m(110)$)	α	β	γ
V. Silvberg (Sundius)	18.7°(±1°)	266°(±1.5°)	136.6°(±2.6°)
Tunaberg (Sundius)	14.2°(±5.4°)	264.7°(±4°)	136.9°(±5.1°)
V. Silvberg (Gilluly)	26°(±10°)	274.5°(±10°)	152°(±10°)
Idaho (Gilluly)	28°(±10°)	276°(±10°)	137°(±10°)
So. Carolina (Gilluly)	36°(±10°)	288.5°(±10°)	140°(±10°)
ρ	α	β	γ
V. Silvberg (Sundius)	60.9°(±0.9°)	53.7°(±2°)	48.5°(±1.4°)
Tunaberg (Sundius)	62.2°(±4°)	56.5°(±6.7°)	46.2°(±5.8°)
V. Silvberg (Gilluly)	57°(±10°)	59°(±10°)	48.5°(±10°)
Idaho (Gilluly)	69°(±10°)	46.5°(±10°)	52°(±10°)
So. Carolina (Gilluly)	73.5°(±10°)	46.5°(±10°)	48.5°(±10°)

"The agreement in the optical orientation, as given in Table 5, is sufficiently close to confirm the essential identity of the mineral from the different localities. The discrepancies can be ascribed to the difficulty of making accurate measurements on the not very satisfactory thin sections, the notable dispersion, and the somewhat variable chemical composition of the mineral from the three localities, not only in percentages of the essential components $FeSiO_3$ and $MnSiO_3$ but also in that of the minor components $CaSiO_3$ and $MgSiO_3$, as given in Table 7.

TABLE 6. ANGLES BETWEEN THE PRINCIPAL OPTICAL PLANE (α, γ) AND THE PRISMATIC CLEAVAGES

	$(\alpha, \gamma)\wedge m\{110\}$	$(\alpha, \gamma)\wedge M\{1\bar{1}0\}$
V. Silvberg (Sundius)	35.5°	84.5°
Tunaberg (Sundius)	32.5°	83.5°
Tunaberg (Sobral)	36°	84.2°
V. Silvberg (Gilluly)	32°	88°
Idaho (Gilluly)	44.5°	87°
So. Carolina (Gilluly)	47°	78°

"These data yield the following angles (Table 6) between the principal optical plane (α, γ) and the prismatic cleavages. The values determined by Sobral on sobralite from Tunaberg as given by Palmgren[16] are added.

"It is evident that the optical orientation, first correctly determined by Sobral, is nearly the same for the mineral from the different localities. The greatest variation from the general average is shown by the pyroxmangite from South Carolina. This occurrence has the highest content of $FeSiO_3$ of any of the pyroxmangites (based on a single analysis and assuming that all the South Carolina pyroxmangite is homogeneous in composition), and the slight deviations of the values for the optical orientations from the general average (including the maximum values of the indices of refraction) may well be a function of the content of the iron component.

"Palmgren[17] assumed an established difference in optical orientation between the Swedish mineral he named sobralite, and the pyroxmangite from South Carolina, emphasizing the supposed difference by contrasting the two orientations in his Figs. 1 and 2 (p. 178). In the original description of pyroxmangite it is stated[18] that the optic axial plane is normal to the parting plane *b*(010). Had an examination of pyroxmangite been made at the time and by the same methods used on sobralite, it would have been seen that such an orientation was not correct and the only apparent difference between sobralite and pyroxmangite would have disappeared. For a triclinic mineral with no crystal faces and only cleavages as a guide to the orientation it is obviously extremely difficult to determine the correct optical orientation without the use of the universal stage."

The following table contains all of the analyses of pyroxmangite and of sobralite in the literature, including the new pyroxmangite described in this paper. Analyses of mixtures of sobralite and iron-rhodonite are not considered. Following the table of analyses is the calculated weight percentages of the components.

In the four analyses, $MnSiO_3$, is greater than $FeSiO_3$ in two and less than $FeSiO_3$ in the other two. It cannot be said, therefore, that either component dominates in pyroxmangite. The quantities of $CaSiO_3$ and of $MgSiO_3$ are similar to those in the rhodonites.

The indices of refraction of the pyroxmangite (sobralite) from Södermanland are about as much lower than those for the mineral from V. Silvberg and from Idaho as those of pyroxmangite from South Carolina

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[16] Palmgren, J., *op. cit.*, p. 175.

[17] Palmgren, J., *op. cit.*, pp. 177–179.

[18] Ford, W. E., and Bradley, W. M., *op. cit.*, p. 170.

Table 7. Chemical Analyses of Pyroxmangite and Sobralite.

		1	2	3	4
SiO_2		45.47	47.14	45.12	46.53
MnO		27.06	20.63	24.25	20.50
FeO		20.91	28.34	22.44	24.69
CaO		2.62	1.88	5.62	5.46
MgO		2.14	—	1.20	1.39
Fe_2O_3		1.50	—	—	0.85
Al_2O_3		none	2.38	1.38	0.21
H_2O		0.32	0.33	—	0.39
BaO		—	—	—	0.08
		100.02	100.70	100.01	100.10
Component composition	$MnSiO_3$	51	41	44	39
	$FeSiC_3$	38	55	41	46
	$CaSiO_3$	6	4	12	12
	$MgSiO_3$	5	0	3	2
		100	100	100	100

1. Pyroxmangite, Idaho. Analyst, E. P. Henderson.
2. Pyroxmangite, Iva, South Carolina. Analyst, W. M. Bradley.
3. Sobralite, ("iron rhodonite"), V. Silvberg, Sweden. Analyst, M. Weibull.
4. Sobralite V. Silvberg, Sweden. Analyst, A. Bygdén.

are higher. The pyroxmangite from South Carolina with the highest indices of refraction, has the highest percentage of $FeSiO_3$. The indices of refraction of the pyroxmangite from Idaho are nearly identical with those of the pyroxmangite (sobralite) from V. Silvberg.

The average percentage ratio of $MnSiO_3$ to $FeSiO_3$ in the four analyses is 44:45, and it may be that pyroxmangite approaches a double salt of the formula $MnO \cdot FeO \cdot 2SiO_2$ in composition.

6. *X*-RAY POWDER PHOTOGRAPHS

The *x*-ray powder photograph of sobralite from V. Silvberg, Sweden, is identical with those of pyroxmangite from Idaho and from South Carolina. The pattern of the sobralite from Sweden is No. 3 in Fig. 3, Nos. 1 and 2 being the patterns of pyroxmangite from Idaho and South Carolina. The remaining three patterns (nos. 4, 5, and 6) shown in Fig. 3 are those of rhodonite. The relation of these two minerals is discussed in later pages.

These *x*-ray powder photographs[19] of pyroxmangite as well as those of

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[19] These *x*-ray films are on record in the reference files of the Geophysical Laboratory, Carnegie Institution of Washington, D.C.

rhodonite were made by Dr. George Tunell and Mr. C. J. Ksanda of the Geophysical Laboratory, Carnegie Institution of Washington, D.C.

The physical and optical properties, chemical composition, and *x*-ray patterns of pyroxmangite and sobralite are so nearly identical that it is evident that they represent the same mineral.

7. Relationship of Pyroxmangite to Rhodonite

The foregoing study of pyroxmangite and sobralite brings out certain characteristics that raise the question as to its relationship to rhodonite. It, therefore, seems advisable to include a comparison of these two minerals as a part of this paper.

Both pyroxmangite and rhodonite are triclinic minerals with similar properties and chemical compositions. Rhodonite is a metasilicate composed dominantly of $MnSiO_3$, with a maximum recorded content of 14.5 per cent of FeO, corresponding to 27 per cent of $FeSiO_3$. Pyroxmangite is a similar metasilicate with percentages of FeO from 20.9 to 28.3, corresponding to 38 to 55 per cent of $FeSiO_3$. Do these relations imply that rhodonite and pyroxmangite are parts of an isomorphous series, and if so, do the so-called iron rhodonites occupy an intermediate position?

Several valuable papers on rhodonite[20] have recently been published, and numerous chemical analyses are available, but a comparison with pyroxmangite indicates the necessity of a critical study of the rhodonites low and high in ferrous iron. For this comparison a rhodonite from Bald Knob, North Carolina, previously described by Ross and Kerr,[21] was selected as a low-iron member. A new sample from this locality was analyzed in order that ample material might be available for detailed study of all of the properties. An iron-rich rhodonite from Broken Hill, New South Wales, Australia,[22] was selected as a representative high-iron type. The chemical analyses (by E. P. H.) and optical properties (by J. J. G.) of these two rhodonites are given in Table 8 together with the rhodonite richest in iron from Tuna Hästberg, Sweden, described by Sundius,[23] and the two pyroxmangites containing the minimum and maximum percentages of FeO.

The compilation (Table 8) shows that in rhodonite with a range of FeO content from 2.44 to 14.51 per cent, there is almost no variation in

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[20] Hey, M. H., The variation of optical properties with chemical composition in the rhodonite-bustamite series: *Mineral, Mag.*, vol. **22,** no. 127, pp. 193–205, 1929.
Sundius, N., *op. cit.*, pp. 488–489; pp. 501–502; and pp. 517–518, 1931.

[21] Ross, C. S., and Kerr, Paul F., The manganese minerals of a vein near Bald Knob, North Carolina: *Am. Mineral.*, vol. **17,** pp. 13–15, 1932.

[22] U. S. National Museum Collection (U.S.N.M. No. 90102).

[23] Sundius, N., *op. cit.*, pp. 501–502; pp. 517–518, 1931.

TABLE 8. ANALYSES AND INDICES OF REFRACTION OF SELECTED RHODONITES AND PYROXMANGITES, WITH VARYING PERCENTAGES OF FeO.

		Rhodonite			Pyroxmangite	
		Bald Knob, N.C.	Broken Hill, N.S.W.	Tuna Hästberg, Sweden	Idaho	Iva, S.C.
SiO_2		45.17	46.45	47.78	45.47	47.14
MnO		45.98	35.10	29.20	27.06	20.63
FeO		**2.44**	**12.65**	**14.51**	**20.91**	**28.34**
MgO		1.31	0.40	1.93	2.14	—
CaO		4.10	5.45	6.55	2.62	1.88
Al_2O_3		—	—	0.08	none	2.38
Fe_2O_3		0.93	0.12	0.11	1.55	—
H_2O		0.30	0.27	0.09	0.32	0.33
		100.23	100.44	100.25	100.02	100.70
Component composition	$MnSiO_3$	82	65	53	51	41
	$FeSiO_3$	5	23	26	38	55
	$CaSiO_3$	9	11	15	6	4
	$MgSiO_3$	3	1	6	5	0
		100	100	100	100	100
Sp Gr.		3.75	3.68	3.65	3.66	3.80
α		1.724	1.726	1.725	1.737	1.748
β		1.728	1.730	1.728	1.740	1.750
γ		1.737	1.739	1.737	1.754	1.764
B		.013	.013	.012	.017	.016
2V		70°	74°	70°	39°	37°

the values of the indices of refraction or of the axial angle. There is, however, a decided discontinuity in these values where those of pyroxmangite are considered. The change in the values for the axial angles between the two minerals is striking.

In the course of a study of johannsenite Dr. W. T. Schaller[24] has compiled the available data on rhodonite, where the optical properties are correlated with chemical composition. In the following table the average values of the birefringence and axial angle are given and correlated with the iron content.

Table 9 shows that the average birefringence of low-iron rhodonite is

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[24] Personal communication.

TABLE 9. AVERAGE BIREFRINGENCE (B) AND AXIAL ANGLE (2V) FOR RHODONITE AND PYROXMANGITE

	Ave. percentage of FeO	B	2V
Average value of B for 10 rhodonites, and of 2V for 9 rhodonites, excluding 2 iron-rich rhodonites	1.54	0.013	71°
Average values for 2 iron-rich rhodonites	13.58	0.013	71°
Average values for 4 pyroxmangites	24.10	0.018	40°

identical with that of the high-iron rhodonite, notwithstanding the fact that the two iron-rich varieties have an average FeO content more than half the average FeO content of 4 pyroxmangites. Therefore, the high-iron rhodonites do not occupy an intermediate position between pyroxmangite and low-iron rhodonites. The axial angle (2V) of rhodonite ranges from 76° down to 63°, with a considerable gap between that and the highest value (42°) for pyroxmangite.

The birefringences of the various rhodonites are rather constant. Schaller's compilation of 12 rhodonites gives 0.013 as the average value. This corresponds closely with the average value of 0.0126 of the 13 determinations given by Sundius.[25] The birefringence of analyzed rhodonite is shown in the following tabulation, compared with that of pyroxmangite.

TABLE 10. BIREFRINGENCE OF ANALYZED RHODONITE AND OF PYROXMANGITE

Rhodonite	Pyroxmangite
0.011 (one determination)	0.016 (one determination)
0.012 (four determinations)	0.017 (two determinations)
0.013 (four determinations)	0.018 (three determinations)
0.014 (two determinations)	0.020 (one determination)
0.016 (one determination)	
0.013 (average)	0.018 (average)

Only one determination of rhodonite exceeds 0.014 and this single high value of 0.016 is probably too high as the 13 acurate determinations given by Sundius range from 0.0118 to 0.014, with no value as high as 0.016.

The indices of refraction of analyzed rhodonite range between the

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[25] Sundius, N., *op. cit.*, pp. 489–502, 1931.

values for α of 1.711 to 1.738, and values for γ of 1.724 to 1.751. These are in general lower than those of pyroxmangite which has values for α ranging between 1.726 and 1.748, and values for γ between 1.744 and 1.764. The values of the indices of refraction, birefringence, and axial angle for pyroxmangite and for rhodonite are shown graphically in Fig. 2 where the indices of refraction are plotted in the order of increasing values for the index β.

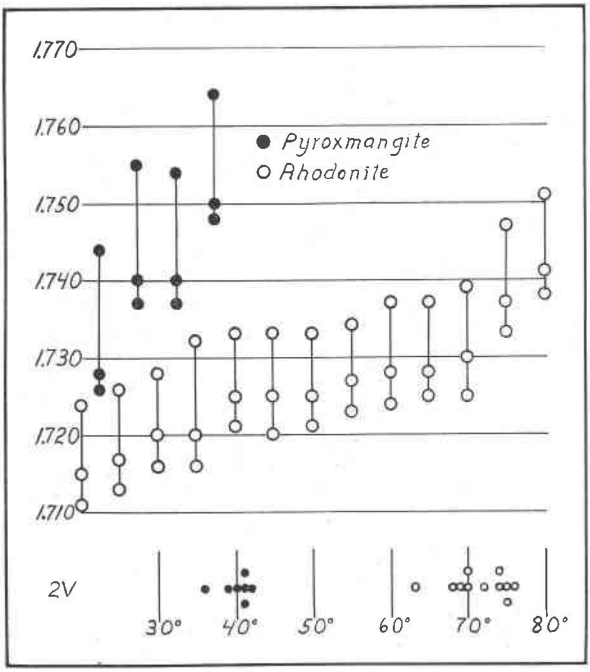

FIG. 2. Indices of refraction, birefringence, and axial angle of pyroxmangite and of rhodonite.

The foregoing comparative study shows that the pyroxmangite series has a slightly higher value for the indices of refraction than the rhodonite series; there is even more marked difference in birefringence between these two minerals; and there is a considerable gap from the highest value for the axial angle of pyroxmangite and the lowest value of rhodonite. These facts strongly suggest that these two minerals do not represent a series of continuously variable components.

The chemical constituents of rhodonite are the same as those of pyroxmangite. So far no rhodonite has been described in which the content of FeO is much greater than about half the average value for pyroxmangite.

The other constituents, CaO and MgO (and in the variety fowlerite, ZnO), are subordinate and of about the same order of importance as they are in pyroxmangite. There apparently is no component in rhodonite which might enter into its composition which would tend to lower the axial angle to within the range for pyroxmangite, or change the other optical properties in closer agreement with those of pyroxmangite.

The close relation between the morphology of rhodonite and pyroxmangite, as expressed by cleavage angles, is shown in the following table.

TABLE 11. COMPARISON OF CLEAVAGE ANGLES OF RHODONITE AND PYROXMANGITE

Angle	Rhodonite	Pyroxmangite
$m(110)\wedge M(1\bar{1}0)$	92°29′	91°47′[a]
$b(010)\wedge m(110)$	45 53	45 18 [a]
$b(010)\wedge M(1\bar{1}0)$	41 39	43 07 [a]
$b(010)\wedge a(100)$	94 26	96[b]
$c(001)\wedge m(110)$	68 45	67[b]
$c(001)\wedge M(1\bar{1}0)$	86 23	84[b]
$\phi(001)$	58 08	62 16[b]
$\rho(001)$	21 46	24 59[b]

[a] Average of angles for pyroxmangite from Idaho and South Carolina.

[b] Measured on material from Idaho.

The comparison of the cleavages of the two minerals is as follows, the data for rhodonite being taken from Palache.[26]

	Pyroxmangite	Rhodonite
$m(110)$	Perfect	Perfect
$M(1\bar{1}0)$	Good	Perfect
$b(010)$	Fair	Very good parting
$c(001)$	Fair	Good
$a(100)$	Very poor	Traces (parting)

In color (when freed from stain) and hardness the two minerals are very similar. Both are triclinic and optically positive. The specific gravity of rhodonite (3.65–3.75) is slightly less than that for pyroxmangite (3.66–3.80).

It was hoped that a comparison of the *x*-ray powder photographs of the two minerals would yield conclusive evidence of their identity or non-identity. This hope was not fully realized but the following statement of Dr. Tunell[27] would seem to support the conclusion reached by a

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[26] Palache, C., *op. cit.*, p. 67.

[27] Personal communication, dated January 8, 1935.

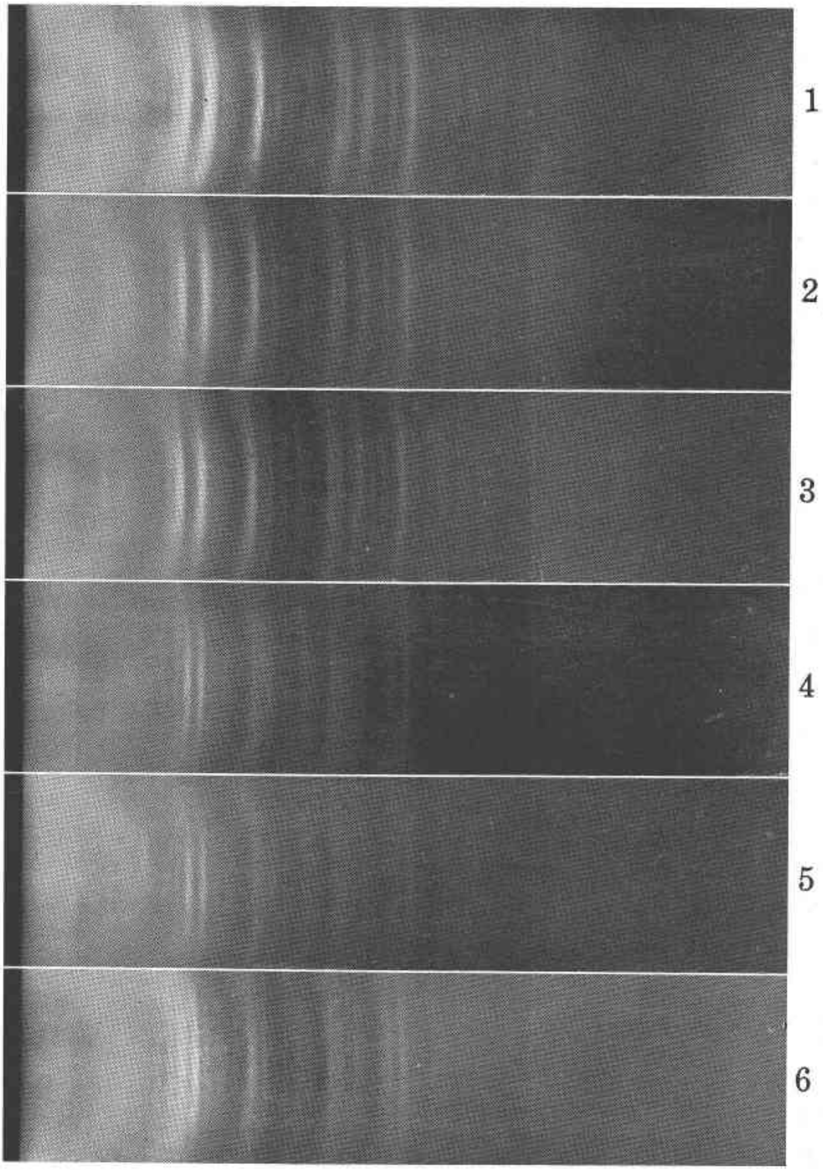

FIG. 3. *X*-ray powder photographs of pyroxmangite and rhodonite.
No. 1. Pyroxmangite from Idaho.
No. 2. Pyroxmangite from South Carolina.
No. 3. Pyroxmangite (sobralite) from V. Silvberg, Sweden.
No. 4. Iron-rhodonite from Broken Hill, N.S.W.
No. 5. Rhodonite from Bald Knob, N.C.
No. 6. Rhodonite from Franklin, N.J.

comparison of the optical properties of the two minerals, namely, that pyroxmangite and rhodonite are distinct species, and do not belong to a single continuously variable series.

The *x*-ray patterns of pyroxmangite from Idaho, South Carolina, and Sweden (sobralite), are shown in Fig. 3 as Nos. 1, 2, and 3. The iron-rich rhodonite from Broken Hill, N.S.W., follows (No. 4), and the last two pictures are of iron-poor rhodonite from Bald Knob, N.C. (No. 5), and from Franklin, N.J. (No. 6).

Dr. Tunell's statement of the comparison of the *x*-ray patterns of pyroxmangite and of rhodonite follows:

" . . . The powder photographs of pyroxmangite and rhodonite show a great similarity which suggests (although it does not prove) a close structural relationship between the two. The question that has been raised is whether or not pyroxmangite and rhodonite belong to the same solid solution series, that is, to a single phase of continuously variable composition. If this were the case, and atoms of iron were substituted for atoms of manganese in pyroxmangite (the atoms of iron in pyroxmangite occupying the same equipoints on which the atoms of manganese are situated in rhodonite), no differences in the intensity of the lines would be expected because the scattering power of magnanese is practically identical with that of iron. Some differences in spacings might be brought about by the substitution of iron for manganese, however, since the atomic radii of iron and manganese differ a little. Actually, one finds on the films that the lines have slightly different spacing in pyroxmangite and rhodonite but that the intensities are closely similar. Certainly the observed differences in the intensities are not great enough to prove that pyroxmangite and rhodonite do not belong to the same solid solution series. The evidence of the spacings suggests to me that there is an appreciable difference between pyroxmangite and rhodonite, which difference is not covered by a continuous change from one to the other. This evidence concerns the first two strong lines in the powder spectrum. The spacing of these two lines in the two pyroxmangites from Idaho and South Carolina are the same within the error of measurement. Likewise the spacings of these two lines in the three samples of rhodonite from Franklin Furnace, N.J., Bald Knob, N.C., and Broken Hill, New South Wales, are the same within the error of measurement. The spacing of the innermost strong line in both samples of pyroxmangite is the same as that in the samples of rhodonite. But the spacing of the second strong line in both samples of pyroxmangite is appreciably different from that in all the samples of rhodonite. It seems that if the presence of 21–28 per cent of FeO in pyroxmangite were responsible for this shift, an intermediate position of the line would be observed in the case of the iron rhodonite from Broken Hill which contains nearly 13 per cent of FeO as compared with the almost pure manganese rhodonite. In other words, the hypothesis of solid solution would call for a continuous shift of the line with variation of composition, whereas the shift does not seem to be continuous. It would not be safe to base a definite conclusion on such meager evidence however, and from our point of view the question of exact relationship between pyroxmangite and rhodonite cannot be settled definitely as yet. Perhaps a complete structural analysis will be necessary in order to throw the desired light on this problem."