

RELATIONSHIP OF ANTHOPHYLLITE, CUMMINGTONITE AND MANGANO-CUMMINGTONITE IN THE METAMORPHOSED WABUSH IRON-FORMATION, LABRADOR

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ABSTRACT

The chemical, optical properties and mutual relationships of anthophyllite, cummingtonite and mangano-cummingtonite from the metamorphosed Wabush iron-formation, Labrador, are discussed in this paper. Anthophyllite and cummingtonite are shown to be different series with limited isomorphism. Mangano-cummingtonite is monoclinic; however, its chemical composition and optical properties are more similar to orthorhombic anthophyllite than to the cummingtonite-grunerite series. Mangano-cummingtonite is regarded as the manganiferous analog of anthophyllite. The unusual chemical and optical properties of mangano-cummingtonite are also explained. Identification of the minerals has been confirmed by x -ray diffraction.

INTRODUCTION

The results of an investigation of the relationship of anthophyllite, cummingtonite and mangano-cummingtonite are discussed in this paper. Optical properties, chemical composition and x -ray patterns of these minerals are compared. Although mangano-cummingtonite is monoclinic it is evident from these properties that it is closely related to anthophyllite.

A large number of high temperature silicate minerals, like anthophyllite, cummingtonite, mangano-cummingtonite, hypersthene, diopside, etc. occur in the metamorphosed Wabush iron-formation of the Labrador geosyncline. The whole formation is divided into two stratigraphic units: the lower Wabush iron-formation consisting of quartz-carbonate-silicate-magnetite rocks, and the upper Wabush iron-formation consisting of quartz-specularite-magnetite rocks or the potential ore bodies. Anthophyllite and mangano-cummingtonite are restricted to the upper Wabush iron-formation, whereas cummingtonite occurs mainly in the lower.

MINERALOGY

The highest and the lowest refractive indices of the minerals were determined by liquid immersion methods in sodium light. Optic axial angles were measured directly on a four-axis universal stage and the

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extinction angles were checked. The intermediate refractive indices were calculated. The probable accuracy of refractive indices below 1.70 is ± 0.002 and above 1.70 is ± 0.005 .

Separation of Minerals

Cummingtonite does not occur directly with anthophyllite or mangano-cummingtonite. Samples with minimum foreign material were chosen and crushed to $-100+150$ mesh size. All magnetite and grains containing magnetite inclusions were separated by using a strong hand magnet. Carbonates were removed by leaching with hot dilute HCl. The samples were then dried and run through the Frantz Isodynamic Separator. A drift tilt of 25° with a cross tilt of 18° and .4 to .5 ampere current was the setting used for separating cummingtonite from quartz. Mangano-cummingtonite was separated from quartz and anthophyllite in other samples by using a higher ampere setting. Specularite was removed at a lower current setting (.25 amp.). After treatment in the Isodynamic Separator, the few impurities which remained could be detected under the binocular microscope and removed by hand picking.

Anthophyllite occurs as pure bands or clusters in these rocks. Samples were taken from bands free of mangano-cummingtonite and a stock sample free of impurities was picked under the binocular microscope. The coarse grain size and lack of intergrowth enabled clean separation of the silicate minerals. After hand-picking portions of the final product were mounted and examined under the petrographic microscope. Inclusions of iron oxide were present in less than one per cent of the silicate grains and the stock obtained for chemical analysis was better than 99 per cent pure.

Anthophyllite

Anthophyllite is found in the Wabush iron-formation in two places. At the Smallwood mine it occurs with specularite, quartz, and a small amount of talc. In Wabush deposits No. 6 and No. 7 it is associated with quartz, magnetite, specularite and a greenish amphibole identified as mangano-cummingtonite. No other silicate minerals occur with anthophyllite. Fibrous varieties of anthophyllite occur as lenticular bands parallel to the regional foliation. Long acicular or prismatic grains are also found, but are rare. Anthophyllite is usually grey, greenish or yellowish brown. In thin section it is colourless, pale green or pale brown.

Optical properties and chemical composition. The optical properties and partial chemical analyses of two samples of anthophyllite are given in Table 1. The optical data were determined from coarse prismatic grains under high magnification.

After an extensive study of the anthophyllite series Rabbitt (1948) concluded that identification of anthophyllite, especially the fibrous

TABLE 1. OPTICAL DATA AND CHEMICAL ANALYSES OF ANTHOPHYLLITE

	60-GF-55 (1) No. 6 Wabush deposit	62-GFC-74 (2) Smallwood mine	Rabbitt, 1948 (3) Table 2, No. 43
SiO ₂	55.79		59.29
Al ₂ O ₃	4.01		.59
Fe ₂ O ₃	2.21		.29
FeO	7.69	8.57	.06
CaO	.10		1.26
MgO	23.20	24.84	30.98
MnO	2.25	2.29	2.77
TiO ₂			.03
Na ₂ O			.37
K ₂ O			.19
H ₂ O			3.80
F			.20
Mn:Fe:Mg Total	1:3.9:8.0		99.83
α	1.610	1.614	
β	1.618	1.622	
γ	1.624	1.626	1.62
$\gamma-\alpha$	.014	.012	
$2V$	-86°	-74°	

(ANALYST: S. Courville.)

varieties, is not certain without *x*-ray analyses. The *d*-spacings and observed intensities of the first sample (1) closely match the data on A.S.T.M. Card 9-455. The diagnostic *x*-ray diffraction lines of anthophyllite are 3.24 and 3.05.

Rabbitt established that limited isomorphism in the anthophyllite series involves 3 components, chiefly magnesium, iron and aluminum. Iron or (Fe²⁺ + Mn²⁺) can substitute for magnesium from about 5 per cent to about 50 per cent, and aluminum replaces up to 2 atoms of silicon in the unit cell. Besides these three essential elements, anthophyllite of the Wabush iron-formation contains an appreciable amount of manganese. Manganese has also been reported in a chemical analysis of anthophyllite from Edwards, N.Y., which Rabbitt described as one of the purest varieties known. The analysis has been cited in Table 1 of this paper for comparison. Ghose (1962) described the distribution of Mg²⁺ and Fe²⁺ in some of the ferromagnesian silicates including cummingtonite and anthophyllite. Similar work on the distribution of Mn in the lattice position of these minerals is still lacking. Considering that Mn is not an essential constituent of anthophyllite the writer suggests two alternatives as to why it may be present: (i) the high manganese content is normal for an anthophyllite which is in equilibrium with manganocummingtonites; or (ii) the manganese-bearing anthophyllite is in a metastable state in these rocks.

Cummingtonite-Grunerite

Members of the cummingtonite-grunerite series are the most abundant silicates in the metamorphosed Wabush iron-formation. Although their stability field has not been definitely established (Flaschen & Osborne, 1957), these are minerals widely known in metamorphosed iron-formations all over the world. Cummingtonite occurs both in the lower and upper Wabush iron-formation as small to coarse prismatic grains or fibrous needles associated with quartz, carbonate, magnetite or other silicates. It is not directly associated with anthophyllite or mangano-cummingtonite. Some cummingtonites occur as coarse grains with poikilitic inclusions.

Optical properties and chemical composition. Cummingtonite is brown, pale brown or amber, and even colourless. All the varieties are non-pleochroic. Prismatic cleavage and multiple twinning are well developed. (001) parting is present in a few grains of coarsely crystalline cummingtonite in association with carbonate. The optical data and partial chemical analyses of 5 cummingtonite samples from different parts of Wabush iron-formation are given in Table 2.

TABLE 2. OPTICAL DATA AND CHEMICAL ANALYSES OF CUMMINGTONITES

	60-GF-54 (4) Boulder Lake	57-GF-84C (5) White Lake	57-GF-86 (6) Carol Lake	60-GF-65 (7) Wabush Lake	60-GF-W4 (8) Luce Lake
SiO ₂	51.60	46.54	51.45	47.64	51.46
Al ₂ O ₃	.62	7.64	.00	4.46	.61
Fe ₂ O ₃	1.37	3.75	2.18	3.22	.40
FeO	38.09	30.62	35.11	34.10	33.01
CaO	.00	.14	.00	.04	1.14
MgO	6.10	8.06	8.00	7.11	10.93
MnO	.66	.34	.83	.36	.58
F	.02				
Mn:Fe:Mg	1:59:7.2	1:97:19			1:57:15
α	1.676	1.670	1.673	1.662	1.655
β	1.699	1.689	1.692	1.680	1.670
γ	1.717	1.707	1.708	1.696	1.687
$\gamma-\alpha$	.041	.037	.035	.034	.032
$Z\Delta c$	14°	15°	15°	17°	20°
$2V$	-83°	-88°	-84°	-89°	+86°

N.B. Ti, V, Ba, Sr, Cr, Ni etc. content were checked by spectrochemical analyses and were found absent or negligible.

(ANALYST: S. Courville.)

From the analyses it is clear that the cummingtonites are predominantly ferromagnesian silicates and are similar to those described by Mueller (1960), Klein (1960) and Kranck (1961) from different parts of the Labrador geosyncline. None of these samples approach the iron end-member of the cummingtonite-grunerite series in optical properties or

chemical composition. Although the compositions of the cummingtonites are very similar, the refractive indices and birefringence are higher in the samples with higher iron content and lower in those with higher magnesium content.

The analyses reveal that two samples of cummingtonite have an appreciable amount of aluminum. Sundius (1933), Rabbitt (1948), and Layton & Phillips (1960) state that aluminum is present in quantity in some anthophyllites but is rare in cummingtonites. Some of the minerals from Strathy, Sutherland, described by Collins (1942) as cummingtonites are relatively high in aluminum, and are similar to the high aluminum cummingtonites from the Wabush iron-formation. Al^{3+} can replace Si^{4+} diadochically in the silicate structures. The lower SiO_2 content of the two samples (5 and 7) from the Wabush iron-formation is compatible with the simultaneous increase in aluminum. The MnO content in the cummingtonites is always very low. Fluorine content of one sample was found to be negligible (.02%).

All the samples of cummingtonite analyzed have been confirmed by *x*-ray diffraction. The intensities, *d*-values and indices of one sample (5) with high alumina are given in the appendix. Noteworthy are the positions of three strong lines at 2.756 Å, 1.660 Å and 1.403 Å on the *x*-ray powder photograph. These lines probably index as (330), (461) and ($\bar{6}$ 61) respectively, and are almost identical in other samples.

Mangano-cummingtonite

Examples of Mn-bearing cummingtonite in the literature are comparatively rare. A few manganiferous cummingtonites were described by Sundius (1924) from the iron-formations and eulysitic rocks of Sweden. Recently Jaffe *et al.* (1961) described one mangano-cummingtonite from manganese carbonate rocks of Nsuta, Ghana.

The mangano-cummingtonite is restricted in its occurrence to the quartz-specularite-magnetite member of the upper Wabush iron-formation. It occurs in the Wabush No. 6 and No. 7 deposits and also in a similar band south of Little Wabush Lake. In the northern part of the Wabush No. 6 and No. 7 deposits the mangano-cummingtonite bearing bands grade, along strike, into quartz-specularite-anthophyllite schists. The presence of this pale greyish to light green amphibole gives the schist a distinctly banded appearance. Klein (1960) also reported the presence of this mineral in the Wabush No. 7 deposit and studied its optical and chemical properties. The mangano-cummingtonite is distinctly fine-grained, acicular or prismatic. Sometimes the needles are seen in stellate groups. Because of great similarity between these amphiboles and members of the tremolite-actinolite series, it is extremely difficult to identify them in hand specimen.

Optical properties and chemical composition. In thin section manganocummingtonite is colourless or pale green. The lamellar twinning is not common, but (001) parting is seen in most of the grains. The optical properties and partial chemical analyses of two of these amphiboles is given in Table 3, along with a few others from the literature for comparison. The analyses show that the manganocummingtonites are in general richer in MgO and MnO content than the common ferromagnesian cummingtonites. The refractive indices and birefringence are remarkably low in the manganocummingtonites. The extinction angles in the first four samples are much higher than in the manganese-poor cummingtonites. Optic axial angles are high and the optic sign is always negative. Richarz (1927) and Sundius (1931) compared the optical properties of manganese-rich and manganese-poor cummingtonites and reported lower refractive indices in the former, but did not put forward any explanation for this phenomenon.

TABLE 3. CHEMICAL ANALYSES AND OPTICAL DATA OF MANGANO-CUMMINGTONITES

	A	B	C	D	E	F	G
SiO ₂	53.00		53.7	57.1	51.96	52.98	50.74
Al ₂ O ₃	5.81		0.75	—	0.44	0.26	0.88
TiO ₂	—		0.005	—	—	—	0.06
Fe ₂ O ₃	5.72		2.16	—	0.39	0.60	1.80
MgO	17.39	19.98	19.1	19.1	9.87	13.58	10.57
FeO	5.44	9.64	3.63	1.2	22.51	21.93	24.13
MnO	7.29	5.22	16.8	19.2	7.65	8.03	7.38
Na ₂ O	—		0.22	—	—	—	0.22
CaO	1.50		1.12	1.5	4.98	0.29	2.00
K ₂ O	—		0.01	—	—	—	0.08
H ₂ O	—		2.21	1.9	2.17	2.36	1.94
P ₂ O ₅	—		0.04	—	—	—	—
CO ₂	—		—	—	0.14	0.09	—
F	—		—	—	—	—	—
Mn:Fe:Mg	1:1.1:1.9		—	—	—	—	0.07
			99.74	100.	100.11	100.12	99.87
	A	B	C	D	E	F	G
α	1.632	1.628	1.630	1.628	1.650	1.650	1.655
β	1.643	1.641	1.644	1.642	1.670	1.665	1.671
γ	1.655	1.651	1.654	1.650	1.685	1.679	1.685
$\gamma-\alpha$	.023	.023	0.024	.022	.035	0.029	0.030
Z Δ c	21°	21°	21°	22°	15°	16°	15.4°
2V	-87°	-83°	-82°	-74°	-81°	-87°	-85.3°

A—Sp. 57-GF-W.I.C.I. South of Little Wabush. Wabush iron-formation. (ANALYST: S. Courville.)

B—Sp. 62-GFC-26A. Wabush deposit No. 6. Wabush iron-formation. (ANALYST: S. Courville.)

C—Klein (1960, p. 53) Wabush deposit No. 7. Wabush iron-formation.

D—Jaffe *et al.* (1961, p. 650). Nsuta, Ghana.

E—Sundius (1924, p. 157). Brunsjogruvan, Sweden.

F—Sundius (1924, p. 157). O. Silvergruvan, Sweden.

G—Sundius (1931, p. 334). Uttersvik, Sweden.

For one sample of manganocummingtonite (A) the measured and calculated d -spacings, observed intensities and indices are given in the appendix. Monoclinic cell dimensions were determined by J. L. Jambor from powder data and single crystal analyses using a Weissenberg camera. The results agree well with the x -ray data for manganiferous cummingtonites described by Klein (1960) and Jaffe *et al.* (1961). It is seen from Table 3 and also by comparing the x -ray data that the refractive indices and cell dimensions of the manganiferous cummingtonites do not change appreciably with an increase or decrease of Mn. Sample A of manganocummingtonite from Wabush iron-formation with Mn:Fe:Mg = 1:1.1:1.9 approaches the composition of mangantremolite $Mn_2(Fe, Mg)_5Si_8O_{22}(OH)_2$. Optical properties of mangantremolite, as reported by Winchell (1951, p. 435) are also very similar to those of manganocummingtonite from the Wabush iron-formation, but manganocummingtonite has distinctive cell dimensions and x -ray patterns.

ANTHOPHYLLITE—CUMMINGTONITE—MANGANO-CUMMINGTONITE RELATION

Most amphiboles of the anthophyllite and cummingtonite-grunerite series can be considered as phases in the system $MgO-FeO-SiO_2-H_2O$. Because of their similarity in composition the earlier workers believed these two series to be isodimorphous. Eskola (1936) cited the occurrence of anthophyllite and cummingtonite in the same rocks of the Orijarvi region and considered them to be polymorphic. But, Eskola's cummingtonite contains 3.96 per cent alkalis, whereas the equivalent anthophyllite contains a negligible quantity. Johannson (1930) showed the difference between the orthorhombic anthophyllite and the monoclinic cummingtonite lattice. Sundius (1933) denied that the two minerals are isodimorphous and showed that anthophyllites contain 6–9 per cent more alumina and ferric oxide than the similar cummingtonites. Rabbitt (1948), and Layton & Phillips (1960) discussed this problem and concluded that anthophyllite is essentially a three component system involving magnesium, iron and aluminum, whereas cummingtonites are ferromagnesian silicates in which manganese and calcium are usually present in significant quantities. Boyd (1959) investigated the system $Mg_7Si_8O_{22}(OH)_2-Fe_7Si_8O_{22}(OH)_2$ and tried to synthesize both orthorhombic and monoclinic amphiboles. No amphiboles richer in iron than about $Mg_{40}Fe_{60}$ could be synthesized. Although both anthophyllite and cummingtonite can be represented by the general formula $(Mg,Fe)_7Si_8O_{22}(OH)_2$, the commonly occurring anthophyllites are magnesia-rich, while most cum-

mingtonites are iron-rich. Natural anthophyllites are restricted to the range from pure Mg end-member to a composition of about $Mg_{40}Fe_{60}$. Natural cummingtonites extend from the pure Fe end-member to about $Fe_{25}Mg_{75}$. It seems therefore that a gap in the isomorphous series exists at the Fe end of the anthophyllite series and at the Mg end of the cummingtonite series. The writer investigated a number of samples from the Wabush iron-formation, but could not find any cummingtonite richer in magnesium than $Fe_{55}Mg_{45}$. Evidently anthophyllites and cummingtonites are different series with limited isomorphism.

Manganiferous cummingtonites were reported by Sundius (1924) from the Swedish iron-formation and eulysitic rocks. The same mineral group has since been restudied by Sundius (1931) and by Richarz (1927). These manganiferous cummingtonites are all rich in iron. Very recently Jaffe *et al.* (1961) reported one mangano-cummingtonite from manganese carbonate rocks of Nsuta, Ghana, which contains 19.2 per cent MnO. These workers, especially Sundius, regarded these minerals as members of the cummingtonite-grunerite series in which manganese substitutes for ferrous iron. Mangano-cummingtonite reported by the writer and Klein (Table 3) from the Wabush iron-formation is interesting in that it occurs with anthophyllite in the same samples. Intergrowths of the two minerals may be seen in thin sections and they can be distinguished by their extinction angles, slight differences in refractive indices, birefringence, and colour. Chemical analyses of the mangano-cummingtonites in Table 3 show that they are very rich in magnesium, which is rather unusual for natural cummingtonites. The lower refractive indices in these minerals is also remarkable. Both Richarz and Sundius tried to correlate the optical properties of the high and low manganese cummingtonites and found sharp discontinuity in the lines representing refractive indices of the two varieties. The x -ray data of mangano-cummingtonite fit best with those of cummingtonite, but are not an exact match and include possible extra lines. Cell dimensions are also a little smaller.

Anthophyllite from Wabush iron-formation (Table 1) contains some Mn. The analyses of mangano-cummingtonites (A and B in Table 3) are very similar to these anthophyllites where Mn^{2+} substitutes for Mg^{2+} . In chemical composition the mangano-cummingtonites are closer to the anthophyllites than to the cummingtonites in this area. In order to verify this statement, and also to furnish a more complete picture of the MnO:FeO:MgO ratios in some of these amphiboles, the diagram of Fig. 1 was prepared. The following analyses were used: anthophyllites from Table 1 and Rabbitt's Table 2 (Nos. 29 and 45); cummingtonites from Table 2, Klein (1960, p. 42), Mueller (1960, Table 2, No. DH-3), and from Kranck (1961, p. 179); and mangano-cummingtonites from Table 3.

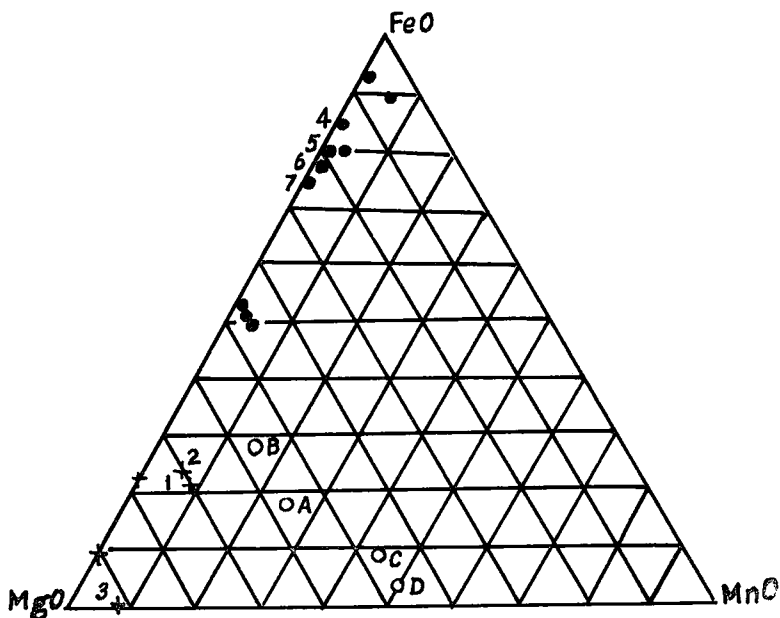


FIG. 1. Diagram showing relative weight percent of MgO, FeO and MnO in cummingtonite-grunerite (solid circles), anthophyllite (+) and mangano-cummingtonite (open circles). Numbers and letters refer to Tables 1, 2, and 3.

The grouping of the points is significant. Cummingtonites show up as Fe-Mg amphibole with little MnO, the anthophyllites fall to the Mg corner, and the mangano-cummingtonites approach the ideal Mg-Mn amphibole. Anthophyllites and mangano-cummingtonites from the Wabush iron-formation are grouped close together and lie almost on a straight line in the diagram. As the weight per cent of Mn increases anthophyllite tends towards mangano-cummingtonite composition. To be more precise about this relationship the writer plotted the weight per cent of MnO against the weight per cent of FeO in anthophyllites, cummingtonite-grunerites and mangano-cummingtonites in Fig. 2. Data were taken from Sundius (1924, 31), Bowen *et al.* (1935), Collins (1942), Miles (1943), Rabbitt (1948), Mueller (1960), Klein (1960), Kranck (1961), and also from Tables 1, 2 and 3 of this paper, showing maximum variation in composition. Samples containing more than 3 per cent MnO were plotted as mangano-cummingtonites. Following the procedure of Dixon & Massey (1957, pp. 201-204) the coefficient of correlation (r) for all these points is -0.27 . Taking only anthophyllites and mangano-cummingtonites, in Fig. 3, the coefficient of correlation is $r = 0.50$. Except for two, all samples lie very near the mean line of correlation. The same amount of correlation between these two groups was obtained

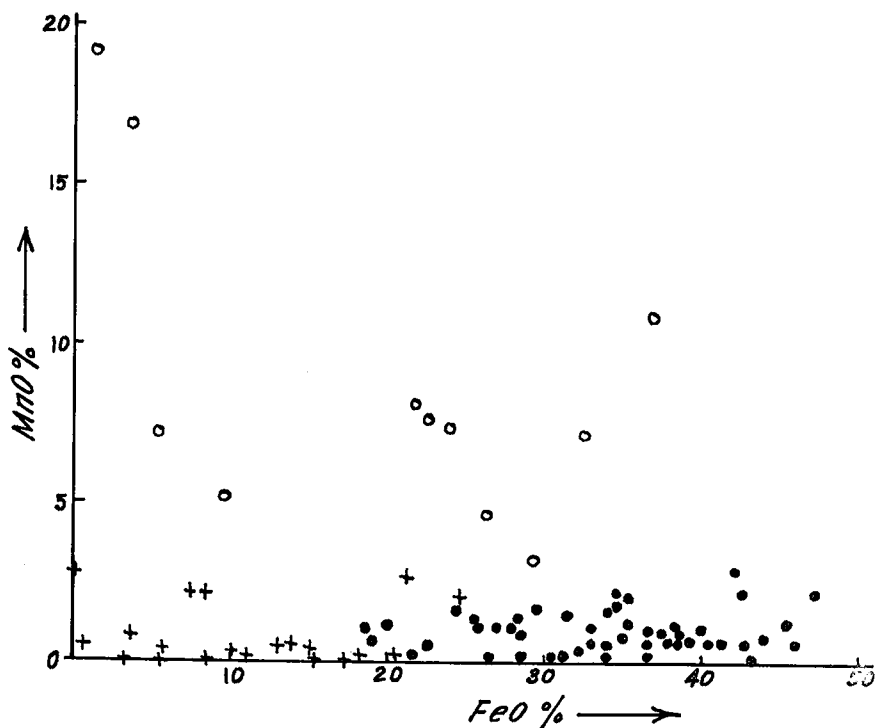


FIG. 2. Diagram showing the weight percent of MnO and FeO in anthophyllite (+), cummingtonite-grunerite (solid circles) and mangano-cummingtonite (open circles) from Wabush Lake samples and analyses reported in literature. Coefficient of correlation, $r = -0.27$.

with a negative inclination of the line when the weight per cent of MnO was plotted against the weight per cent of MgO. The value of r is much reduced when the ferromagnesian cummingtonites are considered together. Therefore the mangano-cummingtonites, at least the high magnesian ones, have a higher degree of correlation in chemical composition with the anthophyllites. As stated before anthophyllite and mangano-cummingtonite occur together in the Wabush iron-formation, without any evidence of replacement. The author, therefore, suggests that mangano-cummingtonite is a manganiferous analog of anthophyllite. As pointed out by Layton & Phillips (1960) both Mn and Ca, because of their larger atomic radii (0.83 Å and 1.03 Å) compared to Fe^{2+} (0.74 Å) and Mg^{2+} (0.66 Å), prefer monoclinic symmetry in amphibole. Therefore gradual increase of Mn^{2+} in place of Mg^{2+} will help the formation of monoclinic mangano-cummingtonite in preference to orthorhombic anthophyllite. The peculiar refractive indices and high magnesia content of mangano-cummingtonite can also be better explained in this way.

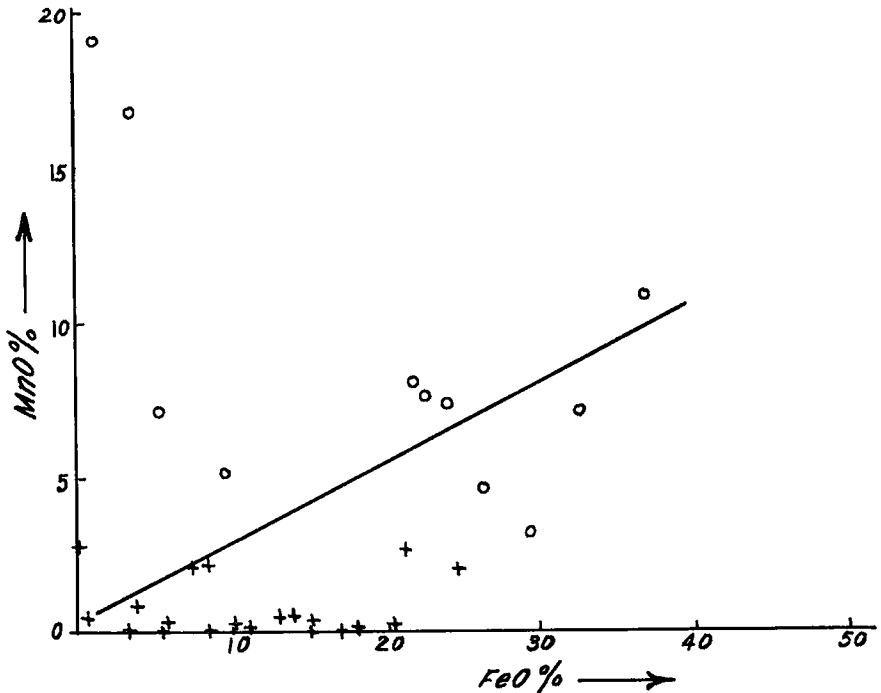


FIG. 3. Diagram showing the coefficient of correlation ($r = 0.50$) for anthophyllite (+) and manganocummingtonite (O).

Instead of becoming lower the refractive indices in fact rise with the increase of Mn in the anthophyllite composition.

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APPENDIX

The d -spacings and intensities for the amphiboles, measured from x -ray powder patterns using Fe radiation, Mn filter and camera diameter = 57.3 mm.

CUMMINGTONITE

(Sp. 57-GF-84C. West of White Lake)

Monoclinic, $C2/m$; $a = 9.57 \text{ \AA}$, $b = 18.22$, $c = 5.33$, $\beta = 102^\circ 08'$

$I(\text{est.})$	$d(\text{meas.})$	hkl	$I(\text{est.})$	$d(\text{meas.})$	hkl
20	9.15	020	5	1.906	$\bar{3}52$
100	8.33	110	5	1.881	$\bar{1}91$
5	5.17	001	5	1.852	460
5	4.84	111	5	1.826	441
10	4.62	200	10	1.790	$\bar{5}31$
10	4.55	040	5	1.716	082
40	4.13	220	5	1.705	390
30	3.86	131	5	1.685	512
30	3.46	131	40	1.660	461
40	3.26	240	20	1.634	
70	3.06	310	20	1.596	
10	2.99	221	10	1.581	
70	2.756	330, 151	10	1.553	
40	2.628	061	30	1.521	
40	2.503	$\bar{2}02$	5	1.509	
5	2.395	$\bar{2}61$	5	1.496	
5	2.369	350	5	1.475	
5	2.309	$\bar{1}71$	10	1.466	
20	2.292	$\bar{3}51, 331$	5	1.434	
5	2.240	421	40	1.403	
30	2.215	$\bar{3}12$	20	1.381	
50	2.189	261	10	1.366	
20	2.096	202, $\bar{3}32$	5	1.353	
5	2.071	440, $\bar{4}41$	5	1.333	
20	2.029	351	10	1.328	
5	1.996	370	5	1.315	
5	1.980	$\bar{1}90$	30	1.300	
20	1.949	402			

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MANGANO-CUMMINGTONITE

(Sp. 57-GF-W.I.C.I. South of Little Wabush Lake)

Monoclinic, $C2/m$; $a = 9.53 \text{ \AA}$, $b = 18.05 \text{ \AA}$, $c = 5.31 \text{ \AA}$, $\beta = 102^\circ 50'$

$I(\text{est.})$	$d(\text{meas.})$	$d(\text{calc.})$	hkl	$I(\text{est.})$	$d(\text{meas.})$	$d(\text{calc.})$	hkl
80	9.02	9.03	020	60	1.648	1.644	461
100	8.32	8.26	110	40	1.616	1.618	481
40	4.83	4.84	111	50	1.587	1.588	153
60	4.51	4.51	040	20	1.569	1.565	402
60	4.13	4.13	220	20	1.554	1.560	1.11.1
60	3.85	3.86	131	5	1.541	1.543	610
60	3.42	3.42	131	5	1.531	1.529	192
60	3.24	3.24	240	40	1.511	1.512	203
100	3.07	3.05	310	40	1.503	1.504	0.12.0
60	2.96	2.961	221	40	1.483	1.488	153
100	2.72	2.72	151	40	1.453	1.459	173
20	2.65	2.66	331	20	1.426	1.431	2.12.0
50	2.60	2.60	061	60	1.404	1.408	642
60	2.51	2.51	202	50	1.372	1.377	660
20	2.36	2.35	350	30b	1.347	1.351	263
50	2.286	2.291	351	20b	1.330	1.332	553
40	2.249	2.256	080	30	1.300	1.306	603
40	2.231	2.230	312	50	1.290	1.295	5.10.0
40	2.183	2.190	171	30	1.276	1.281	024
60	2.170	2.169	261	5	1.262	1.267	3.13.0
40	2.076	2.074	202	20	1.255	1.258	403
40	2.019	2.021	222	20	1.219	1.224	0.13.2
20	1.980	1.982	370	5	1.198	1.203	771
40	1.958	1.963	401	5	1.191		
5	1.911	1.918	421	50	1.182		
40	1.860	1.863	191	5	1.115		
20	1.815	1.820		40	1.111		
40	1.797	1.801	531	40	1.087		
5	1.782	1.776	530	5	1.080		
5	1.749	1.750	203	5	1.075		
50	1.694	1.701	082	40	1.057		
20	1.673	1.682	2.10.0	50	1.036		

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