PYROXMANGITE FROM INVERNESS-SHIRE, SCOTLAND

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The anorthic iron-manganese silicate, pyroxmangite has now been recognised from four localities: Iva (South Carolina); Tunaberg and Vester Silvberg, Sweden; Idaho.

At the Swedish localities the mineral was originally described under the name of sobralite (Palmgren 1917), but the comparative studies of Henderson and Glass (1936) have shown that sobralite has so close agreement in optical characters with the previously described pyroxmangite that the identity of these two minerals can be regarded as established.

The discovery of a further occurrence of pyroxmangite among the Lewisian rocks of Scotland has provided additional data on this interesting mineral.

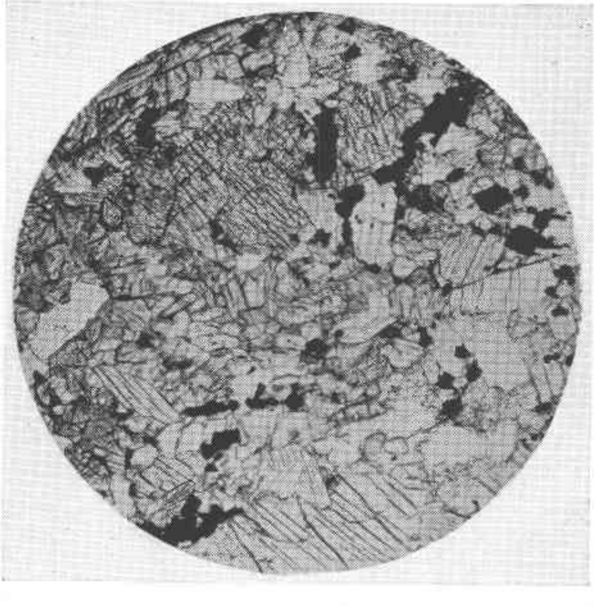

FIG. 1. Pyroxmangite-grunerite-garnet schist, Glen Beag, Glenelg, Inverness-shire. The constituents visible are pyroxmangite (most abundant), grunerite and magnetite. Spessartine-alamandine is present in adjacent portions of the slice. 26 diams.

The Lewisian inlier of Glenelg, Inverness-shire contains among its para-gneisses a group of manganiferous eulysites and related grunerite schists (Tilley 1936), and from one outcrop of these latter rocks both pyroxmangite and rhodonite are now recorded.

The pyroxmangite forms an important constituent of a manganiferous schist interbedded with a series of para-gneisses comprising biotite epidote gneisses, amphibole schists and lenses of limestone in the gorge of Glen Beag, Glenelg (1″ sheet 71, Geological Survey Scotland). The rock type with which the pyroxmangite is more intimately associated is a grunerite garnet schist carrying in places veins of rhodonite up to 1″ in width. The constituent minerals of the principal band of rock are grunerite, manganiferous garnet, magnetite, pyroxmangite together with accessory hedenbergite, iron hypersthene and pyrrhotite (Fig. 1).

Pyroxmangite in this rock occurs in pink grains of $\frac{1}{2}$–$\frac{3}{4}$ mm. average grain size. Exceptionally grains up to 5 mm. diameter may appear as porphyroblasts. In thin section the mineral is colourless and subidioblastic, usually tabular on (001) with a tendency to develop the forms of the two more prominent cleavages $m(110)$, $M(1\bar{1}0)$. A parting parallel to (010) is locally developed but a cleavage on (001) has been recognized only in crushed fragments under the microscope. A lamellar twinning on (010) is infrequently observed. As the extinction of the mineral is commonly somewhat undulose this twin development is probably of secondary origin. The birefringence of the mineral is distinctly greater than that of the rhodonites of the associated rocks. It is further distinguished by its much smaller optic axial angle. On material analysed $2V\gamma=41°$ while the rhodonites examined gave an average value $2V\gamma=74°$. Fragments resting on the principal cleavage (110) show an extinction $c\wedge\gamma'=32°$. In immersion liquids the refractive indices are determined as $\alpha 1.732$, $\beta 1.735$, $\gamma 1.750$. The mineral has a specific gravity of 3.63 and is unattacked by hydrochloric acid.

Pure material for analysis was selected from the crushed rocks by hand picking under a low power lens. This material gave the following result.

TABLE 1. ANALYSIS OF PYROXMANGITE FROM GLENELG
(Miss H. Bennett, analyst)

	Analysis	Metal atoms on basis of 6 oxygen atoms		
SiO_2	47.44	1.975	2.00	
Al_2O_3	0.66	0.030		$\alpha 1.732$
Fe_2O_3	1.45	0.045		$\beta 1.735$
FeO	15.02	0.522		$\gamma 1.750$
MnO	28.25	0.995	1.98	$2V_\gamma 41°$
MgO	4.56	0.285		Sp. Gr. 3·63
CaO	3.00	0.135		
	100.38			

Table 2. Analyses of Pyroxmangites and Iron Rhodonite

	1	2	3	4	5
SiO_2	46.53	47.14	45.47	47.44	47.78
Al_2O_3	0.21	2.38	nil	0.66	0.08
Fe_2O_3	0.85	—	1.55	1.45	0.11
FeO	24.69	28.34	20.91	15.02	14.51
MnO	20.50	20.63	27.06	28.25	29.20
MgO	1.39	—	2.14	4.56	1.93
CaO	5.46	1.88	2.62	3.00	6.55
TiO_2	0.08	—	—	nil	—
	(BaO)				
H_2O	0.39	0.33	0.32	—	0.09
	100.10	100.70	100.02	100.38	10.25

1. Sobralite, V. Silvberg, Sweden. (Sundius 1931.)
2. Pyroxmangite, Iva, South Carolina. (Ford and Bradley 1913.)
3. Pyroxmangite, Idaho. (Henderson and Glass 1936.)
4. Pyroxmangite, Glenelg, Scotland.
5. Rhodonite, Tuna Hästberg, Sweden. (Sundius 1931.)

The selected material contained no obvious mixed magnetite and in the interpretation of the analysis (Table 1) Fe_2O_3 has been treated as an integral constituent. The figures show good agreement with a metasilicate ratio.

When this analysis is compared with those of described pyroxmangites it is seen that the Glenelg mineral shows closest approximation in composition to the pyroxmangite of Idaho (Table 2, analysis 3). Its composition is, however, even closer to that of the iron rhodonite of Tuna Hästberg described by Sundius (Table 2, analysis 5); nevertheless the optical characters are more closely in agreement with those of pyroxmangites with varying iron and manganese contents (Table 3).

The contrasted optical properties of the Tuna Hästberg rhodonite and the Glenelg pyroxmangite afford support to the suggestion of Henderson and Glass (1936) that the two minerals are distinct species and are not members of a single continuously variable species. This suggestion had already been made by Sundius when he compared the optical characters of the Swedish sobralites with those of rhodonite.

Sundius (1931) has discussed the relations existing between the various manganese bearing compounds in the ternary system $MnSiO_3$–$FeSiO_3$–$CaSiO_3$. He concluded that the variation of optical characters in the group of bustamites were such that they could be regarded as manganese bearing wollastonites despite the fact that the most lime-rich bustamite contained only 52 wt. % of $CaSiO_3$.[1]

TABLE 3

	% FeO	Δ	$2V$	α	β	γ
Pyroxmangite (Glenelg)	15.02	0.018	41°	1.732	1.735	1.750
Rhodonite (Tuna Hästberg)	14.51	0.012	70°	1.725	1.728	1.737
Pyroxmangite (Idaho)	20.91	0.017	39°	1.737	1.740	1.754
Sobralite (V. Silvberg)	24.69	0.017	42°	1.738	1.740	1.755

Since the studies of Sundius our knowledge of the ternary system has been increased. Wollastonite since shown to be anorthic is now known to form an extended series of solid solutions in the system $CaSiO_3$–$FeSiO_3$ (Bowen and Schairer 1933). Bowen (1933) has further shown that crystals of the anorthic slag silicate vogtite (Hallimond 1919) can be reoriented and referred to a similar axial system as the anorthic wollastonite and has pointed out the isomorphous character of the two substances. The existence of a wide series of solid solutions including iron bearing wollastonites, bustamites and vogtite is thus to be envisaged. Among natural minerals the gap between wollastonite and the bustamites (analysis 25 of Fig. 2) is bridged only by the analysis of a mangan-wollastonite described by Goldschmidt (1911) from the Oslo field. The only optic data presented for this mineral is the value $2E=43°$ (cf. wollastonite $2E=69°$ $2V=40°$). Using a probable approximate value $\beta=1.640$, $2V$ for this mineral is 26°, significantly lower than the values for wollastonite or the most lime rich bustamite (analysis 25). These facts warrant a closer study of wollastonites of skarn deposits where manganiferous wollastonites with still lower optic axial angles may occur.

The compositions of the anorthic minerals of the system $MnSiO_3$–$FeSiO_3$–$CaSiO_3$ are indicated in the ternary plot of Fig. 2, the key to which is indicated in the description subjoined to Fig. 2. The content in MgO of the natural minerals, usually small in amount is calculated as $MgSiO_3$ and added to $CaSiO_3$. If optical data were not under consideration it would have been more appropriate to consider $MgSiO_3$ with $FeSiO_3$.

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[1] The lattice dimensions of bustamite have since been shown to have values close to those of wollastonite (Berman and Gonyer 1936).

Sundius inferred that bustamite and rhodonite were distinct minerals. This opinion was based on a discontinuity revealed in the optical properties of analysed iron poor rhodonites and bustamites and furthermore by the occurrence together in intimate association of these two minerals in rocks as at Långban.

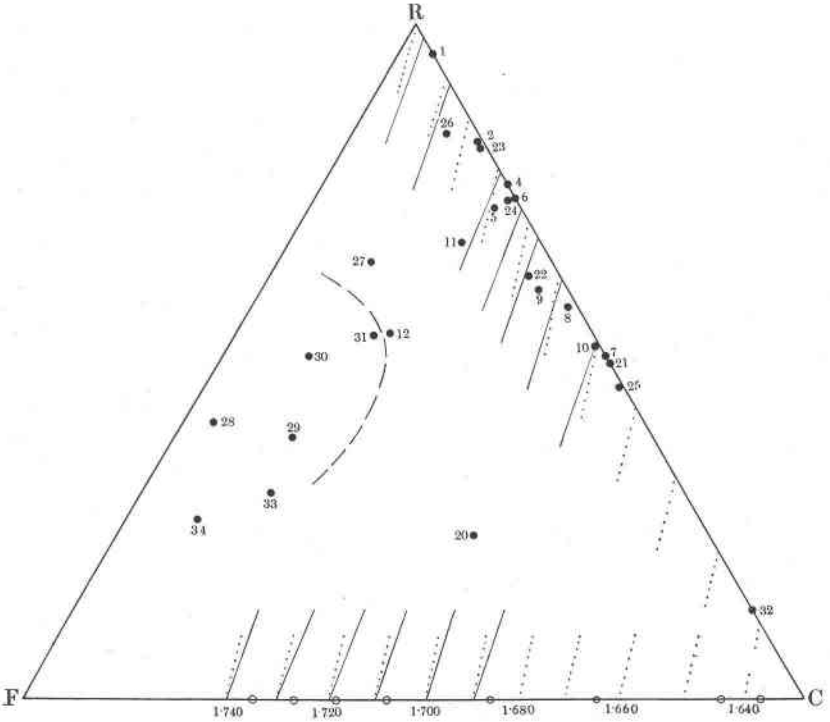

FIG. 2. Compositions of rhodonites, bustamites and pyroxmangites in the system $MnSiO_3$ (R), $FeSiO_3$ (F), $(CaMg)SiO_3$ (C) (wt. %).

The numbers refer to analyses of minerals as follows: 1–12 (Sundius 1931), Table I, p. 517); 20 (Hallimond 1919); 21–23 (Hey 1929); 24–25 (Larsen and Shannon 1922); 26–30 (Henderson and Glass 1936); 31 Glenelg pyroxmangite; 32 (Goldschmidt 1911); 33, 34 (Whiteley and Hallimond 1919). Open circles—wollastonite solid solutions (Bowen-Schairer 1933).

Further data on the system $CaSiO_3$–$MnSiO_3$ are provided by the experimental studies of Voos (1935). He has presented his results in the form of a binary diagram showing complete miscibility between wollastonite (β $CaSiO_3$) and the compound $MnSiO_3$. The optical data of this continuous solid solution series is given in graphical form and shows divergence from the values for the natural rhodonites and bustamites studied by Sundius.

From a study of x-ray powder photographs of his synthetic preparations Voos confirms the deduction from his thermal data but also states that the rhodonite (analysis 1) and bustamite (analysis 7) of Sundius show complete identity with the synthetic products of corresponding composition. Nevertheless the optic data are not in accord. The synthetic products show a value of the γ index on an average 0.01 lower than the natural products. This discrepancy holds for minerals which contain insignificant contents of MgO and FeO.

This is made evident in Fig. 2 where the interpolated γ values of the iron wollastonite solid solution series is projected (a) towards the interpolated γ values of rhodonites and bustamites (full lines), (b) towards the interpolated γ values of the synthetic $CaSiO_3$–$MnSiO_3$ solid solutions (dotted lines).

The manner in which the optic data on the synthetic $CaSiO_3$–$MnSiO_3$ solid solutions has been obtained lead us to except no great accuracy in the results. The synthetic products are reported as developing in fibrous aggregates and apparently only approximate maximum and minimum refractions (γ', α') were obtained. Until data in this system on homogeneous single crystals are provided the values of Voos should be treated with reserve. At the same time it must be remembered that Sundius by expressing his data on a binary diagram is treating (Fe, Mn) and (Ca, Mg) each as single variables. His curves are drawn on minerals showing up to 3.8 molecular per cent $FeSiO_3$ (analysis 5) and 14.20 per cent $MgSiO_3$ (analysis 6) and it is still questionable whether notable discontinuities would be revealed in a true binary system (Ca, Mn). The existence side by side in rocks of bustamite and rhodonite may simply be an expression of limited miscibility at low temperatures.

In the interior of the plot the paucity of data prohibits any conclusion as to the detailed course of the γ isofracts within the ternary system. The optical data on vogtite show β 1.701 but this compound contains more than 13 wt. per cent of $MgSiO_3$.

In the diagram the field of the analyses of pyroxmangites has been separated on the basis of the distinctive properties of this group of minerals compared to the rhodonites.

Two other analyses—those of "iron rhodonites" from slags described by Whiteley and Hallimond (1919) may be referred to here. They have the following compositions (analyses 33, 34, Fig. 2):

	$MnSiO_3$	$FeSiO_3$	$MgSiO_3$	$CaSiO_3$
33	30.5	53	5	11.5
34	26.8	64.2	n.d.	n.d.

The compositions of both these "iron rhodonites" lie on the $FeSiO_3$ side of the field of the analysed pyroxmangites. No optic data of these compounds has hitherto been published and I am indebted to Dr A. F. Hallimond for a specimen of No. 34 on which the following data have been determined. The crystals show the characteristic rhodonite cleavages parallel to *m*(110) and *M*(1$\bar{1}$0) and fragments mounted in immersion liquids show a characteristic extinction angle of 30°–32° ($c \wedge \gamma'$) when lying on the best cleavage (110). The optic data presented below show a remarkable agreement with those of pyroxmangites and are compared here with the most iron rich pyroxmangite of Iva, South Carolina.

Pyroxmangite Iva, South Carolina		"Iron Rhodonite" (34), acid slag	
$FeSiO_3$	55	$FeSiO_3$	64.2
$MnSiO_3$	41	$MnSiO_3$	26.8
$CaSiO_3$	4	$(CaMg)SiO_3$	n.d.
$\alpha 1.748$		$\alpha 1.750$	
$\beta 1.750$		$\beta 1.754$	
$\gamma 1.746$		$\gamma 1.767$	
$2V\gamma 37°$		$2V\gamma 27°$	

In Fig. 3 are plotted the approximate compositions of the three slags (indicated by arrow heads) described by Whiteley and Hallimond as well as the compositions of the three metasilicates (20, 33, 34) (indicated by circles) contained in the respective slags. The duplication indicated refers to alternative methods of grouping MgO with FeO (full lines) or with CaO (dotted lines). In the case of slag 33 the crystallisation of

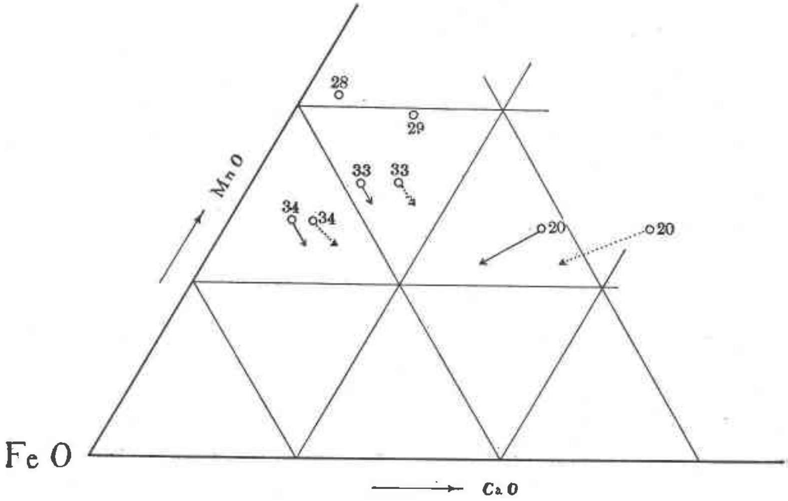

FIG. 3

metasilicate was preceded by that of cristobalite but metasilicate formed the primary phase in slags 20 and 34.

The pyroxmangites and the slag compound (34) show greater distinctions in optical properties from vogtite than this compound does from the iron-bearing wollastonite, e.g.

	$FeSiO_3$	$2V$	sign	γ
Slag crystals (34)	64.2	37°	positive	1.767
Vogtite (20)		65.5°	negative	1.701(β)
Iron wollastonite	70.0	85°	negative	1.734

but there is a considerable gap to be bridged between the compositions of these three solid solutions. On the other hand the pyroxmangites show a considerable range of composition with but moderate variation in optical characters. Hallimond and Whiteley indeed were of opinion that their "iron rhodonites" and vogtite were distinct, vogtite crystallising from the slags with more than 8 per cent CaO and giving these slags an acicular fracture. Further support for this opinion is given by Dr. Hallimond who has informed me that slags were obtained in which vogtite and "iron rhodonite" occurred together as distinct phases. The optic data now presented are in harmony with this view and point furthermore to the probable identity of this slag mineral with pyroxmangite which is itself distinct from rhodonite. A comparative *x*-ray study of these solid solutions is now in progress at Cambridge.

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