

is fragile. The specific gravity of synthetic material has been measured as 2.05; calculation from the unit cell contents gives 2.09 and from Gladstone-Dale's Law, 2.00. The synthetic material forms stout rods elongated along *c* and with prominent {110}. The mineral is soluble in water. It is optically biaxial negative, $2V$ 61° (calc.), refractive indices α 1.522(2), β 1.544(2), γ 1.552(2); extinction oblique, angle $+26(1)^\circ$. Synthetic material is also biaxial negative, $2V$ 65° (obs.), 66° (calc.), α 1.521, β 1.542, γ 1.551; $b = X$, $c \wedge Y = +25^\circ$. It is colourless under the microscope.

$(\text{NH}_4)_2\text{Ca}(\text{HPO}_4)_2 \cdot \text{H}_2\text{O}$ is dimorphic and mundrabillaite is referred to as form-A. Form-B is also monoclinic but this phase is not present in the mundrabillaite specimens examined. This was con-

firmed by the X-ray powder pattern and optical examination following reference to PDF Card 20-0204.

Type specimens of mundrabillaite are preserved in the Government Chemical Laboratories mineral collection as MDC 5906.

REFERENCES

- Bridge, P. J. (1977). *Mineral. Mag.* **41**, 33-5.
Frazier, A. W., Lehr, J. R., and Smith, J. P. (1964). *J. Agric. Food Chem.* **12**, 198.

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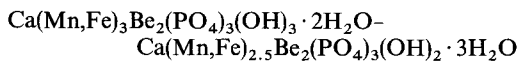
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Iron-rich roscherite from Gunnislake, Cornwall

ROSCHERITE, a monoclinic hydrous phosphate of Ca, Mn, Fe, and Be, has so far been recorded from about half a dozen occurrences, usually in phosphate pegmatites. Originally described by Slavik (1914), it was not until the work of Lindberg (1958) that the presence of essential Be in the mineral was recognized. Subsequent crystal structure work by Fanfani *et al.* (1977) has shown that a triclinic modification of roscherite exists, occurring when the mineral has a significant trivalent metal content. Their work suggests that the normal monoclinic roscherite, containing only divalent metals, should have a formula in the series



The major isomorphous substitution is therefore that of Mn by Fe, although replacement of Mn by Mg is noted in one specimen (Fanfani *et al.*, 1975). Al occurs in minor amounts as the principal trivalent substitution.

Lindberg (1958) has recorded a roscherite from the Nevel Quarry, Newry, Maine, with an Fe:Mn ratio approaching 2:1, and this has remained the highest iron figure obtained for the mineral. However, the recent discovery of roscherite in cavities

in the granite at Gunnislake, Cornwall, reported in this paper, provides examples of virtually end-member iron-bearing material. Lindberg (1958) suggested that the name roscherite should apply to all members of the structural group irrespective of the degree of Ca-Mn-Fe substitution (it is now known that Ca does not contribute to isomorphous substitution in the mineral). Despite the extreme Fe content recorded for this roscherite, it does not, on the basis of Lindberg's definition, warrant a new name.

Occurrence. This Fe-rich roscherite has been found at the Clitters United Mine (also known as Gunnislake Clitters), in Calstock Parish in Cornwall, on a steep hillside overlooking the river Tamar. The mine operated mainly during the last century on E.-W. trending lodes, close to the killas contact, carrying copper, tin, arsenic, and tungsten. It was amalgamated with the Hingston Down Mine towards the end of the nineteenth century, and finally ceased operations in 1919.

The main lode at Clitters United Mine was worked from Skinners Engine Shaft, the collar of which was just below the road from Gunnislake to Chilsworthy at GR 422719 ($2\frac{1}{2}''$ OS map SX 47). There are large dumps on the hillside below the

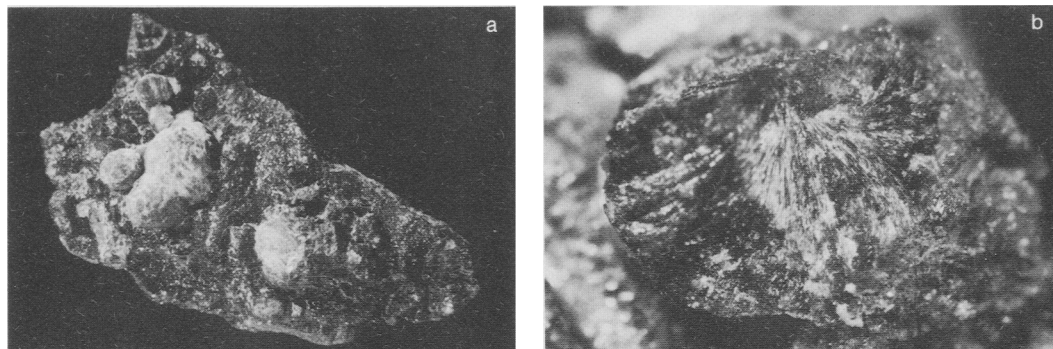


FIG. 1. (a) Botryoidal aggregates of roscherite on a matrix of apatite crystals coated with iron oxide. Specimen size 21×12 mm. (b) Enlarged view of a broken roscherite spherule showing its radiating fibrous structure. Field of view approx. 3.5×2.5 mm.

shaft and it was here that the roscherite was discovered in 1978. The dumps were being cleared sporadically (and have now vanished) and repeated visits resulted in the discovery of several specimens.

The specimens known to have been found consist of two types. The most common consists of dark sage-green spherules of roscherite, with a silky crystalline exterior and showing an internal radiating structure. The spherules range up to 5 mm in diameter and occur liberally scattered on top of minute colourless carbonate-fluorapatite crystals lining cavities in quartz, with a little siderite and

earthy red hematite (fig. 1). The second type consists of partly iron-stained quartz with flat radiating aggregates of roscherite to 1 cm in size on joints, rather resembling wavellite in appearance. Both the two specimens from which the data in this paper have been obtained are of the former type.

Chemical composition. Analyses of two separate samples of the Gunnislake roscherite have been made and are given in Table I, with the analytical details as footnotes. The two theoretical formulae are the hypothetical end-members of the Fe-rich roscherite series, as formulated by Fanfani *et al.*

TABLE I. Analyses of iron-rich roscherite from Gunnislake, Cornwall

	Wt. %				Recalculated to $3(\text{PO}_4)$		
	1	2	3	4	1	2	
CaO	9.45	10.76	9.38	9.83	Ca	0.96	1.20
Al_2O_3	0.68	—	—	—	Al	0.08	—
FeO	27.04	30.40	36.07	31.47	Fe	2.14	} 2.29
MnO	0.91	0.50	—	—	Mn	0.07	
BeO	8.49	10.05*	8.37	8.77	Be	1.93	0.04
P_2O_5	37.45	34.12	35.63	37.31	P	3.00	2.51
H_2O	11.95	11.80	10.55	12.62	OH	7.54	3.00
insol.	—	0.70	—	—			8.16
Total	95.97	98.33	100.00	100.00			2.68

* This figure may include some Al_2O_3 .

1. Dark grey-green globule from specimen BM 1980,346 analysed at the British Museum (Natural History) using electron probe microanalysis for Fe and Mn (pure element standards), Ca (analysed wollastonite standard), P (analysed apatite standard); H_2O determined using an elemental analyser and Be using atomic absorption spectrometry.
2. Wet chemical analysis at Leeds University on central portion of bottle-green globule, rather heavily altered and iron stained on outside.
3. Theory for $\text{CaFe}_{2.5}^{2+}\text{Be}_2(\text{PO}_4)_3(\text{OH})_3 \cdot 2\text{H}_2\text{O}$.
4. Theory for $\text{CaFe}_{2.5}^{2+}\text{Be}_2(\text{PO}_4)_3(\text{OH})_2 \cdot 3\text{H}_2\text{O}$.

TABLE II. X-ray powder data for iron-rich roscherite (material used for analysis 1)

hkl	d _{calc}	d _{meas}	I _{meas}	hkl	d _{calc}	d _{meas}	I _{meas}	hkl	d _{calc}	d _{meas}	I _{meas}	hkl	d _{calc}	d _{meas}	I _{meas}	d _{meas}	I _{meas}
110	9.49	9.42	88	401	3.261	-	-	2.41	2.533	-	-	005	2.198	-	-	1.571	9
200	7.88	7.86	8	11 $\bar{2}$	3.167	-	-	15 $\bar{2}$	2.529	2.523	8	441	2.196	-	-	1.536	5
001	6.60	-	-	330	3.163	3.156	100	60 $\bar{1}$	2.518	-	-	20 $\bar{3}$	2.167	-	-	1.520	5
-	-	6.42	6	20 $\bar{2}$	3.141	-	-	132	2.476	-	-	11 $\bar{3}$	2.167	2.176	20	1.500	5
020	5.94	5.88	62	112	3.065	3.075	32	530	2.467	2.469	6	350	2.163	-	-	1.490	10
11 $\bar{1}$	5.55	5.56	9	510	3.048	-	-	402	2.427	-	-	24 $\bar{2}$	2.158	-	-	1.476	4
20 $\bar{1}$	5.29	-	-	42 $\bar{1}$	3.029	3.043	32	42 $\bar{2}$	2.417	-	-	71 $\bar{1}$	2.153	2.151	9	1.462	5
111	5.29	5.26	8	040	2.970	2.970	32	620	2.404	2.400	19	512	2.150	-	-	1.456	5
201	4.86	-	-	202	2.952	-	-	440	2.372	-	-	-	-	2.051	16	1.443	10
310	4.81	4.79	32	33 $\bar{1}$	2.912	-	-	601	2.371	2.361	12	-	-	2.021	9	1.434	6
220	4.74	-	-	022	2.883	2.891	10	53 $\bar{1}$	2.364	-	-	-	-	1.973	16	1.395	9
021	4.41	4.38	11	51 $\bar{1}$	2.860	-	-	150	2.349	-	-	-	-	1.954	9	1.384	5
-	-	4.22	4	421	2.859	-	-	35 $\bar{2}$	2.345	-	-	-	-	1.919	12	1.353	15
31 $\bar{1}$	4.04	-	-	31 $\bar{2}$	2.826	2.825	15	51 $\bar{2}$	2.339	2.332	12	-	-	1.883	6	1.346	11
22 $\bar{1}$	3.951	-	-	331	2.795	-	-	62 $\bar{1}$	2.318	-	-	-	-	1.840	5	1.318	10
400	3.942	3.935	5	240	2.779	-	-	44 $\bar{1}$	2.270	-	-	551	(1.799)	1.799	5	1.288	8
130	3.841	-	-	22 $\bar{2}$	2.777	2.771	70	531	2.261	2.261	9	352	(1.781)	1.780	5	1.278	5
221	3.759	-	-	041	2.708	-	-	422	2.247	-	-	-	-	1.763	20	1.265	4
311	3.745	3.755	8	511	2.682	2.691	10	332	2.245	-	-	-	-	1.737	12	1.256	4
40 $\bar{1}$	3.522	3.467	5	40 $\bar{2}$	2.645	-	-	15 $\bar{1}$	2.222	-	-	-	-	1.692	11	1.245	4
13 $\bar{1}$	3.350	-	-	222	2.643	-	-	710	2.213	2.209	40	-	-	1.659	12	1.234	5
002	3.297	3.320	35	600	2.628	-	-	042	2.207	-	-	-	-	1.644	29	1.210	5
131	3.289	-	-	312	2.623	2.628	58	151	2.204	-	-	-	-	1.605	14	1.201	8
420	3.285	3.269	12	24 $\bar{1}$	2.590	2.570	5	621	2.202	-	-	-	-	1.581	16	-	-

(1977). Both analytical determinations fall reasonably close to this series, although the FeO values are low. The fibrous nature of the material and the fact that it is intergrown with carbonate-fluorapatite may account for these departures from theoretical composition.

Optical and physical properties. The refractive indices of the roscherite are α 1.628, β 1.644, γ 1.650; $\alpha \parallel [010]$, β : $[001]$ 24°; 2V (calc.) 64°. No interference figure was observed. D_{meas} was determined as 2.96 and D_{calc} (from analysis 1) as 2.92. Calculation of the Gladstone–Dale relationship gives the chemical refractive energy K_c as 0.209 for both analyses, with the physical refractive energy K_p as 0.216 (using D_{meas}).

X-ray examination. The X-ray powder pattern for the Gunnislake roscherite, obtained on material used for is analysis 1 given in Table II. It is in good agreement with patterns published by Lindberg (1958), on which our initial indexing was based.

Our pattern indexes well on a monoclinic cell of a 15.83, b 11.88, c 6.62 Å and β 95° in space group $C2/c$ with $Z = 4$.

The roscherite reported here extends the known range of Fe–Mn substitution, from an Mn : Fe ratio of 10 : 7 (type material from Greifenstein, Saxony, in Lindberg, 1958) to a composition very close to the iron end member.

REFERENCES

- Fanfani, L., Nunzi, A., Zanazzi, P. F., and Zanzari, A. R. (1975) *Tschermaks Mineral. Petrogr. Mitt.* **22**, 266–77.
 — Zanazzi, P. F., and Zanzari, A. R. (1977) *Ibid.* **24**, 169–78.
 Lindberg, M. L. (1958) *Am. Mineral.* **43**, 824–33.
 Slavik, F. (1914) *Mitt. böhm. Ak.* no. 4.

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