Grovesite, the manganese-rich analogue of berthierine.

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[Read March 24, 1955.]

A DARK brown (blackish-brown) mineral forms a thin crust on manganese ore on the specimen [B.M. 1944,35] from no. 5 ore-body of the Benallt mine, Rhiw, Carnarvonshire, North Wales. This is the specimen on which the first measurable crystals of banalsite were discovered in 1944 (Min. Mag., 1945, vol. 27, pp. 63–64). The mineral occurs as closely-packed, small rosettes, at most 0·5 mm. across, and is partly coated with a thin layer of baryte. An X-ray photograph by Dr. Bannister suggested that the mineral might belong to the chlorite group. Its optical properties were determined and nothing further was done with it at the time. When detailed work was started on the brown chlorite from veinlets in other specimens of the Benallt ore and more X-ray photographs were taken it was at once noticed that there were significant differences between the chlorite we have described and named pennantite (Min. Mag., 1946, vol. 27, pp. 217–220) and the chlorite-like mineral of the dark-brown rosettes first examined from no. 5 ore-body.

The mineral from no. 5 ore-body [B.M. 1944,35] was then carefully re-examined. It appears to be uniaxial, negative. Its pleochroism and absorption are similar to those of pennantite; $\beta = \gamma$, parallel to the cleavage, very dark brown, α perpendicular to the cleavage, red-brown; $\beta = \gamma > \alpha$. Refractive indices for Na-light are α' 1·658±0·001, $\beta = \gamma$ 1·667±0·001; slightly higher than for pennantite α' 1·646±0·001, $\beta = \gamma$ 1·661±0·001. This implies a higher birefringence for pennantite, but it is to be noted that the determinations of α are dependent on observations on flakes resting edge-on and vertical and consequently are less reliable than determinations for γ and β made on flakes lying flat. One can only claim that the lowest refractive indices so far measured on the two minerals are as given above.

As the X-ray photographs revealed interesting differences, it was decided to obtain sufficient of the pure mineral for micro-analysis. Thin pieces of the 'chlorite' crust were cut from the specimen, freed from ore by careful chipping and hand-picking, and then purified, as was done for pennantite, by density and magnetic separations. About 150 mg. of very pure material was obtained and 70 mg. was used for a micro-analysis, additional separate portions being used for determination of H_2O (60 mg.) and of the state of oxidation of the manganese and iron (20 mg.). The analysis was made by the same methods as were used for pennantite (loc. cit., p. 219).

The complete micro-analysis is given in table I, together with the empirical unit-cell contents calculated using the measured density of the analysed sample and the cell dimensions obtained from the X-ray photographs. The chemical composition is practically the same as that of pennantite.

TABLE I. Chemical analysis and empirical unit-cell contents of grovesite.

	%				
SiO_2	22·0	Si	5·37±0·13		8·00
Al_2O_3	18·8	Al	5·41±0·16	2·63 2·78	
Fe_2O_3	4·1	Fe	0·75±0·02		
MnO	43·4	Mn	8·97±0·14		12·82
MgO	0·8	Mg	0·29±0·04		
BaO	0·3	Ba	0·03±0·01		
H_2O	9·0	Total cations	20·82±0·50		
	98·4	OH	14·54±0·51		
		O	22·02±0·29		
		(O+OH)	36·56±0·45		

The 'probable errors' are calculated, assuming maximum probable errors of 0·5 % in the MnO, SiO_2, and Al_2O_3, of 0·1 % in the Fe_2O_3, MgO, and BaO, and of 0·3 % in the H_2O; 0·02 Å. in *a* and *b*, 0·04 Å. in *c*, and 0·02 in the density, by the method described by one of the authors (Min. Mag., 1954, vol. 30, p. 481).

The density of $D_4^{16} = 3{\cdot}150 \pm 0{\cdot}02$ is also closely comparable to the value obtained on the analysed sample of pennantite, which was 3·06±0·02 (but there is reason to suspect that this figure may be a little low). The unit-cell dimensions are

$$a\ 5{\cdot}51 \pm 0{\cdot}02, \qquad b\ 9{\cdot}54 \pm 0{\cdot}02, \qquad c\ 14{\cdot}36 \pm 0{\cdot}04\ \text{Å}.$$

From these we deduce the chemical formula

$$4[(Mn,Mg,Al)_3(Si,Al)_2(O,OH)_9].$$

In 1946, when the above observations were made, the X-ray powder and rotation photographs of the new mineral were compared with those of a variety of chlorites and a number of other manganese silicates and aluminosilicates; but no resemblances sufficiently extensive to suggest structural similarity were found. Recently the possibility occurred to one of the authors (M.H.H.) that the new mineral might bear a relation to the chlorite, pennantite, similar to that between berthierine[1] and chamosite. Comparison confirmed this idea. While X-ray powder photographs of pennantite closely resemble those of the other chlorites, and especially the iron-rich members such as thuringite and chamosite, those of the new mineral closely resemble powder photographs of cronstedtite and berthierine. There is one notable difference: the new mineral shows a fairly strong line corresponding to a spacing of 14 Å., which has not been recorded for cronstedtite or berthierine.

It is clear that the new mineral is not a chlorite, but a member of the cronstedtite-berthierine-amesite group, with a structure based on the two-layer sheets of the kaolin family, but presumably with a two-sheet repeat as compared with the three-sheet repeat of cronstedtite. It is also clear that the presence of a 14 Å. spacing is not necessarily evidence of a chlorite structure, but may be associated with a 'K-type' structure.

We propose for the new mineral the name *grovesite*, in honour of Dr. A. W. Groves, of the Mineral Resources Division of the Colonial Geological Surveys, who was geologist to the Home Ore Department, Iron and Steel Control, Ministry of Supply, during the war. Dr. Groves was responsible for the geological advice throughout the development and operation of this successful but sole Ministry of Supply manganese mine (1940–1946). During his periodic examination of the working he kept watch for unusual minerals, and it is due to him that the British Museum received the material in which the new minerals, banalsite, cymrite, pennantite, and now grovesite were discovered, along with others new to Great Britain.

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[1] Chamosite (Berthier, 1820, originally from Chamoson, Switzerland) and berthierine (Beudant, 1832, originally from Hayanges, France) have long been supposed to be identical, but a variety of evidence recently accumulated (Bannister, Min. Mag. **25**–459; Orcel, Hénin, and Caillière, M.A. **11**–210; Orcel, Caillière, and Hénin, Min. Mag. **29**–331; Brindley, M.A. **11**–104 and Min. Mag. **29**–502) leads to the conclusion that they are distinct minerals. Chamosite is an oxidized chlorite (Min. Mag. **30**–279), while berthierine is structurally allied to cronstedtite, amesite, and the kaolin family. The names 'kaolin-type chamosite' and 'K-type chamosite' have been used as provisional names for berthierine before the true nature of the Hayanges mineral was established.