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POLYTYPES OF PENNANTITE

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ABSTRACT

Pennantite-IIb and pennantite-Ia, the trioctahedral Mn chlorites, occur at Benallt mine, North Wales; pennantite-Ia occurs at Bald Knob, North Carolina, and zincian pennantite-Ia, $(Mn_{2.6}Zn_{1.3}Al_{1.3}Mg_{0.6}Fe^{3+}{}_{0.2})$ $(Si_{2.7}Al_{1.3})$ $O_{10}(OH)_8$, occurs at Franklin, New Jersey. Unit-cell dimensions (*e.g.*, *a* 5.45, *b* 9.50, *c* 14.40 Å, ß 97.3°) of both polytypes are similar. Indexed X-ray powder-diffraction data are given for both polytypes. The name *grovesite* is relegated to a synonym of pennantite-Ia.

Keywords: pennantite, grovesite, chlorite polytypes, unit-cell values, powder-diffraction data.

SOMMAIRE

On trouve la pennantite, chlorite manganifère trioctaédrique, en polytypes IIb et Ia à la mine Benallt, au nord du Pays de Galles; on trouve la pennantite-Ia à Bald Knob (Caroline du Nord) et la pennantite-Ia zincifère $(Mn_{2.6}Zn_{1.3}Al_{1.3}Mg_{0.6}Fe^{3+}{}_{0.2})(Si_{2.7}Al_{1.3})O_{10}(OH)_8$ à Franklin (New Jersey). Les dimensions de la maille (*e.g.*, *a* 5.45, *b* 9.50, *c* 14.40 Å, ß 97.3°) sont semblables pour les deux polytypes. On présente leur cliché de poudre (données récoltées au diffractomètre). Le nom *grovesite* serait synonyme de pennantite-Ia.

(Traduit par la Rédaction)

Mots-clés: pennantite, grovesite, polytypes de chlorite, dimensions de la maille, cliché de poudre.

INTRODUCTION

The nomenclature of the trioctahedral chlorites was reviewed by Bayliss (1975), and this review was accepted by the International Clay Minerals Nomenclature Committee (Bailey 1980). The chlorite group has the end-member compositions as follows: clinochlore $(Mg_5Al)(Si_3Al)O_{10}(OH)_8$, chamosite $(Fe^{2+}{}_5Al)(Si_3Al)O_{10}(OH)_8$, nimite (Ni_5Al) $(Si_3Al)O_{10}(OH)_8$ and pennantite (Mn_5Al) $(Si_3Al)O_{10}(OH)_8$. The varieties between these end-member compositions should be described by adjectival modifiers that reflect enrichment in a particular cation. The polytype symbols of Brown & Bailey (1962), which are determined from the intensities of the 20*l* reflections, should be used.

A literature review suggests that the following polytypes occur: clinochlore-IIb (PDF 26–1211), clinochlore-Ia (PDF 16–362), clinochlore-Ib (ß 97°) (PDF 16–351), chamosite-IIb (PDF 21–1227), chamosite-Ib (ß 90°) (PDF 13–29), and nimite-IIb (PDF 22–712). In this paper, I consider the polytypes of pennantite, which have not yet been determined.

METHODS

X-ray powder-diffraction patterns of polycrystalline ball-mount specimens were taken with a 114.6-mm Gandolfi camera with Cu radiation and Ni filter (λ 1.5418 Å). Intensities were estimated visually. Unit-cell dimensions (Table 1), which were refined with the least-squares programme of Appleman *et al.* (1972), are based upon the *hkl* values listed in Table 2.

An electron microprobe was used at 15 kV and a sample current of 0.025 μA standardized on brass. The standards used are manganite for Mn, synthetic ZnO for Zn, and hornblende for all other elements. The data were corrected using standard Bence–Albee factors.

BENALLT MINE SPECIMENS

Pennantite from the Benallt mine, Rhiw, Carnarvonshire, North Wales was studied originally by Smith *et al.* (1946) with single-crystal methods; these presumably indicated the 2-layer nature. The weak $k \neq 3n$ reflections that indicate a 2-layer periodicity probably would not be observed on a powder photograph. Their X-ray powder-diffraction photograph is stated to be identical to that of chamosite (formerly called thuringite) from Schmiedefeld, Thuringia by von Engelhardt (1942); however, the unit-cell dimensions *a* 5.43, *b* 9.4, and *c′* 28.5 Å (ß not given) of pennantite are larger than those of chamosite: *a* 5.37, *b* 9.30 *c* 14.10 Å, and ß 97°20′.

The unit-cell dimensions calculated for specimen NMNH 105855 (Table 1) are similar to those of Smith *et al.* (1946), except that *c* is not doubled. The X-ray powder-diffraction data are recorded in Table 2. This pattern is similar to that of chamosite-IIb (PDF 3–67) from Schmiedefeld, Thuringia (von Engelhardt 1942). Therefore, the original description of Smith *et al.* (1946) refers to the polytype pennantite-IIb.

Grovesite (BM 1944, 35) from the Benallt mine, Rhiw, Carnarvonshire, North Wales was described originally by Bannister *et al.* (1955). Although the chemical composition of grovesite is practically the same as that of pennantite, the X-ray powder-

TABLE 1. POLYTYPES AND UNIT-CELL DIMENSIONS FOR PENNANTITE

Specimen Number	Location	Poly-type	*a* (Å)	*b* (Å)	*c* (Å)	ß (°)
NMNH C6247	Franklin, New Jersey	Ia	5.41	9.40	14.34	96.8
NMNH 137139	Bald Knob, North Carolina	Ia	5.45	9.45	14.42	97.3
BM 1944,35	Benallt Mine, North Wales from Peacor *et al.* (1974)	Ia	5.45	9.50	14.40	97.3
NMNH 105855	Benallt Mine, North Wales	IIb	5.47	9.47	14.29	97.3

TABLE 2. POWDER X-RAY DIFFRACTION DATA FOR PENNANTITE

	Polytype-Ia			Polytype-IIb		
hkl	d_{calc}	d_{obs} +	I/I_1	d_{calc}	d_{obs} *	I/I_1
001	14.28Å	14.3Å	40	14.17Å	14.15Å	30
n.i.	-	12.6	5			
002	7.14	7.1	100	7.09	7.12	100
003	4.76	4.75	30	4.72	4.73	30
004	3.570	3.57	80	3.54	3.56	90
005	2.856	2.85	20	2.835	2.840	10
200	2.705	2.70	40	2.715	2.708	15
$20\bar{2}$				2.650	2.646	70
201	2.598	2.60	10	2.606	2.600	50
$20\bar{3}$				2.494	2.494	40
202	2.430	2.43	80	2.434	2.431	50
$20\bar{4}$	2.301	2.30	20	2.300	2.302	50
203				2.235	2.235	5
$20\bar{5}$	2.101	2.10	5			
204	2.036	2.03	40	2.034	2.034	60
$20\bar{6}$	1.911	1.908	15	1.906	1.914	20
206	1.684	1.683	30	1.680	1.686	5
$20\bar{8}$	1.585	1.585	20	1.578 }	1.578	100
060	1.575	1.574	30	1.579 }		
062	1.538	1.537	20	1.541	1.541	40
063				1.497	1.494	5
064	1.441	1.440	5	1.442	1.441	10
0.0.10	1.428	1.428	5	1.417	1.415	5
208				1.404	1.403	15
$40\bar{2}$	1.361	1.361	5			
400				1.357	1.357	10
$2.0.\overline{10}$	1.335	1.335	10			
$40\bar{4}$	1.321	1.322	5	1.325	1.325	5
402	1.299	1.300	5			
$40\bar{6}$	1.246	1.246	5			
$40\bar{8}$	1.150	1.150	10			
406	1.117	1.117	10			
0.6.10	1.058	1.059	15			

+ Data from BM1944,35 by Peacor *et al.* (1974)
* Data from NMNH105855

diffraction patterns are different. Unit-cell dimensions determined from rotation photographs are *a* 5.51, *b* 9.54, *c* 14.36 Å (ß not given). Bannister *et al.* (1955) concluded that grovesite is the manganese analogue of berthierine in the kaolinite–serpentine group despite their observation of a fairly strong 14 Å reflection, which is incompatible with a berthierine-type crystal structure.

Peacor *et al.* (1974) published an unindexed X-ray powder-diffraction pattern of grovesite (PDF 29–884) obtained from type material (BM 1944, 35), Benallt mine, Rhiw, Carnarvonshire, North Wales. They deduced that grovesite is not a kaolinite–serpentine-group mineral, but belongs to the chlorite group.

The unindexed data published by Peacor *et al.* (1974) were indexed, and a unit cell of BM 1944,35 was calculated (Table 1). This unit cell is similar to that determined by Bannister *et al.* (1955). Since more reflections are observed in the type specimen (BM 1944,35) from Benallt mine published by Peacor *et al.* (1974) than in specimens from Franklin or Bald Knob described below, Table 2 contains their data together with *hkl* and d_{calc}. In conclusion, this specimen should be called pennantite-Ia, using the nomenclature of Bayliss (1975) and the polytypes of Brown & Bailey (1962).

Bald Knob Specimen

Grovesite from Bald Knob, North Carolina, which was described by Peacor *et al.* (1974), has unit-cell dimensions *a* 5.44, *b* 9.40, *c* 14.27 Å, ß 97.2°, as determined from single-crystal studies. Their unit cell is similar to that calculated from specimen NMNH 137139 (Table 1). The X-ray powder-diffraction pattern of NMNH 137139 is similar to the data for the specimen from the Benallt mine (Table 2). This specimen also should be called pennantite-Ia, using the nomenclature of Bayliss (1975) and the polytypes of Brown & Bailey (1962).

Franklin Specimen

The chlorite from Franklin, New Jersey (NMNH 105855) occurs as thin coatings on secondary willemite crystals. The chlorite in turn is coated with prehnite, then datolite, and, finally, roeblingite. Other associated minerals are clinohedrite and hancockite. The specimens, which were collected many years ago, come from museum collections, and thus little is known of the exact geological occurrence within the Franklin mine. The dark red platy chlorite crystals are very small, and most crystals are less than 0.05 mm in maximum length. They are attached to the willemite prisms by their edges such that the [001] of the chlorite is subparallel to the [0001] of willemite. The aggregates of platy crystals are uniformly fine grained.

The electron-microprobe analysis yields: SiO_2 23.9, Al_2O_3 19.1, Fe_2O_3 2.6, MgO 3.4, ZnO 15.9, and MnO 27.4 wt.% ($\Sigma = 92.3$). Because the 7.7 wt.% of H_2O calculated by difference is lower than that expected for chlorite of this composition, some H_2O appears to have volatilized in the electron beam, which increases the weight percentage of oxides determined. The chlorite structural formula, which is based upon a $A_6T_4O_{10}(OH)_8$ model, was calculated from the chemical data to be

$(Mn_{2.6}Zn_{1.3}Al_{1.3}Mg_{0.6}Fe^{3+}{}_{0.2})(Si_{2.7}Al_{1.3})O_{10}(OH)_8$. The oxidation state of Fe was not determined, but assigned as Fe^{3+} because Fe^{3+} was found in the wet-chemical analysis of Smith *et al.* (1946) and Bannister *et al.* (1955).

The unit cell and polytype are given in Table 1. The X-ray powder-diffraction pattern is similar to the data for the specimen from the Benallt mine (Table 2). This specimen is a zincian pennantite-Ia, using the nomenclature of Bayliss (1975) and the polytypes of Brown & Bailey (1962).

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References

Appleman, D.E., Evans, H.T., Jr. & Handwerker, D.S. (1972): Job 9214: Indexing and least-squares refine ment of powder diffraction data. *U.S. Geol. Surv. Comp. Contr.* **20.**

Bailey, S.W. (1980): Summary of recommendations of AIPEA nomenclature committee. *Clays Clay Minerals* **28,** 73-78.

Bannister, F.A., Hey, M.H. & Smith, W.C. (1955): Grovesite, the manganese-rich analogue of berthierine. *Mineral. Mag.* **30,** 645-647.

Bayliss, P. (1975): Nomenclature of the trioctahedral chlorites. *Can. Mineral.* **13,** 178-180.

Brown, B.E. & Bailey, S.W. (1962): Chlorite polytypism. I. Regular and semi-random one-layer structures. *Amer. Mineral.* **47,** 819-850.

Peacor, D.R., Essene, E.J., Simmons, W.B., Jr. & Bigelow, W.C. (1974): Kellyite, a new Mn–Al member of the serpentine group from Bald Knob, North Carolina, and new data on grovesite. *Amer. Mineral.* **59,** 1153-1156.

Smith, W.C., Bannister, F.A. & Hey, M.H. (1946): Pennantite, a new manganese-rich chlorite from Benallt mine, Rhiw, Carnarvonshire. *Mineral. Mag.* **27,** 217-220.

von Engelhardt, W. (1942): Die Strukturen von Thuringit, Bavalit und Chamosit und ihre Stellung in der Chloritgruppe. *Z. Krist.* **104,** 142-159.

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