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EARLSHANNONITE, THE Mn ANALOGUE OF WHITMOREITE, FROM NORTH CAROLINA

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ABSTRACT

Earlshannonite, ideally $MnFe^{3+}_2(PO_4)_2(OH)_2{\cdot}4H_2O$, a new mineral species, is the Mn-analogue of whitmoreite. It is monoclinic, space group $P2_1/c$, with a 9.910(13), b 9.669(8), c 5.455(9) Å, β 93.95(9)°, with $Z = 2$. Microprobe analysis yielded: Al_2O_3 0.1, Fe_2O_3 33.8, FeO 4.6, MgO 0.8, CaO 0.6, MnO 8.2, P_2O_5 30.0, H_2O [21.9], sum = 100.0 wt.%. Earlshannonite occurs as euhedral reddish brown crystals in radial aggregates associated with rockbridgeite, laueite and mitridatite at the Foote Mineral Company spodumene mine, near Kings Mountain, North Carolina. Earlshannonite has a vitreous luster; D (meas.) = 2.90(4), (calc.) = 2.92 g/cm^3; hardness (Mohs) is approximately 3–4. There are two poor cleavages (one likely to be {100}). Optically, earlshannonite is biaxial negative, $2V = 64(4)°$, with α 1.696(4), β 1.745(4) and γ 1.765(4). Pleochroism is moderate: $X = Y$ light yellow brown, Z yellow brown; absorption: $Z > X \cong Y$; orientation is $Z = c$. Earlshannonite also occurs in the Hagendorf pegmatites, Bavaria, West Germany, where it forms radial aggregates of bright yellow crystals coating rockbridgeite–frondelite. Earlshannonite is named in honor of Earl V. Shannon, former mineralogist, chemist, and curator at the U.S. National Museum.

Keywords: earlshannonite, phosphate, pegmatite, new mineral species, North Carolina, Foote mine, Hagendorf, Bavaria.

SOMMAIRE

L'earlshannonite, nouvelle espèce minérale de formule simplifiée $MnFe^{3+}_2(PO_4)_2(OH)_2{\cdot}4H_2O$, est l'analogue manganifère de la whitmoreïte. Monoclinique, de groupe spatial $P2_1/c$, elle a les paramètres réticulaires suivants: a 9.910(13), b 9.669(8), c 5.455(9) Å, β 93.95(9)°, $Z = 2$. Une analyse à la microsonde (et des considérations de stoechiométrie) donnent: Al_2O_3 0.1, Fe_2O_3 33.8, FeO 4.6, MgO 0.8, CaO 0.6, MnO 8.2, P_2O_5 30.0, H_2O [21.9], total 100.0% en poids. L'earlshannonite se présente en cristaux rouge-brun idiomorphes en agrégats fibroradiés accompagnée de rockbridgeïte, laueïte et mitridatite dans la mine de spodumène de la Foote Mineral Company, près de Kings Mountain, en Caroline du Nord. Elle possède un éclat vitreux; D(mes.) 2.90(4), (calc.) 2.92; dureté Mohs ~ 3 - 4; deux plans de clivage imparfait, dont un serait {100}. Optiquement négative, avec $2V = 64(4)°$, α 1.696(4), β 1.745(4), γ 1.765(4), elle montre un pléochroïsme modéré: $X = Y$ jaune pâle brunâtre, Z jaune brunâtre, absorption $Z > X \cong Y$; orientation $Z = c$. L'earlshannonite se trouve aussi dans les pegmatites de Hagendorf (Bavière) en agrégats fibroradiés de cristaux d'un jaune vif sur rockbridgeïte -frondelite. Le nom honore Earl V. Shannon, qui fut minéralogiste, chimiste et conservateur au U.S. National Museum.

(Traduit par la Rédaction)

Mots-clés: earlshannonite, phosphate, pegmatite, nouvelle espèce minérale, Caroline du Nord, mine Foote, Hagendorf (Bavière).

INTRODUCTION

In late 1982, Mr. James Fowler of Grenville, South Carolina, provided us with a sample containing some dark reddish brown, radiating crystals that had been found at the Foote Mineral Company's spodumene mine, near Kings Mountain, North Carolina. Preliminary examination of these crystals by X-ray-diffraction techniques indicated that they are isostructural with whitmoreite, $Fe^{2+}Fe^{3+}_2(PO_4)_2(OH)_2{\cdot}4H_2O$. However, because these crystals are associated with Mn-bearing species such as jahnsite and laueite, among others, we decided to investigate their chemical composition to ascertain the extent of Mn substitution in whitmoreite. Our subsequent investigation has revealed that these crystals and some bright yellow crystals from Hagendorf, Bavaria (West Germany), are the Mn-analogue of whitmoreite, herein described as a new species.

We have named this mineral *earlshannonite* in honor of the late Earl V. Shannon (1895–1981), mineralogist and chemist at the U.S. National Museum until his retirement for medical reasons in 1930. Despite the brevity of his career, Mr. Shannon was a prolific contributor to mineralogy, authoring over 112 papers, contributing chemical analyses to innumerable others, and authoring several mono-

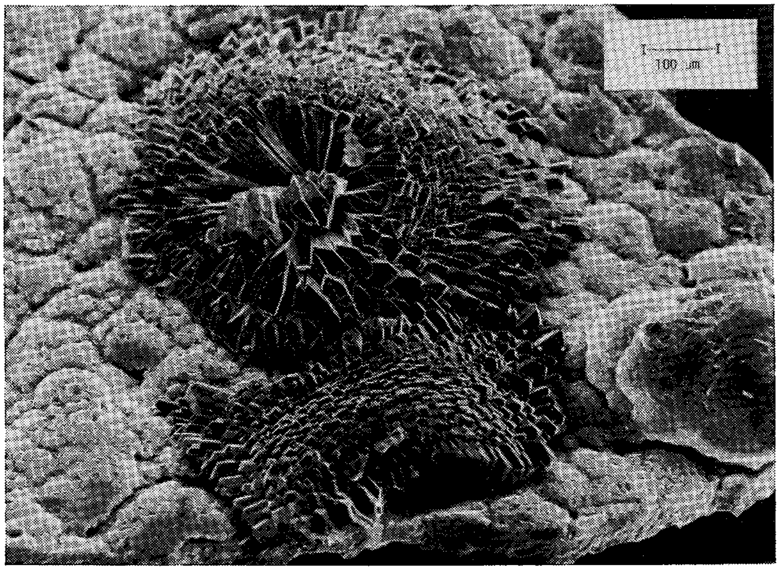

FIG. 1. Radial aggregates of earlshannonite crystals on mitridatite showing characteristic hemispherical clustering.

graphs, one of which is entitled *The Minerals of Idaho* (Shannon 1926). The mineral and the name have been approved by the Commission on New Minerals and Mineral Names. Type material is deposited in the Smithsonian Institution under catalog #NMNH 150168.

CRYSTALLOGRAPHY

Earlshannonite occurs as monoclinic crystals up to 0.5 mm in length, but most are considerably smaller. The crystals are prismatic, elongate on [001], with forms {110} (dominant) and {100} and {011} (minor). They are twinned on {100}, and commonly exhibit parallel growth with [001] in common. A representative SEM photomicrograph of the earlshannonite is shown in Figure 1. Earlshannonite crystals closely resemble those of whitmoreite as described by Moore *et al.* (1974).

The space group, $P2_1/c$, was determined using precession and Weissenberg single-crystal X-ray-diffraction methods. The lattice parameters determined from the resulting photographs were refined by least squares using data obtained from a powder photograph: *a* 9.910(13), *b* 9.669(8), *c* 5.455(9) Å, β 93.95(9)°. The powder-diffraction data were obtained utilizing Fe$K\alpha$ radiation, with silicon as an internal standard, and a polycrystalline sample in a 114.6-mm-diameter Gandolfi camera. The powder data are listed in Table 1.

TABLE 1. X-RAY POWDER-DIFFRACTION DATA FOR EARLSHANNONITE

I/I_0	d (Obs)	d (Calc)	hkl	I/I_0	d (Obs)
100	9.8	9.89	100	10	2.003
80	6.9	6.91	110	10	1.982
40	4.95	4.94	200	10	1.951
5	4.82	4.83	020		
40	4.38	4.38	$11\bar{1}$	5	1.882
		4.40	210		
60	4.18	4.18	111	10	1.807
60	3.45	3.46	220	2	1.715
		3.45	$12\bar{1}$	5	1.673
2	3.34	3.35	121	2	1.577
		3.32	211	10	1.551
5	3.07	3.06	130	5	1.533
30	2.987	2.983	$22\bar{1}$	5	1.527
60	2.856	2.856	221	5	1.488
70	2.789	2.785	$31\bar{1}$	2	1.458
40	2.712	2.723	320	1	1.445
		2.721	002	2	1.385
		2.700	230		
				5	1.373
2	2.646	2.646	131	2	1.346
30	2.577	2.578	102	5	1.334
		2.575	$11\bar{2}$		
2	2.451	2.456	$23\bar{1}$		
		2.456	$20\bar{2}$		
30	2.389	2.395	410		
		2.383	231		
		2.382	321		
		2.381	$21\bar{2}$		
2	2.345	2.348	140		
1	2.303	2.304	330		
1	2.250	2.254	212		
30	2.210	2.209	041		
1	2.119	2.120	$31\bar{2}$		
30	2.089	2.090	222		
		2.086	331		

PHYSICAL AND OPTICAL PROPERTIES

Earlshannonite from Kings Mountain (unless otherwise noted, all data were determined on specimens from this locality) occurs as reddish brown, transparent crystals with a vitreous lustre on both crystal and cleavage surfaces. The streak is light brown. It does not fluoresce in ultraviolet radiation. The Mohs hardness is approximately 3–4. Earlshannonite is brittle. There are two poor cleavages, observed only on crushed grains; their indices are not known, but one is likely {100} inasmuch as that is a known cleavage for the isostructural mineral whitmoreite. The fracture is even. The density, measured using heavy-liquid techniques, is 2.90(4) g/cm^3; the calculated density (assuming 4.00 H_2O) is 2.92 g/cm^3. Optically, earlshannonite is biaxial negative, $2V_x = 64(4)°$, with indices of refraction α 1.696(4), β 1.745(4) and γ 1.765(4). Pleochroism is moderate: $X = Y$ light yellow brown, Z yellow brown. Absorption: $Z > X \cong Y$. The orientation is $Z = c$. Indices of refraction were determined in sodium light. We have not studied the earlshannonite from Hagendorf in detail, and we note here only that it is bright yellow in color.

CHEMISTRY

Earlshannonite was chemically analyzed using an ARL–SEMQ electron microprobe utilizing an operrating voltage of 15 kV and a sample current of 0.025 μA, measured on brass. We used the following standards: maričite (Fe), montgomeryite (Ca,Al,Mg,P), manganite (Mn) and ZnO (Zn). The data were corrected using standard Bence-Albee factors. There was inadequate material for the direct determination of water; it was, therefore, calculated by difference. The resulting value is very similar to that predicted from the known crystal-structure of the isostructural mineral whitmoreite (Moore *et al.* 1974). The oxidation state of Fe was determined on the basis of microchemical tests (these showed that Fe^{3+} is the dominant species) and the known relations for the whitmoreite structure; *i.e.*, this structure has two sites of ranks 2 and 4 that require occupancy by cations with 2+ and 3+ valence states, respectively. A wavelength-dispersion scan indicated the absence of elements with atomic number greater than 8, except those reported here. The analysis yields: Al_2O_3 0.1, Fe_2O_3 33.8, FeO 4.6, MgO 0.8, CaO 0.6, MnO 8.2, P_2O_5 30.0, H_2O [21.9], sum = 100.0%. The formula, calculated on the basis of P = 2, is $(Mn_{0.55}Fe_{0.30}Mg_{0.09}Ca_{0.05})_{\Sigma 0.99}(Fe^{3+}{}_{2.00}Al_{0.01})_{\Sigma 2.01}(PO_4)_{2.00}(OH)_{2.01}\cdot 4.75H_2O$ or ideally, $MnFe^{3+}{}_2(PO_4)_2(OH)_2\cdot 4H_2O$, with $Z = 2$.

We also analyzed crystals from the second occurrence of earlshannonite at Hagendorf. These crystals have the composition Al_2O_3 0.3, Fe_2O_3 34.4, FeO 2.5, MgO 2.3, MnO 7.3, ZnO 0.3, P_2O_5 31.0, H_2O (by difference) 21.9%. This yields the formula, based on P = 2: $(Mn_{0.47}Mg_{0.26}Fe_{0.16}Zn_{0.02})_{\Sigma 0.91}(Fe^{3+}{}_{1.97}Al_{0.03})_{\Sigma 2.00}(PO_4)_{2.00}(OH)_{1.82}\cdot 4.66H_2O$ or, ideally, $MnFe^{3+}{}_2(PO_4)_2(OH)_2\cdot 4H_2O$, with $Mn^{2+} > Fe^{2+}$.

OCCURRENCE

Earlshannonite was found in 1982 on the dumps of the Foote Mineral Company's spodumene mine, near the town of Kings Mountain, Cleveland County, North Carolina. Little can be said about the geological relations of the occurrence; we have not seen the mineral *in situ*. The geology of the Foote mine has been described by Kesler (1961) and Kunasz (1982), and a discussion of the parageneses at the Foote mine was presented by Dunn *et al.* (1979). On the type specimens, the quartz matrix has a thin, dull green coating of mitridatite, $Ca_3Fe^{3+}{}_4(PO_4)_4(OH)_6\cdot 3H_2O$, which is in turn coated by randomly distributed crystals and crystal clusters of laueite, a jahnsite-group mineral, rockbridgeite and earlshannonite. Sequential growth relationships are ambiguous, but earlshannonite is among the last species to form in the sequence of late-stage secondary phosphates. The phosphate species are coated by bulbous, irregular aggregates of a Mn-oxide that gives no X-ray-diffraction pattern.

The second occurrence of earlshannonite was discovered on one specimen labeled as rockbridgeite from the Hagendorf pegmatites, near Waidhaus, Bavaria, West Germany. On this specimen, bright yellow, divergent sprays of earlshannonite form an encrustation on rockbridgeite–frondelite. We note with interest that Mücke (1981) described such an occurrence of "whitmoreite" but did not provide analytical data. It may be that the yellow "whitmoreite" seen by Mücke is in fact earlshannonite.

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