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FERRILOTHARMEYERITE, A NEW Ca–Zn–Fe^{3+} HYDROXYL ARSENATE FROM TSUMEB, NAMIBIA[1]

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ABSTRACT

Ferrilotharmeyerite occurs at the Tsumeb mine, Tsumeb, Namibia, as multiple subhedral crystallites and as tabular to wedge- or lozenge-shaped crystals associated with tennantite, scorodite, conichalcite, schneiderhöhnite and beudantite. The mineral is monoclinic, space group $C2$, Cm or $C2/m$ (diffraction aspect $C*/*$), with refined unit-cell parameters a 8.997(7), b 6.236(2), c 7.390(3) Å, β 115.74(4)°, V 373.5(5) Å^3, a:b:c 1.443:1:1.185, Z = 2. The strongest seven lines of the X-ray powder-diffraction pattern [d in Å(I)(hkl)] are: 4.95(70)(110), 3.398(100)(20$\bar{2}$), 3.175(100)(11$\bar{2}$), 2.938(100)(201), 2.823(70)(021), 2.702(70)(31$\bar{1}$), 2.544(100)(22$\bar{1}$). The crystallites are transparent to translucent, medium to brownish yellow with an adamantine to greasy lustre and a pale yellow streak. The mineral is brittle, with an uneven fracture and a good {001} cleavage. D(meas.) 4.25(5), D(calc.) 4.25 and 4.38 g/cm^3 for two empirical formulas. Optically, the mineral is biaxial positive, with α 1.811(5), β 1.844(5), γ 1.88(1), 2V(meas.) 85(5)°, 2V(calc.) 89°, X approximately $\parallel a$, $Y \parallel b$. Pleochroism is strong: X olive green, Y pale green, Z colorless. Absorption is $X > Y \gg Z$. Inclined dispersion of the optic axes is distinct, $r > v$. The ideal chemical formula is $Ca(Zn,Cu)(Fe^{3+},Zn)(AsO_3OH)_2(OH)_3$, derived from electron-microprobe analyses, water determination and microchemical tests. Ferrilotharmeyerite is the ferric iron analogue of lotharmeyerite, and is named to reflect this relationship.

Keywords: ferrilotharmeyerite, calcium zinc ferric iron hydroxyl arsenate, new mineral species, X-ray data, chemical composition, Tsumeb mine, Namibia.

SOMMAIRE

La ferrilotharmeyerite, nouvelle espèce minérale provenant de la mine Tsumeb, en Namibie, est présente sous forme de petits cristaux sub-idiomorphes ou en tablettes ou en losanges, associés à tennantite, scorodite, conichalcite, schneiderhöhnite et beudantite. Elle est monoclinique, groupe spatial $C2$, Cm ou $C2/m$ (aspect de diffraction $C*/*$); les paramètres réticulaires ont été affinés: a 8.997(7), b 6.236(2), c 7.390(3) Å, β 115.74(4)°, V 373.5(5) Å^3, a:b:c 1.443:1:1.185, Z = 2. Les sept raies les plus intenses du cliché de diffraction (méthode des poudres) [d en Å(I)(hkl)] sont: 4.95(70)(110), 3.398(100)(20$\bar{2}$), 3.175(100)(11$\bar{2}$), 2.938(100)(201), 2.823(70)(021), 2.702(70)(31$\bar{1}$), 2.544(100)(22$\bar{1}$). Les petits cristaux sont transparents à translucides, jaune moyen à jaune brunâtre, avec un éclat adamantin ou gras et une rayure jaune pâle. C'est un minéral cassant dont la fracture est irrégulière; le clivage {001} est bon. Densité 4.25(5) (mesurée), 4.25 et 4.38 (valeurs calculées pour les deux formules empiriques). Biaxe positif, avec α 1.811(5), β 1.844(5), γ 1.88(1), 2V(mes.) 85(5)°, 2V(calc.) 89°, X à peu près $\parallel a$, $Y \parallel b$. Le pléochroïsme est intense: X vert olive, Y vert pâle, Z incolore. L'absorption est $X > Y \gg Z$. La dispersion inclinée des axes optiques est distincte, $r > v$. La formule chimique idéale, $Ca(Zn,Cu)(Fe^{3+},Zn)(AsO_3OH)_2(OH)_3$, est dérivée de données obtenues à la microsonde électronique, des déterminations de la teneur en H_2O, et de tests microchimiques. Le ferrilotharmeyerite est l'analogue

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ferrifère de la lotharmeyerite, et son nom témoigne de cette relation.

(Traduit par la Rédaction)

Mots-clés: ferrilotharmeyerite, arsenate de calcium, zinc, fer ferrique hydroxylé, nouvelle espèce minérale, données aux rayons X, composition chimique, mine de Tsumeb, Namibie.

INTRODUCTION

A new mineral, ferrilotharmeyerite, has been identified on a specimen (NMC 64573) in the National Mineral Collection of the Geological Survey of Canada. The sample was collected in 1983 by John Innes, from the Tsumeb mine (32 level, W40 stope), Tsumeb, Namibia. The mineral occurs as multiple subhedral crystallites, averaging 0.2 mm in length, with crudely formed faces slightly elongate in the *b* direction. The matrix appears to be feldspathic quartzite showing pervasive staining by hematite. Ferrilotharmeyerite rims conichalcite and is in contact with tennantite. Large crystals of scorodite and schneiderhöhnite also occur on the specimen.

After most of the data needed to define the species had been obtained on the NMC specimen, additional ferrilotharmeyerite from the same locality was found on a specimen of massive tennantite and calcite from the Museum of Victoria, Melbourne, Australia (M38092). This specimen has a 7 × 7 cm crust of dark brown tabular beudantite crystals up to 1 mm across, and yellowish brown ferrilotharmeyerite crystals up to about 0.6 mm in size. The water analysis for ferrilotharmeyerite was obtained from this specimen because of the dearth of material on the NMC specimen.

The mineral is the ferric iron analogue of lotharmeyerite (Dunn 1983, Kampf *et al.* 1984) and is named to reflect this relationship. The mineral and mineral name have been approved by the Commission on New Minerals and Mineral Names, I.M.A. The two specimens described above have been designated cotype, and are the only known specimens of ferrilotharmeyerite.

X-RAY CRYSTALLOGRAPHY

Precession studies were undertaken on several fragments of ferrilotharmeyerite 0.1 to 0.2 mm in size from NMC 64573, but in all cases orientation photographs indicate that single-crystal multiple crystallites are present. Even the smallest fragment is composed of at least four individuals. Nevertheless, *h0l* and $b^* \wedge 201^*$ photographs of one fragment clearly show monoclinic symmetry and gave measured unit-cell parameters: *a* 8.98, *b* 6.23, *c* 7.38 Å, *β* 115.57°. These data are consistent with those reported for lotharmeyerite by Kampf *et al.* (1984). Because upper-level precession photography was impossible and the X-ray powder patterns of the two minerals are very similar, it was decided to index the powder pattern of ferrilotharmeyerite by analogy with the powder data provided for lotharmeyerite by Kampf *et al.* (1984). Ferrilotharmeyerite crystals from specimen M38092 are also unsuitable for single-crystal precession study.

The X-ray powder-diffraction data for specimen NMC 64573 (Table 1) were refined using twelve reflections between 3.544 and 1.559 Å for which unambiguous indexing was possible. The refined unit-cell parameters are: *a* 8.997(7), *b* 6.236(2), *c* 7.390(3) Å, *β* 115.74(4)°, *V* 373.5(5) Å^3, *a*:*b*:*c* 1.443:1:1.185, with Z = 2. The possible space-groups, also by analogy, are *C2*, *Cm* or *C2/m* (diffraction aspect *C**/*). The cell parameters and cell volume are slightly lower than those reported by Kampf *et al.* (1984) for lotharmeyerite. Contributing factors for the smaller unit cell are the small but significant differences in ionic radii between Fe^{3+} (0.64 Å) and Mn^{3+} (0.66 Å), and between Cu^{2+} (0.72 Å) and Zn^{2+} (0.74 Å).

PHYSICAL AND OPTICAL PROPERTIES

Ferrilotharmeyerite on specimen NMC 64573 occurs as subhedral crystals, averaging 0.2 mm in

TABLE 1. X-RAY POWDER DATA FOR FERRILOTHARMEYERITE

*I*est.	*d*(meas.)	*d*(calc.)	*hkl*	*I*est.	*d*(meas.)	*d*(calc.)	*hkl*
30	6.66	6.66	001	5	2.070	2.069	311
70	4.95	4.94	110	5	2.026	2.026	400
30	4.60	4.59	$11\bar{1}$	5	1.983	1.988	$13\bar{1}$
10	4.44	4.42	$20\bar{1}$			1.986	$40\bar{3}$
20	3.544	3.544	111	5	1.925	1.924	$22\bar{3}$
100	3.398	3.395	$20\bar{2}$	30	1.847	1.850	113
100	3.175	3.178	$11\bar{2}$			1.847	$20\bar{4}$
20	3.121	3.118	020	20	1.811	1.812	$13\bar{2}$
100	2.938	2.940	201			1.808	023
70	2.823	2.824	021	10	1.773	1.772	222
70	2.702	2.702	$31\bar{1}$	50	1.701	1.721	$11\bar{4}$
100	2.544	2.547	$22\bar{1}$			1.708	$33\bar{1}$
50	2.475	2.474	112	50	1.674	1.691	312
		2.471	220			1.675	$42\bar{3}$
10	2.297	2.296	$22\bar{2}$	20	1.589	1.589	$22\bar{4}$
10	2.268	2.276	022	30	1.559	1.559	040
		2.260	$11\bar{3}$	20	1.518	1.519	421
10	2.210	2.219	003			1.509	331
		2.208	$40\bar{2}$	30	1.468	1.469	223
20	2.147	2.154	202			1.468	$20\bar{5}$
		2.139	221				

- 114.6 mm Debye-Scherrer powder camera, Cu radiation Ni-filter (λCu*K*α 1.54178 Å)
- intensities estimated visually, values of *d* quoted in Å
- indexed with *a* 8.997, *b* 6.236, *c* 7.390 Å, ß 115.74°

size, in randomly oriented to subparallel aggregates up to 3 mm in maximum dimension. The crystals are transparent, medium yellow to brownish yellow, with an adamantine lustre and a very pale yellow streak. For M38092, the ferrilotharmeyerite crystals are tabular to wedge- or lozenge-shaped, average about 0.6 mm in size, and are commonly intergrown with beudantite. These crystals are translucent, with a greasy lustre and a pale yellow streak. The mineral is brittle, with an uneven fracture and a good {001} cleavage. The Mohs hardness is approximately 3. Ferrilotharmeyerite is not fluorescent under either long- or short-wave ultraviolet light. The density for ferrilotharmeyerite from NMC 64573, as determined by the heavy-liquid flotation technique using Clerici solution, is 4.25(5) g/cm^3. The calculated value is 4.25 g/cm^3 on the basis of the empirical formula for M38092, and 4.38 g/cm^3 on the basis of the empirical formula for NMC 64573.

Optically, the mineral from NMC 64573 is biaxial positive, with α 1.811(5), β 1.844(5), γ 1.88(1), $2V$(meas.) 85(5)°, as determined in sodium light (λ 589 nm), and $2V$(calc.) 89°, X approximately parallel to a, and Y parallel to b. Pleochroism is strong: X olive green, Y pale green, Z colorless. Absorption is $X > Y >> Z$. Inclined dispersion of the optic axes is distinct, $r > v$.

CHEMICAL COMPOSITION

Ferrilotharmeyerite was analyzed by electron microprobe in two laboratories, at the Department of Geology, University of Melbourne, Australia, and the Smithsonian Institution, Washington. Operating conditions, standards and analytical results are given in Table 2. A wavelength-dispersion scan revealed no elements heavier than oxygen other than those reported. The Australian Mineral Development Laboratories (AMDEL) in Melbourne, Australia, provided the water analysis by CHN Analyzer. Microchemical tests were negative for Fe^{2+} and positive for Fe^{3+}.

TABLE 2. CHEMICAL COMPOSITION OF FERRILOTHARMEYERITE

		NMC 64573	M38092	
CuO	wt.%	2.9	5.75	(3.82-7.91)
ZnO		15.8	13.94	(12.35-15.25)
Fe_2O_3		14.1	13.96	(13.20-15.20)
CaO		12.1	10.86	(10.50-11.23)
PbO		n.d.	2.13	(0.67-3.47)
Al_2O_3		n.d.	0.13	(0.02-0.30)
MnO		tr.	n.d.	
MgO		tr.	n.d.	
As_2O_5		46.7	48.66	(48.38-48.90)
H_2O		n.g.	5.85*	
Total		91.6	101.28	

tr. = trace; n.d. = not detected; n.g. = not given; * = determined by C-H-N analyser.

NMC 64573: SEMQ electron microprobe operated at 15 kV, 0.025 μA sample current, with standards: manganite (Mn), cuprite (Cu), fluorapatite (Ca), zinc oxide (Zn), olivenite (As), and hornblende (Fe,Mg).

M38092: JEOL electron microprobe operated at 15 kV, 0.02 μA sample current, with standards: copper (Cu), wollastonite (Ca), zinc (Zn), arsenopyrite (As), hematite (Fe), corundum (Al), and galena (Pb). Values in brackets are the ranges.

The empirical formula for NMC 64573, on the basis of As = 2, is $Ca_{1.06}(Zn_{0.82}Cu_{0.18})_{\Sigma 1.00}(Fe_{0.87}Zn_{0.14})_{\Sigma 1.01}[AsO_{3.10}(OH)_{0.90}]_2(OH)_{2.80}$. The empirical formula for M38092, on the basis of As = 2, is $(Ca_{0.92}Pb_{0.05})_{\Sigma 0.97}(Zn_{0.66}Cu_{0.34})_{\Sigma 1.00}(Fe_{0.83}Zn_{0.15}Al_{0.01})_{\Sigma 0.99}[AsO_{3.41}(OH)_{0.58}]_2(OH)_{1.90}$. By analogy with lotharmeyerite, the idealized formula is $Ca(Zn,Cu)(Fe^{3+},Zn)(AsO_3OH)_2(OH)_3$. Because proven cases of solid solution involving Cu^{2+} and Fe^{3+} are unknown, but Cu–Zn solid solution has been reported in secondary arsenates and phosphates, such as philipsburgite (Peacor *et al.* 1985) and kipushite (Piret *et al.* 1985), all Cu is assumed to substitute for Zn.

The compatibility indices of NMC 64573 ferrilotharmeyerite, on the basis of the Gladstone–Dale relationship (Mandarino 1979) are 0.025 (for the measured density) and 0.054 (for the calculated density), indicating a good to excellent agreement between the physical and chemical data.

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