Obradovicite, a new complex arsenate–molybdate from Chuquicamata, Chile

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ABSTRACT. Obradovicite, ideal formula $H_4CuFe_2(AsO_4)$ $(MoO_4)_5 \cdot 12H_2O$, occurs as fine pea-green clusters on quartz from Chuquicamata, Chile. Obradovicite is ortho-rhombic, space group Pcnm; $a = 15.046$, $b = 14.848$, $c = 11.056$ Å, $Z = 4$. The strongest powder pattern lines are (d Å, I, hkl) 10.565(8)(110), 8.906(10)(101), 7.424(8)(020), 5.733(5)(211), 3.761(3)(400), 3.686(4)(032), 3.466(3)(411), 3.344(4)(420). It is biaxial positive with $\alpha = 1.790$, $\beta = 1.798$, $\gamma = 1.811$, $2V_z = 81°$, $a = Z$, $b = X$, $c = Y$, with strong dispersion and pale yellow pleochroism. Specific gravity is 3.55 (meas.) or 3.68 (calc.) and the Mohs hardness is $2\frac{1}{2}$ with no obvious cleavage. Obradovicite is similar to betpakdalite and sodium-betpakdalite except that it contains essential Cu and K (K > Na).

KEYWORDS: obradovicite, new mineral, arsenates, molybdates, Chuquicamata, Chile.

OXIDIZED molybdenum-bearing rocks have yielded a variety of complex, often poorly described, compounds in addition to the more common species such as jarosite and ferrimolybdate. Recently described species include melkovite (Egorov *et al.*, 1969), betpakdalite (Ermilova and Senderova, 1961), sodium-betpakdalite (Skvortsova *et al.*, 1971), mendozavilite, and paramendozavilite (Williams, 1986). To this list we are now adding a new species, obradovicite.

Obradovicite is pea-green in colour and occurs in dense clusters of platy crystals on brecciated, slightly leached, vein quartz or on crusts of earthy tan jarosite at Chuquicamata, Chile. Tiny wulfenite crystals occur sparingly with obradovicite. It is named for Mr Martin T. Obradovic from whose mineral collection the type material came. The mineralogical data and name have been approved prior to publication by the IMA Commission on New Minerals and mineral Names.

Physical and optical properties. The crystals of obradovicite are pea-green (RHS 149A) in colour with a paler (RHS 149C) streak and are translucent. Individual crystals are tabular and show ortho-rhombic symmetry with the most prominent forms being $a \{100\}$, $m \{110\}$, and $d \{011\}$ (fig. 1). Crystals

occur in dense clusters and are up to 0.1 mm in their largest dimension. No twinning was observed.

Obradovicite has a Mohs hardness of $2\frac{1}{2}$ with no distinct cleavage observed. The specific gravity measured using Clerici solution was 3.55 ± 0.05 compared to a calculated value of 3.68 based on the normalized formula. It is insoluble in cold 1:1 HNO_3 but dissolves rapidly upon heating, readily soluble in cold 1:1 HCl, rapidly turns dull brick orange in 40% KOH, and is unaffected by 20% NH_4OH.
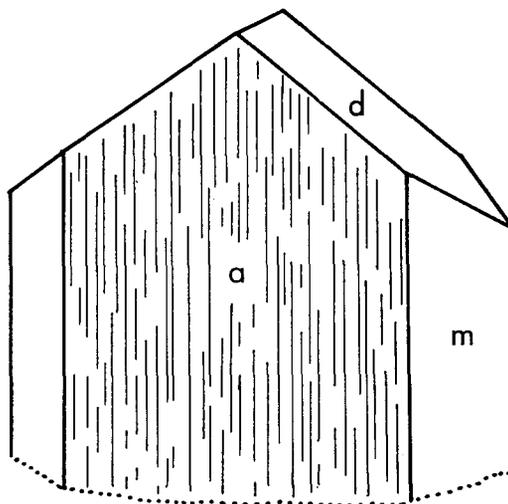

FIG. 1. Obradovicite; crystals are slightly elongated along c and $\{100\}$ faces are striated in the c direction.

Optically, obradovicite is biaxial positive with $2V_z = 81°$. The refractive indices are $\alpha = 1.790$, $\beta = 1.798$, $\gamma = 1.811$ (measured with Na-D line). The optic orientation is $a = Z$, $b = X$, $c = Y$. Dispersion of the optic axes is extreme with $2V = 65°$ at the C line and $112°$ at the G line. The mineral

shows a weak yellow pleochroism with the absorption $Z > X = Y$, and does not flouresce under short-wavelength ultra-violet light.

Chemical analysis. Results of wet chemical analysis performed on portions ranging in weight from 1 to 3.8 mg are summarized in Table I. The analysis corresponds to an empirical formula $H_4(K_{0.71} Na_{0.24})Cu_{0.99}Fe^{+3}_{1.77}As_{0.99}Mo_{5.17}O_{24} \cdot 11.6H_2O$ on the basis of $O = 22$ in the anhydrous part. The ideal formula is $H_4(K,Na)CuFe_2(AsO_4)(MoO_4)_5 \cdot 12H_2O$ with $K > Na$. The ideal formula is similar to both betpakdalite, $H_4CaFe_2(AsO_4)_2(MoO_4)_5 \cdot 12H_2O$ (Ermilova and Senderova, 1961) and sodium-betpakdalite $(Na,Ca)_3Fe_2(AsO_4)_2(MoO_4)_6 \cdot 15H_2O$ (Skvortsova *et al.*, 1971) however, potassium and copper, which are absent in both of the above minerals, are essential in obradovicite.

Table I. Wet chemical analysis of Obradovicite

	1	2
Na_2O	0.56%	0.58%
K_2O	2.48	2.56
CuO	5.85	5.81
Fe_2O_3	10.12	11.66
As_2O_5	8.46	8.39
MoO_3	55.29	52.57
H_2O	18.33	18.42
Total	101.09	99.99

1.   Actual analysis

2.   Theoretical for $H_4(K,Na)CuFe_2(AsO_4)$ $(MoO_4)_5 \cdot 12H_2O$ with K_2O: $Na_2O = 2.933$

X-ray study. Precession data (Mo-$K\alpha$, Zr filtered) showed obradovicite to be orthorhombic space group Pcnm. Powder diffraction data (Cr-$K\alpha$ V filtered) gave the unit cell dimensions $a = 15.046$, $b = 14.848$, $c = 11.056 Å$ with $Z = 4$. The cell constants are distinctly different from Na-betpakdalite which is monoclinic, $a = 11.28$, $b = 19.30$, $c = 17.67 Å$, $\beta = 94° 30'$, $Z = 4$ (Skvortsova *et al.* 1971). No cell dimensions are given for betpakdalite which is also apparently monoclinic (Ermilova and Senderova, 1961). The measured specific gravity of 2.98 and 3.05 for betpakdalite are however consistent with a cell of similar size and unit cell contents. The reported specific gravity of Na-betpakdalite, 2.02, however, does not agree with the calculated value 3.32 based on the cell dimensions and analysis. An indexed powder pattern of obradovicite is given in Table II.

Type specimen. The type specimen of obradovicite is preserved at the Colorado School of Mines

Table II. X-ray powder data for obradovicite

I/Io	d(obs)Å	d(calc)Å	hkl
1	14.848	14.849	010
8	10.565	10.569	110
10	8.906	8.909	101
8	7.424	7.424	020
1	6.650	6.658	120
5	5.733	5.737	211
2	5.531	5.528	002
2	5.284	5.284	220
1	5.165	5.180	012
2	4.763	4.768	221
		4.752	310
2	4.434	4.434	022
1	4.328	4.327	131
1	4.250	4.253	122
		4.156	320
1	4.148	4.135	230
3	3.761	3.762	400
4	3.686	3.685	032
		3.604	140
		3.603	312
2	3.595	3.581	132
1	3.523	3.519	041
3	3.466	3.463	411
4B	3.344	3.355	420
4B	3.220	3.224	123
3	3.080	3.082	042
		3.023	223
3	3.019	3.019	142
		2.971	332
6	2.969	2.970	303
		2.969	050
5B	2.898	2.900	133
2	2.818	2.817	151
5	2.761	2.764	004
		2.762	250
		2.592	413
3B	2.591	2.590	024

Museum and a portion of this material will be on file with the Smithsonian Institution, Washington, DC. A large, very rich specimen is also in the collection of the Mining Museum in Copiapo, Chile.

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