Wupatkiite from the Cameron Uranium District, Arizona, a new member of the halotrichite group

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Abstract

Wupatkiite $(Co,Mg,Ni)Al_2(SO_4)_4{\cdot}22H_2O$ is a new member of the halotrichite group. It occurs 8 miles ESE of Gray Mountain, Arizona, near the prehistoric pueblo dwelling Wupatki. It occurs as cross-fibre veinlets with fibres up to 8mm long. Colour: empire rose (RHS48C), streak white, H. = 1½. G = 1.92, D(calc) = 1.87g/cm^3. Nonpleochroic with $\alpha = 1.477$, $\gamma = 1.484$, Z^fibre axis = 12°. Wet chemistry gave MgO 1.63, CaO 0.10, MnO 0.17, FeO 0.15, NiO 0.52, CuO 0.12, CoO 3.41, Al_2O_3 11.30, SO_3 35.97, H_2O 42.26 (total 95.63%); rem. = montmorillonite and quartz. Parameters refined from the powder pattern are close to those of halotrichite. Wupatkiite is monoclinic $P2_1/c$ with a = 6.189 Å, b = 24.23 Å, c = 21.20 Å, β = 100.33°. Strongest lines are 4.790, 100 (024); 4.295, 27 (140); 3.945, 26 (025); 3.768, 33 (062); 3.494, 92 (124, 063).

KEYWORDS: wupatkiite, halotrichite, new mineral, Gray Mountain, Arizona.

Introduction

THE new mineral was discovered by both authors in June 1993 8 miles ESE of Gray Mountain, Coconino County, Arizona. The locality is not far from the Little Colorado River. It is a post-mine mineral occurring as encrustations on the walls of a shallow open cut that was exploited for uranium during the prospecting frenzy of several decades past. The Cameron uranium district has been described by S. R. Austin (1964) and the type locality is typical of deposits in the area.

Wupatkiite is named for the prehistoric pueblo dwelling Wupatki not far to the south of the discovery site. The new mineral and the mineral name have been approved by the Commission on New Minerals and New Mineral Names of the International Mineralogical Association (IMA). A portion of the type sample will be deposited in the mineralogical collection of the Ecole Nationale Superieure des Mines of Paris.

Occurrence

Primary ores of U–Co–Ni–Mo occur as colloidal sooty black material cementing grits of the Shinarump member in the upper Chinle Formation. The mineralized bed is 1–2m thick and carries considerable carbonized wood trash admixed with quartz-rich detritus. The mineralogy of the primary ore was not studied, but two samples of it gave an averaged analysis as follows (by X-ray fluorescence): Co 404 ppm, Ni 110 ppm, Cu 499 ppm, and Mn 0.66%. Even the freshest-appearing ore has experienced some oxidation and splendent crystals of supergene gypsum are common in the interstices of the grit.

Wupatkiite occurs in slabs of transported sulphate-rich material that have formed a curious concrete-like crust on the wall of the open cut. Much of this material is clastic quartz, detached from the rock and embedded in a maze of cross-fibre veins of pickeringite. The pickeringite veins may change

Mineralogical Magazine, September 1995, Vol. 59, pp. 553–556

TABLE 1. X-Ray powder data for wupatkiite and halotrichite

Present study				JCPDS no. 39-1387	
I/I_o	$d_{obs.}$	$d_{calc.}$	*hkl*	d_{obs}	*hkl*
8	15.8	15.8	011	15.8	011
1	12.2	12.1	020	12.1	020
7	10.43	10.48	002	10.46	021 002
10	9.57	9.58	012	9.58	012
10	7.90	7.90	022	7.91	022
1	6.70	6.68	013	6.71	013
7	6.40	6.38	032		
22	6.03	6.03	023	6.02	023
				5.92	110
7	5.82	5.82	041	5.82	041
1	5.71	5.73	$\bar{1}02$	5.68	$\bar{1}02$ $\bar{1}12$
				5.46	$\bar{1}21$ 111
11	5.27	5.27	033	5.27	033 042
5	5.09	5.10	014	5.11	014 $\bar{1}22$
13	4.947	4.945	$\bar{1}13$	4.93	$\bar{1}13$ 102
				4.86	130
100	4.790	4.790	024	4.78	024
10	4.660	4.663	$\bar{1}23$	4.66	$\bar{1}23$
12	4.586	4.592	131	4.58	131
<1	4.536	4.535	122	4.54	122 043
14	4.384	4.381	034		
2	4.366	4.367	$\bar{1}04$	4.38	$\bar{1}04$
27	4.295	4.295	140	4.29	140
17	4.159	4.161	$\bar{1}42$	4.16	$\bar{1}42$ 113
		4.158	113		
22	4.106	4.108	$\bar{1}24$	4.09	$\bar{1}24$ 141
		4.105	141		
14	3.980	3.986	123	3.987	123
		3.976	053		
26	3.945	3.945	025	3.947	025
8	3.885	3.880	$\bar{1}43$	3.876	$\bar{1}43$
33	3.768	3.766	062	3.751	062 133
				3.705	$\bar{1}52$
8	3.657	3.660	151		
		3.650	104	3.659	104
9	3.608	3.610	114	3.610	$\bar{1}25$
92	3.494	3.495	124	3.484	124 006
		3.493	063		
15	3.441	3.442	152	3.442	045
		3.441	016		
12	3.345	3.342	026		
8	3.322	3.327	134	3.343	134
8	3.272	3.272	161	3.285	$\bar{1}62$ 072
				3.252	$\bar{1}54$
				3.199	064
7	3.205	3.202	$\bar{1}45$	3.239	$\bar{1}45$
				3.199	064
8	3.168	3.169	$\bar{1}26$	3.172	$\bar{1}26$ 115
5	3.101	3.099	073	3.112	073
1	3.072	3.074	$\bar{2}02$	3.062	$\bar{2}02$ $\bar{2}11$
		3.068	$\bar{2}11$		
9	3.043	3.044	200	3.037	080
		3.042	$\bar{1}36$		
9	3.018	3.015	046	3.021	046 210
12	2.962	2.965	$\bar{1}64$	2.964	$\bar{1}64$ 017
13	2.887	2.887	$\bar{1}46$		
		2.884	074	2.889	074
<1	2.858	2.855	221		
12	2.826	2.826	172	2.820	106 $\bar{1}27$
		2.825	056		
11	2.779	2.777	083	2.779	083 $\bar{2}24$
6	2.763	2.761	231	2.751	212 $\bar{2}42$
6	2.715	2.717	$\bar{1}81$		
		2.713	$\bar{1}74$	2.715	$\bar{1}74$ 222
13	2.679	2.677	$\bar{1}82$	2.677	$\bar{1}82$
7	2.634	2.636	$\bar{2}25$	2.643	232
		2.635	066		
9	2.607	2.607	092	2.611	
		2.607	$\bar{2}51$		
		2.606	213		
5	2.576	2.575	182		
6	2.562	2.562	223		
		2.561	$\bar{2}35$		
8	2.550	2.550	$\bar{1}75$		
		2.549	146		
5	2.513	2.512	$\bar{2}16$		
		2.512	251		
1	2.487	2.489	$\bar{1}84$		
3	2.468	2.467	$\bar{2}45$		
		2.467	$\bar{1}91$		
5	2.455	2.456	$\bar{2}61$		
		2.453	127		
2	2.431	2.431	260		
		2.431	156		
8	2.396	2.398	067		
		2.397	224		
3	2.383	2.382	$\bar{1}76$		
<1	2.343	2.344	175		
5	2.299	2.299	$\bar{2}72$		
		2.296	262		
7	2.278	2.284	086		
2	2.247	2.245	$\bar{2}65$		
4	2.230	2.234	225		
3	2.192	2.192	$\bar{2}47$		
		2.191	$\bar{1}95$		
1	2.157	2.158	$\bar{2}82$		
2	2.123	2.124	087		
<1	2.100	2.102	216		
3	2.079	2.080	$\bar{2}84$		
		2.079	226		
2	2.057	2.058	255		
		2.056	195		
		2.055	$\bar{3}12$		
2	2.039	2.041	$\bar{2}76$		
7	2.012	2.011	$\bar{3}14$		
2	1.969	1.970	$\bar{1}97$		
		1.968	330		
3	1.951	1.953	$\bar{3}42$		
1	1.921	1.922	312		
2	1.891	1.888	$\bar{3}53$		
6	1.873	1.872	350		
5	1.858	1.857	$\bar{3}36$		
		1.857	$\bar{2}87$		

abruptly to wupatkiite along strike, or separate veins of the two minerals may run in parallel. On the surface of the encrustation small spherules of moorhouseite are present. Other minerals identified during the study are nickel-boussingaultite, hydrohonessite, magnesiocopiapite, and ilsemannite. These minerals were not found in the cobalt-rich material, however.

Physical and optical properties

Single crystals of wupatkiite are mere fibres 5–10 μm in diameter but up to 8mm long. All of the material found occurs as cross-fibre veins though occasionally the fibres may extend into a void forming tufts of delicate twisted fibres. The Mohs hardness of massive material is 1½. The luster is silky in asbestiform masses.

The colour of the wupatkiite is empire rose (RHS 48C). Paler colours occur at the junction with pickeringite in the veins but these are merely transitory. The streak of the mineral is white. The specific gravity was determined with a Berman Balance in toluene (at 26°C) using a 6.80 mg sample and is 1.92.

Isolated fibres show a maximum extinction angle to Z of 12°. They also display a cleavage oblique (about 70°) to the length of the crystallites. Pleochroism is not visible in such minute crystals but in parallel bundles of them it is a very pale pink with the strongest colour parallel to the length of the bundle. The fibre bundles give an impression of polysynthetic twinning but this is not the case. Rather, the orientation of fibres about their length appears to be at random.

The indices of refraction measured as n_g and n_p are 1.484 and 1.477 respectively. White light was employed for the measurement and evidently dispersion is weak.

Crystallography

Owing to the minuteness of the fibres, single crystal work was not feasible and cell parameters were obtained by least squares refinement of the d_{hkl} values from the X-ray powder pattern. The pattern was obtained with a Philips diffractometer (Cu-$K\alpha$) and also with a 360 mm diameter Guinier-de Wolff Nonius camera (Cu-$K\alpha$). Quartz was added as an internal standard. With both instruments the d_{hkl} values were similar; intensities given here are those recorded by the diffractometer.

X-ray powder patterns of wupatkiite and halotrichite match very well, so the refinement was performed in several stages using the parameters given in JCPDS PDF no. 39-1387 for halotrichite from Hungary. In order to avoid ambiguity, owing to the large values of b and c, lines which could be indexed without any doubt were used first.

Wupatkiite is monoclinic $P2_1/c$ with a = 6.189 (4) Å, b = 24.234 (10) Å, c = 21.204 (10) Å, and β = 100.33 (5). The indexed powder pattern is given in Table 1 and compared with the data presented for halotrichite. A few faint lines corresponding to clay admixed with the sample are omitted.

Chemistry

Water was determined in the closed tube (SAW) and it was observed as well. Using an 18.33mg sample the water loss was 40.45%. Wupatkiite melts readily producing a bright pink syrupy liquid; when all water has been lost, a dense blue slag of distinctive colour (Wistaria blue, RHS 92B) is the result.

Chemical analysis was performed on several tens of milligrams using atomic absorption spectroscopy for Ni, Fe, Mg, Cu, and Al, colorimetry for Co, ICP.ES for Ca, and gravimetry for S. Water was determined independently (HV) by the Penfield method.

Analytical results and molecular ratios calculated on the basis Co + Ni + Mg + ... + Al = 3 are given in Table 2. The total of 95.63% is readily explained as due to the presence of insoluble quartz and montmorillonite residue. The latter mineral caused turbidity of the initial solution as a suspended solid.

TABLE 2. Chemical analysis and molecular ratios for wupatkiite

	Wt. %	Mol. ratio
CoO	3.41	0.424
MgO	1.63	0.376
NiO	0.52	0.065
MnO	0.17	0.022
FeO	0.15	0.019
CaO	0.10	0.017
CuO	0.12	0.014
Al_2O_3	11.30	2.063
SO_3	35.97	4.181
H_2O	42.26	21.83
Total	95.63	

These data lead to the simplified formula $(Co,Mg)Al_2(SO_4)_4.22H_2O$ with cobalt in excess over magnesium. A pure cobalt end-member of the series has not yet been found.

A second analysis of cobalt was performed by atomic absorption to verify the predominance of cobalt, using another sample taken from the original material, and it gave 3.24% Co.

Concluding remarks

Wupatkiite is a new member of the halotrichite group for it is the first such mineral found with cobalt the predominant cation. It gives a Co:Mg ratio of 1.126:1 vs. a ratio of Co:Mg = 0.325:1 for 'kasparite', a cobaltian pickeringite described by Dubanskŷ (1956). Kasparite contains 2.52% MgO and 1.52% CoO.

Acknowledgements

The authors thank Héléne Vachey for the chemical analysis and Marie-Claude Sichère for collecting the diffractometer data.

References

Austin, S.R. (1964) *Mineralogy of the Cameron Area, Coconino County, Arizona.* U.S. Atomic Energy Comm. RME-99, Tech. Inf. Serv., Oak Ridge, 99.

Dubanskŷ, A. (1956) Pžispěvky K Poznani geochemie sekundarnich sulfatu III, Sulfaty z Dubniku u Prešóva. *Chem. Lasty Praha*, **50,** 1347-61.

[*Manuscript received 31 October 1994*]