Jurbanite, a new post-mine aluminum sulfate mineral from San Manuel, Arizona

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Abstract

Jurbanite, $AlSO_4OH \cdot 5H_2O$, is a new species discovered at the San Manuel underground porphyry copper mine, Pinal County, Arizona. It occurs as tiny, clear, colorless crystals in a post-mine stalactitic assemblage which includes epsomite, hexahydrite, pickeringite, starkeyite, and other hydrated sulfates. The crystals are monoclinic and show only {110} and {011}. Morphological measurements gave $\phi(110) = 56.44°$, $\phi(011) = 18.79°$, and $\rho(011) = 34.53°$, from which $a:b:c = .679:1:.647$ and $\beta = 102.2°$. The mineral is biaxial and optically negative with $\alpha = 1.459$, $\beta = 1.473$, $\gamma = 1.483$. The optic angle is $2V(\text{obs}) = 80°$; $2V(\text{calc}) = 80°$. The optical orientation is $b = Y$, $a \wedge Z = -5°$. Unit cell data are: $P2_1/n$; $a = 8.3913(14)$, $b = 12.4846(18)$, $c = 8.1545(13)$Å, and $\beta = 101.90(3)°$. The X-ray derived axial ratio is $a:b:c = .67213:1:.65317$. The most intense powder X-ray lines are: 3.723 **100** *130,031;* 4.013 **90** *121,002;* 6.80 **80** *110,011;* 4.954 **80** *120,021;* 4.494 **80** *12$\bar{1}$;* 5.74 **70** *11$\bar{1}$;* 3.922 **70** *210;* 3.823 **70** *21$\bar{1}$,012.*

The mineral is brittle and exhibits no discernible cleavage. Specific gravity is $1.786 \pm 0.008(\text{obs})$ and $1.828(\text{calc})$, on the basis of 4 formula units in the cell. The ideal chemical composition is established as $AlSO_4OH \cdot 5H_2O$ by X-ray proof that jurbanite is identical with that compound (Johansson, 1962). The mineral is named for Mr. Joseph E. Urban who first observed it.

Introduction

The new mineral species herein described is one of at least seven phases in post-mine stalactitic material found on the 2075 foot level of the Magma Copper Company's San Manuel mine, Pinal County, Arizona. The minute, clear crystals were recognized as unusual in such a mineralogical mélange by Mr. Joseph E. Urban, a mineral collector residing in Tucson, Arizona. X-ray diffraction shows the mineral to be identical with the compound $Al_2(OH)_2(H_2O)_8(SO_4)_2 \cdot 2H_2O$ (Johansson, 1962). The mineral is named in honor of Mr. Urban. The name and species have been approved by the IMA Commission on New Minerals and Mineral Names.

Occurrence

Jurbanite occurs as small, clear, colorless crystals with at least six other phases in post-mine stalactitic material deposited on lagging and overhead pipes. Other identified phases are epsomite, hexahydrite, pickeringite, starkeyite, and $NH_4Fe(SO_4)_2 \cdot 12H_2O$. One additional phase, a white, fluffy, powdery mineral, was not identified from its powder pattern and

apparently represents at least one other species, although it may be a mixture of more than one phase. Jurbanite is found in intimate association with the unidentified fluffy mineral as isolated crystals and as clumps of crystals. Exceptional clumps may contain about 50 to 100 tiny individual crystals.

We obtained the specimen containing these minerals only after it had undergone some dehydration. The original material, which apparently formed by precipitation from mine water at about 27°C and 100 percent relative humidity, was probably dominantly epsomite and the precursor to the fluffy mineral, together with minor pickeringite and jurbanite. Dehydration then apparently produced hexahydrite and starkeyite from the epsomite, and the fluffy material from its precursor. It is not certain if jurbanite and pickeringite were original precipitates or the products of the decomposition of original phases; however both occur as clear crystals and an origin as primary precipitates may thus be favored. Jurbanite shows no sign of decomposition under the normal low humidity conditions prevailing in the southwestern desert. The phase $NH_4Fe(SO_4)_2 \cdot 12H_2O$ occurs as very thin, yellowish crusts on starkeyite. The source of ammo-
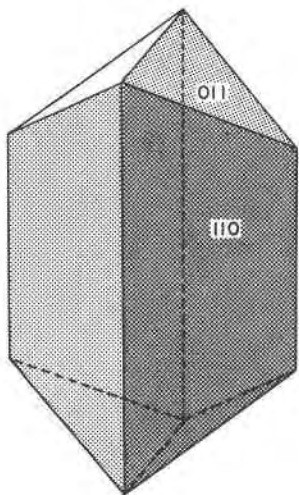
FIG. 1. Typical morphological development of jurbanite.

nium ion is probably NH_4NO_3 used for blasting in the mine.

Physical, crystal, and optical properties

Crystals of jurbanite are colorless and transparent and vary in size from about 0.03 to 0.3 mm in maximum dimension and are generally about twice as long as wide. Crystals are brittle and fracture without apparent cleavage. The Mohs scale hardness is about two and one half. The specific gravity was determined in toluene on the Berman density balance by averaging repeated measurements made with the powder basket attachment on a mass of single crystals weighing 7 mg. A value of 1.786 ± 0.008 was obtained.

The crystals exhibit relatively high luster and, although they appear to be sharp, detailed microscopic, optical goniometric, and single crystal X-ray examination shows them to be rather imperfect, a crystal usually being composed of an almost parallel intergrowth of several individuals. Crystal morphology is very simple; only the forms {110} and {011} were observed. {110} is usually slightly dominant as shown in Figure 1. The axial ratio and β resulting from the averaging of inferior optical goniometric measurements of six faces on each of four crystals are: $a:b:c = 0.679:1:0.647$ and $\beta = 102.2°$. These are based on average measurements with c polar as follows: $\phi(110) = 56.44°$ (14 faces), $\phi(011) = 18.79°$ (10 faces), and $\rho(011) = 34.53°$.

The optical properties of jurbanite were determined in white light with the aid of a spindle stage. It was found to be biaxial negative with indices of refraction $\alpha = 1.459$, $\beta = 1.473$, and $\gamma = 1.483$, all ±0.002. The birefringence is thus 0.024. The optic angle is $2V(obs) = 80°$; $2V(calc) = 80°$. The optic orientation is $b = Y$, $a \wedge Z = -5°$, and is shown in Figure 2. Data of the physical parameters are summarized in Table 1.

X-ray diffraction results

A powder diffraction pattern was prepared using $CuK\alpha$ ($\lambda = 1.5418$ Å) radiation and a 114.59 mm Debye-Scherrer camera with Wilson mounting. Relative intensities were obtained by visual comparison to a standard scale. The resulting pattern was shown to match that of $Al_2(OH)_2(H_2O)_8(SO_4)_2 \cdot 2H_2O$ (Johansson, 1962) by the use of a computer pattern search program (Nichols, private communication).[1] The two patterns are compared in Table 2.

Single crystals were examined by oscillation and Weissenberg techniques using $CuK\alpha$ radiation. Systematic omissions on Weissenberg films, coupled with the diffraction symmetry $2/m$, showed the space group to be $P2_1/n$. Measurements of 2θ for 97 Weissenberg reflections were used to refine the unit cell by the method of least squares. A quartz single crystal ($a = 4.9131$Å at 22°C) was used for film calibration. The cell dimensions are: $a = 8.3913(14)$, $b = 12.4846(18)$, $c = 8.1545(13)$Å, and $\beta = 101.90(3)°$. The X-ray axial ratio is $a:b:c = 0.67213:1:0.65317$.
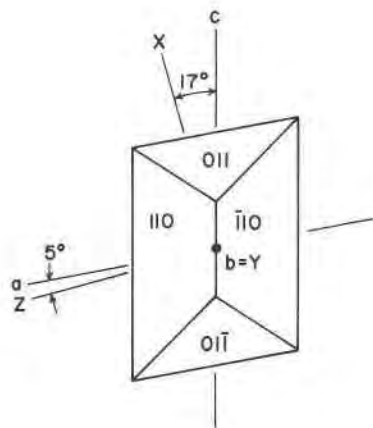
FIG. 2. The optic orientation of jurbanite.

[1] Our initial search through the JCPDS file failed to show a match of the jurbanite pattern with any listed compound. Subsequently, Monte C. Nichols of Sandia Laboratories, Livermore, California, processed the pattern data through his search program and obtained a match with the compound $Al_2(OH)_2(H_2O)_8(SO_4)_2 \cdot 2H_2O$. Our failure to establish the match initially seems to arise from the fact that Johansson (1962) reported the intensities of the eight strongest lines as "S".

TABLE 1. Data for Jurbanite

Crystal system	Monoclinic	Forms	{110},{011}
Color	Colorless	Hardness	2-1/2
α	1.459	Optic sign	Negative
β	1.473	B	.024
γ	1.483	2V	80°
Optic orientation	b = Y, a∧Z = −5°		
$\underline{a}$	8.3913(14)Å*	β	101.90°(3)
$\underline{b}$	12.4846(18)	Cell volume	835.92
$\underline{c}$	8.1545(13)		
$\underline{a}$:$\underline{b}$:$\underline{c}$ (X-ray)	.67213:1:65317		
$\underline{a}$:$\underline{b}$:$\underline{c}$ (morphology)	.679:1:647		
Space group	$\underline{P2_1/n}$		
Composition	$AlSO_4OH \cdot 5H_2O$	Cell content	4
Density(obs.)	1.786(8)	Density(calc.)	1.828

* Numbers in parentheses are estimated standard errors and refer to the last places.

These results are compared with those of Johansson (1962) in Table 3.

Chemical composition

Comparison of the X-ray diffraction data proves beyond a reasonable doubt that jurbanite is chem-

TABLE 2. Comparison of X-Ray Data of $Al_2(OH)_2(H_2O)_8(SO_4)_2 \cdot 2H_2O$ and Jurbanite

$Al_2(OH)_2(H_2O)_8(SO_4)_2 \cdot 2H_2O$			Jurbanite				
I(obs)	d(obs)	hkl	I(obs)	I(calc)	d(obs)	d(calc)	hkl
m	6.90	011	80B	43	6.80	6.86	110
s	6.76	110		58		6.72	011
vw	6.44	10$\bar{1}$		2		6.42	10$\bar{1}$
s	5.73	11$\bar{1}$	70	72	5.74	5.71	11$\bar{1}$
vvw	5.22	101	10	14	5.23	5.21	101
m	4.976	021	80	36	4.954	4.969	120
m	4.935	120		64		4.917	021
vvw	4.828	111		8		4.809	111
s	4.481	12$\bar{1}$	80	83	4.494	4.476	12$\bar{1}$
s	4.002	121	90	55	4.013	4.000	121
s	3.992	200		65		3.990	002
s	3.909	012	70	74	3.922	3.900	210
m	3.817	11$\bar{2}$	70	44	3.823	3.811	21$\bar{1}$
w	3.807	210		22		3.800	012
vw	3.748	21$\bar{1}$		9		3.740	11$\bar{2}$
s	3.713	031	100	100	3.723	3.712	130
m	3.692	130		31		31690	031
w	3.365	220	30	16	3.376	3.361	022
w	3.218	211	25	7	3.227	3.216	112
		20$\bar{2}$		8		3.211	20$\bar{2}$
m	3.114	21$\bar{2}$	40	25	3.127	3.110	21$\bar{2}$
vvw	2.939	221		3		2.937	122
				3		2.917	140
vvw	2.908	140		7		2.907	041
m	2.887	13$\bar{2}$	70B	20	2.891	2.884	23$\bar{1}$
				12		2.880	032
m	2.857	22$\bar{2}$		4		2.856	22$\bar{2}$
		23$\bar{1}$		13		2.854	13$\bar{2}$
w	2.709	11$\bar{3}$	30	14	2.714	2.704	31$\bar{1}$
s	2.602	310	50	7	2.612	2.601	013
		231		18		2.599	132
w	2.554	212	50	25	2.556	2.550	212
vw	2.546	23$\bar{2}$		6		2.542	23$\bar{2}$
vvw	2.466	21$\bar{3}$		6		2.462	31$\bar{2}$
vw	2.444	24$\bar{1}$	30	6	2.456	2.442	14$\bar{2}$
		103		7		2.439	301
vvw	2.432	31$\bar{2}$		3		2.430	21$\bar{3}$
vw	2.407	222	20	14	2.412	2.404	222
			5	1	2.337	2.330	32$\bar{2}$
			10	3	2.291	2.287	330
				3		2.277	241
			10	4	2.244	2.241	033
				2		2.238	24$\bar{2}$
vvw	2.144	30$\bar{3}$	20	2	2.151	2.150	33$\bar{2}$
				10		2.141	30$\bar{3}$
vvw	2.131	33$\bar{2}$		7		2.129	23$\bar{3}$

TABLE 2, Continued

I(obs)	d(obs)	hkl	I(obs)	I(calc)	d(obs)	d(calc)	hkl
vvw	2.119	250		6		2.116	052
		15$\bar{2}$	40	6	2.112	2.110	31$\bar{3}$
		25$\bar{1}$		4		2.106	15$\bar{2}$
vvw	2.108	133		15		2.104	331
			5	3	2.055	2.058	340
vvw	2.027	32$\bar{3}$		3		2.025	32$\bar{3}$
		340		1		2.024	043
vvw	2.010	41$\bar{1}$		1		2.011	11$\bar{4}$
		152	40B	9	2.009	2.008	251
				3		2.001	40$\bar{2}$
vw	2.001	242		7		2.000	242
		251		9		1.997	152
vvw	1.959	40$\bar{2}$	5	5	1.967	1.957	34$\bar{2}$
		243					
vvw	1.938	41$\bar{2}$	5	2	1.923	1.937	12$\bar{4}$
vvw	1.923	42$\bar{1}$		5		1.922	341
		143					
m	1.900	420	30	14	1.905	1.898	143
		34$\bar{1}$					
		16$\bar{2}$					
vvw	1.848	260	10	3	1.845	1.845	062
		053					
w	1.800	430	40	13	1.801	1.797	41$\bar{3}$
		31$\bar{4}$					
		34$\bar{3}$					
m	1.766	261	30	10	1.767	1.764	162
		26$\bar{2}$					
vvw	1.746	153					
		32$\bar{4}$	35	8	1.746	1.744	42$\bar{3}$
				3		1.743	170

(Plus 21 additional lines to d = 1.299.)

Data for $Al_2(OH)_2(H_2O)_8(SO_4)_2 \cdot 2H_2O$ are from Johansson (1962).

Observed data for jurbanite were obtained with Ni filtered CuKα radiation in a 114.59 mm camera with Wilson mounting. Calculated intensities are based on the crystal structure of Johansson, and calculated d are based on the cell found in the present study. Indexing of the jurbanite pattern is based on the conventional ($c<a$) cell used in the present work. The transformation matrix from Johansson's cell to the jurbanite cell is 001/0$\bar{1}$0/100.

ically and structurally identical with the compound described by Johansson (1962). Further chemical verification was obtained from qualitative chemical tests. An emission spectrographic analysis showed major Al, very minor Fe, Mg, Mn, Si, Cu, and Ca, and traces of B, Ni, and Cr.[2] Loss on ignition is comparable to the water content found by Johansson in his analysis of the compound. A qualitative microchemical test for selenium gave a positive result. Examination of the unit cell parameters of the sulfate and of the selenate isotype, $Al_2(OH)_2(H_2O)_8(SeO_4)_2 \cdot 2H_2O$, for which $a = 8.26$, $b = 12.76$, $c = 8.48$Å, and $\beta = 102.1°$ (Johansson, 1962), shows that jurbanite cannot contain more than small amounts of Se. Cast in conventional mineralogical form, the idealized composition of jurbanite is $4[AlSO_4OH \cdot 5H_2O]$. The density calculated on the basis of this unit cell content is 1.828. The lower value obtained by the measurement of specific gravity (1.786) in part may be due to partial dehydration of the mineral which was exposed to

[2] Spectrographic analysis and loss on ignition performed by Pacific Spectrochemical Laboratory, Los Angeles.

TABLE 3. Comparison of Unit Cell and Axial Ratio of
$Al_2(OH)_2(H_2O)_8(SO_4)_2 \cdot 2H_2O$ and Jurbanite

$Al_2(OH)_2(H_2O)_8(SO_4)_2 \cdot 2H_2O$ (Johansson, 1962)		Jurbanite	
		X-ray	morphology
$\underline{a}$	8.15Å	$\underline{c}$	8.1545Å	
$\underline{b}$	12.48	$\underline{b}$	12.4846	
$\underline{c}$	8.40	$\underline{a}$	8.3913	
$\overline{\beta}$	101.9°	$\overline{\beta}$	101.90°	102.2°
$\underline{a/b}$	.6530	$\underline{c/b}$	.65317	.647
$\underline{c/b}$	.6731	$\underline{a/b}$	.67213	.679

conditions of low atmospheric relative humidity for some months before the measurements were made.

Note added in proof

Khademite (Bariand, Berthelon, Cesbron, and Sadrzadeh, 1973) has the same chemical formula as jurbanite, and the two are thus dimorphs.

References

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JOHANSSON, GEORG (1962) The crystal structure of $[Al_2(OH)_2(H_2O)_8]$ $(SO_4)_2 \cdot 2H_2O$ and $[Al_2(OH)_2(H_2O)_8](SeO_4)_2 \cdot 2H_2O$. *Acta Chem. Scand.* **16,** 403–420.