Wilcoxite and lannonite, two new fluosulphates from Catron County, New Mexico

S. A. WILLIAMS AND F. P. CESBRON

Phelps Dodge Corporation, Douglas, Arizona, USA

ABSTRACT. Both species were found as post-mine minerals in the Lone Pine mine, Catron County, New Mexico. They occur encrusting ores of fluorite–pyrite with khademite and gypsum.

Wilcoxite is clear, colourless to white, $H = 2$, $D = 1.58$. Abundant as spongy masses of perfect to somewhat rounded crystals. Stubby prisms are bounded by $\{100\}$, $\{010\}$, $\{110\}$, $\{\bar{1}10\}$, and $\{0\bar{1}1\}$. Triclinic $P\bar{1}$ or $P1$ with $a = 14.90$, $b = 6.65$, $c = 6.77$ Å, $\alpha = 117°\ 26'$, $\beta = 100°\ 35'$, $\gamma = 80°\ 10'$, and $Z = 1$. Strongest lines are 5.654(9) 110, $11\bar{1}$, 4.908(10) $1\bar{1}1$, 4.371(6) 201, 210, and 3.384(5) $11\bar{2}$, 111. Biaxial negative with $\alpha = 1.424$, $\beta = 1.436$, $\gamma = 1.438$, $2V_\alpha = 48°$. Analysis gave MgO 6.61 %, Al_2O_3 8.13, Fe_2O_3 0.46, MnO 0.13, SO_3 27.50, H_2O 56.40, F 3.48, total 101.24 (corr. for O ≡ F) leading to $MgAl(SO_4)_2F \cdot 18H_2O$.

Lannonite is usually as chalky white aggregates of microscopic tetragonal (square) platelets; $H = 2$, $D = 2.22$. Indexed as tetragonal $a = 6.84$, $c = 28.01$ Å, and $Z = 1$. Strongest lines are 13.98(10) 002, 4.840(7) 110, 3.980(5) 116, and 3.456(7) 017. Uniaxial positive with $\omega = 1.460$ and $\varepsilon = 1.478$. Analysis gave CaO 12.06 %, MgO 4.46, Al_2O_3 11.06, SO_3 34.40, H_2O 32.00, F 9.44, total 99.45 (corr. for O ≡ F) leading to $HCa_4Mg_2Al_4(SO_4)_8F_9 \cdot 32H_2O$.

Both minerals and mineral names have been approved by the Commission on New Minerals and New Mineral Names, IMA.

New analytical data for the khademite associated with these species are presented.

SAMPLES of these new minerals were first found and brought to us for examination by R. A. Jenkins in the course of geologic studies of the area. The Lone Pine mine, where the minerals occur, is a small one that produced some gold in the past, the gold occurring with pyrite and native tellurium in a prominent silicified structure. Tellurites are common in the oxide zone, including rajite, another species recently discovered in the area (Williams, 1979). The primary ores have been briefly described by Ballmer (1932).

The adit of the Lone Pine mine cuts pyritic and fluorite-rich veins and rubble zones within the main silicified structure, and the sulphate assemblage has formed in these. Indeed, it seems likely that the sulphates were forming in the vicinity without man's intervention, but since they are readily water-soluble they have been washed into the adit, concentrating there. The sulphates form not only within the breccia zones but even in pools of water on the adit floor, or as efflorescences on the back and walls. Gypsum is the most abundant, occurring as minute needles covering the rock and even as thin crusts where stagnant pools have begun to dry out. Khademite occurs on occasion as thick chalky crusts, but its appearance may be seasonal; it has been found only in the summertime, vanishing in cooler weather. Wilcoxite and lannonite are stable year round and also survive nicely indoors long after they are collected.

Wilcoxite frequently occurs alone as large porous masses of loosely attached crystals. They are best formed in certain dried pools, forming crusts of nearly pure mineral up to 150 cm thick. Lannonite is far more restricted in occurrence, found only on or near rock that is fluorite-rich as small white warts closely associated with gypsum.

Physical properties and morphology. Wilcoxite crystals are limpid and clear inclining to milky white. Generally they show rounded edges as though partially melted. When well-formed the crystals are distinctly triclinic. Examination on the two-circle goniometer showed the forms: $\{010\}$, $\{110\}$, $\{100\}$, $\{\bar{1}10\}$, and $\{0\bar{1}1\}$. The crystal measured is shown in fig. 1. The morphological elements are given in Table I. These were calculated on the basis of the precession-camera data. The morphological data agreed well but the faces were not sufficiently perfect to justify duplicate calculations.

The Mohs hardness of wilcoxite is 2. The specific gravity was found to be 1.58 ± 0.01 using a 21.6 mg sample on the Berman balance (six trials in toluene).

A curious feature of wilcoxite is its behaviour when viewed under the microscope. If a hot or bright light source is employed, crystals dissolve in their water of crystallization. They become shape-
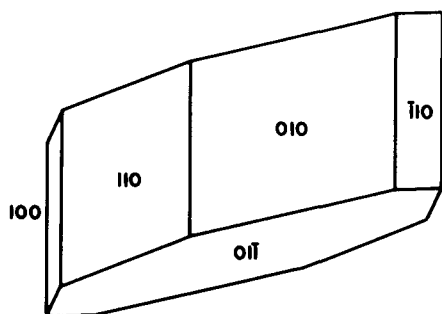
FIG. 1. Idealized crystal of wilcoxite.

TABLE I. *Angle table for wilcoxite*

$a:b:c = 2.23600:1:1.01415$
$\alpha = 117.55°; \beta = 100.33°; \gamma = 80.26°$
$p_0:q_0:r_0 = 0.40800:1.01230:1$
$\lambda = 63.53°; \mu = 83.36°; \nu = 95.67°$
$p'_0 = 0.46330; q'_0 = 1.1495$
$x'_0 = 0.18224; y'_0 = 0.50619$

	ϕ	ρ		ϕ	ρ
010	0	90	$\bar{1}10$	−21.09	90
110	22.67	90	$0\bar{1}0$	164.18	33.76
100	95.67	90			

less tubes with a tough outer skin filled with liquid, and seem to writhe in agony on a smooth glass surface. If pierced with a needle they leak briefly, then heal themselves quickly.

Lannonite is invariably bright chalky white. It forms nodules composed of unnumerable tiny (10–20 μm) square plates. The nodules give a hardness of 2. Using a 3.79 mg sample on the Berman balance (in toluene) a specific gravity of 2.22 was found.

Chemistry. Wilcoxite is easily dissolved by cold water and dilute acids. Taken into solution with water, it does not recrystallize upon drying. The evaporated water leaves behind a tough, clear pliable film that may be peeled off. If the water drop is treated with $AgNO_3$ arborescent silver immediately forms. Microchemical tests showed the presence of sulphate. Cations were found by DC arc spectrography.

Lannonite also gives a strong sulphate test and cations were found spectrographically. It is insoluble in water but is readily dissolved by cold, dilute acids. Both mineral species evolve water and HF in the closed tube. The results of wet chemical analyses of the minerals are given in Table II.

Crystallography. Wilcoxite is triclinic and was

TABLE II. *Chemical analyses of wilcoxite and lannonite*

Wilcoxite (%)			Lannonite (%)	
MgO	6.61	6.87	CaO	12.06	12.23
Al_2O_3	8.13	8.69	MgO	4.46	4.40
Fe_2O_3	0.46	—	Al_2O_3	11.06	11.11
MnO	0.13	—	SO_3	34.40	34.95
SO_3	27.50	27.29	H_2O	32.00	31.91
H_2O	56.40	55.27	F	9.44	9.32
F	3.48	3.24			
				103.42	103.92
	102.71	101.36	−O F	3.97	3.92
−O F	1.47	1.36			
			Total	99.45	100.00
Total	101.24	100.00			

1. For wilcoxite, Mg on 3392 μg and 10472 μg; F on 10472 μg; Al and Mg on 25007 μg; SO_3 on 3730 μg; Fe and Al on 10417 μg. Water on 11.431 mg (Penfield). M. Duggan analyst.
2. Col. 2; theory for $MgAl(SO_4)F \cdot 18H_2O$.
3. For lannonite, Ca on 773, 958, and 1120 μg; Al on 958 μg; F on 958 and 1120 μg; SO_3 on 1120 μg; water on 2.232 mg (Penfield).
4. Col. 4, theory for $HCa_4Mg_2Al_4(SO_4)_8F_9 \cdot 32H_2O$.

first investigated by the precession method. The values obtained were refined using the powder data (114 mm camera, Cr-$K\alpha$) and are: $a = 14.90$ Å, $b = 6.65$, $c = 6.77$, $\alpha = 117°\ 26'$, $\beta = 100°\ 35'$, $\gamma = 89°\ 10'$. Using the formula proposed in Table II and this cell, the calculated density is 1.67 g/cm^3. An indexed powder pattern is presented in Table III.

Lannonite was never found in crystals sufficiently large for X-ray single crystal work.

TABLE III. *X-ray powder data for wilcoxite. 114 mm camera, Cr-$K\alpha$*

$I_{est.}$	$d_{meas.}$ (Å)	$d_{calc.}$ (Å)	hkl	$I_{est.}$	$d_{meas.}$ (Å)
3	14.55	14.58	100	2	3.278
4	5.877	5.877	010	3	3.210
9	5.654	{ 5.643	$11\bar{1}$	3B	3.141
		{ 5.647	110	3	3.082
2	5.304	5.304	101	$\frac{1}{4}$	3.016
$\frac{1}{2}$	4.978	4.972	$21\bar{1}$	4	2.980
10	4.908	4.907	$1\bar{1}1$	1	2.958
$\frac{1}{2}$	4.813	4.813	210	1	2.918
6	4.371	{ 4.369	$2\bar{1}0$	1	2.874
		{ 4.368	201	4	2.834
4	4.117	4.120	$31\bar{1}$	4	2.804
1	4.058	4.059	$2\bar{1}1$	2	2.749
3	3.645	3.644	400	1	2.718
2	3.575	{ 3.576	$3\bar{1}0$	1	2.685
		{ 3.564	301	$\frac{1}{2}$	2.656
$\frac{1}{4}$	3.525	—	n.i.	2	2.635
3	3.482	3.486	011	2B	2.522
		{ 3.379	$11\bar{2}$	+21 lines to	
5	3.384	{ 3.394	$41\bar{1}$	$d = 1.918$ none	
		{ 3.381	111	with $I_{est.}$ more	
				than 3.	

TABLE IV. *X-ray powder data for lannonite. 114 mm camera, Cr-Kα*

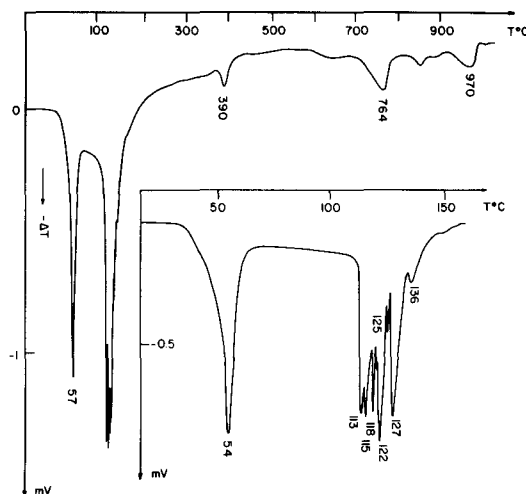| $I_{est.}$	$d_{meas.}$	$d_{calc.}$	hkl	$I_{est.}$	$d_{meas.}$
10	13.98	14.00	002	3	2.420
7	4.840	4.838	110	1	2.183
4	4.666	4.668	006	3	2.164
3	4.570	4.573	112	2	2.068
1	4.334	4.334	015	2	2.054
5	3.980	3.980	114	2	2.000
3	3.857	3.856	016	1	1.982
3	3.501	3.501	008	2	1.957
7	3.456	3.454	017	2	1.848
3	3.417	3.421	020	1	1.840
5	3.325	3.323	022	3	1.801
4	2.908	2.907	213	3	1.712
1	2.835	2.836 / 2.833	118 / 019		
4	2.760	2.759	026		

FIG. 2. Main curve—DTA chart for the decomposition of wilcoxite at 10 °C/min. Inset—a similar curve using a heating rate of 5 °C/min to show the complexity of water loss.

Measured under the microscope they are sensibly tetragonal. Also, a tetragonal cell was found with $a = 6.84$ Å, $c = 28.01$ and this cell indexes the powder data nicely. These data are given in Table IV. Using the cell, with $Z = 1$, the calculated density is 2.32 g/cm³.

Both minerals yield calculated densities higher than the measured values. For wilcoxite the calculated value is 5.6% higher; for lannonite 4.5% higher. The problem is likely due to fluid inclusions or other non-essential water in the crystals.

Optics. The indices for wilcoxite are $\alpha = 1.424$, $\beta = 1.436$, $\gamma = 1.438$. The calculated $2V_\alpha$ is 48°. There is no noticeable dispersion. The indices of lannonite are $\omega = 1.460$, $\varepsilon = 1.478$. It is presumably uniaxial but this could not be verified. At least basal sections show absolutely no interference colour.

Thermal behaviour. Only a DTA curve was obtained for wilcoxite for we feared pollution of the microbalance enclosure by SO₃ and F that would ensue from a TGA run. The DTA curve shown in fig. 2 was obtained from a 3.2 mg sample heated at a rate of 10 °C/min. It shows two major endothermic peaks, one simple, one complex, both indicating loss of water. The point at which fluorine is lost is uncertain. The smaller plot (see inset, fig. 2) was another run, using the same quantity, with a heating rate of 5 °C/min. and a faster chart speed to show the complexity of water loss.

Khademite. The presence of abundant khademite at the locality was fortunate because one of us (FPC) was involved in its description and because there had been some uncertainty about its formula in the original description owing to lack of material at the type locality. In the original paper (Bariand et al., 1973) the formula was taken as $Al(SO_4)(OH)\cdot$ 5H₂O. The SO₃ and H₂O were determined by TGA. The later determination of the structure of khademite (Bachet et al. 1981) led to the formula $Al(SO_4)F \cdot 5H_2O$. Arguments for this included a residue of electronic density at the site of supposed OH, failure to find the hydrogen atom in OH although all other protons had been located, and the shortness of bond between supposed OH and Al.

To test the formula proposed by Bachet et al. (1981) samples of khademite from Lone Pine were submitted to analysis for Al and F (M. Duggan, analyst) giving 8.3% Al and 5.53% F (averaged from two and three analyses respectively). These results give the ratio Al:F = 1:0.946. The low absolute values were due to contamination by colloidal smectite. The data support $Al(SO_4)F \cdot 5H_2O$ for khademite.

Discussion. Wilcoxite is named for William Wilcox who discovered the district in 1879. He was killed by a band of Apaches led by Chief Victorio near Alma, New Mexico, on 28 April 1880 (Looney, 1968). Lannonite is named for Dan Lannon who staked important claims in the district in 1893.

Portions of type material will be donated to the British Museum (N.H.) and the Geological Museum, University of Arizona.

S. A. WILLIAMS AND F.P.CESBRON

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