

# Creaseyite, $\text{Cu}_2\text{Pb}_2(\text{Fe},\text{Al})_2\text{Si}_5\text{O}_{17}\cdot 6\text{H}_2\text{O}$ a new mineral from Arizona and Sonora

SIDNEY A. WILLIAMS

Phelps Dodge Corporation, Douglas, Arizona

AND RICHARD A. BIDEAUX

Computing Associates, Tucson, Arizona

**SUMMARY.** Creaseyite was first noted in specimens from Tiger, Arizona, and was then found at Wickenburg, Arizona, and Caborca, Sonora, prior to description. It is an oxide zone mineral occurring with wulfenite, willemite, mimetite, chrysocolla, wickenburgite, and ajoite. The composition is  $[\text{Cu}_2\text{Pb}_2(\text{Fe},\text{Al})_2\text{Si}_5\text{O}_{17}\cdot 6\text{H}_2\text{O}]$ . Colour Agathia green (R.H.S. 142B) with pale streak,  $H = 2\frac{1}{2}$ ,  $D_{\text{meas}} = 4.1$ , calc. 4.01. Crystals are orthorhombic with  $a$  12.483,  $b$  21.395,  $c$  7.283.  $Z = 4$ .  $2V_\gamma$  69° meas;  $\alpha$  1.737,  $\beta$  1.747,  $\gamma$  1.768.

CREASEYITE was first examined by X-ray diffraction in 1967 on specimens from Tiger, Arizona, during a study of minerals from that mine by Richard A. Bideaux. No identification was made but the X-ray powder data were given to Miss Eva Fejer (B.M.N.H.) for her file of unknowns. Creaseyite was again found at Wickenburg in 1968 by S. A. Williams. Checking its powder pattern (in 1970) against Miss Fejer's file showed a match with the Tiger unknown, resulting in this joint study. Creaseyite also occurred in one sample from the Collins vein (Tiger) in a sample collected by Dr. S. C. Creasey during his study (Creasey, 1950). And early during this study, samples collected by H. A. Mendoza from near Caborca, Sonora, also proved to contain creaseyite. With few exceptions this work is based on Tiger material, for only tiny amounts were found at the other two localities.

*Occurrence.* At the type locality creaseyite occurs in a breccia of andesite fragments loosely cemented with iron oxides and large wulfenite crystals. Other species apt to be present include fluorite, as small crystals scattered on fracture surfaces in the breccia, murdochite, mimetite, diopside, willemite, and descloizite. Creaseyite occurs as densely packed spherules of small size (less than 1 mm diameter) on the wulfenite or, more commonly, perched directly upon rock. Often there is a kernel of earthy hisingerite, hematite, and goethite at the centre of these spherules. Creaseyite also occurs as matted fibres lying between spherules, occupying cavities in wulfenite or cerussite, or loosely scattered on diopside. It appears to be a late oxidation product but it is difficult to ascertain its age relation to descloizite, willemite, and murdochite and it can only be noted that it is younger than wulfenite, cerussite, and diopside. Fluorite, descloizite, and murdochite have been noted perched on creaseyite.

At the Potter-Cramer mine creaseyite was found sparingly in a few large chunks of breccia on the dump; it was also only in these pieces that ajoite was found. These are

breccias of small andesite fragments cemented by massive sugary fluorite. Cavities in the breccia may be lined with wickenburgite or with ajoite and creaseyite. Creaseyite seems confined to cavities in iron-oxide-stained portions of the breccia. Sprays of radiating fibres up to 0.3 mm long by 0.05 mm line the walls of cavities and may be overgrown and replaced by ajoite; later chrysocolla replaces both minerals. Thin veinlets of mimetite cut all other features.

The gangue at Caborca, Sonora is also a breccia of andesite fragments. These are silicified and cemented by sugary quartz, baryte, and chlorite stained with hematite. Portions of the breccia contain relicts of pyrite, galena, sphalerite, and chalcopyrite while other areas are thoroughly oxidized. Although mimetite, willemite, cerussite, and desclozite were noted, creaseyite tends to occur alone in cavities and eventually is replaced by chrysocolla.

*Physical properties.* At all localities creaseyite occurs as fibrous crystals either in spherules or as matted, twisted, and intertwined needles. The maximum size noted is 0.5 mm long, the maximum width 0.05 mm. The colour is Agathia green (R.H.S. 142B and/or C) for Tiger material. For the other two localities the colour is similar but a match for Cyprus green (R.H.S. 140C) was best for Potter-Cramer material. The streak is invariably a similar but whiter colour. The general appearance resembles that of mixite. The Mohs hardness is  $2\frac{1}{2}$  for spherules; individual crystals could be harder but are much too small to test. No fluorescence was observed in long or short wave U.V. The specific gravity was determined by sink-float methods in slightly diluted Clerici solution in comparison with measured standards. A value of  $4.1 \pm 0.1$  was found at 23.6 °C.

*Chemistry.* Spectrographic analyses of creaseyite showed the following elements: Si, Mg, Pb, Fe, Cu, Ca, Al and, in one of two samples, traces of As (due to contamination by mimetite). Microchemical tests demonstrated the absence of  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$ ,  $\text{Br}^-$ ,  $\text{I}^-$ ,  $\text{NO}_3^-$ , and  $\text{CO}_3^{2-}$ . A sample fused in NaOH was dissolved and examined by ion-specific electrode to demonstrate the absence of F. The presence of water was shown by the Penfield method. Subsequent analysis by atomic absorption showed that Ca and Mg were trace constituents.

The results of quantitative analyses are shown in Table I. As the footnotes indicate, Cu, Pb, and Fe can be freed from the structure by leaching in hot or cold 1:1  $\text{HNO}_3$ . All analyses for Cu, Pb, Zn, and Fe were done by atomic absorption in 1:1  $\text{HNO}_3$ , regardless of the mode of chemical attack. Analyses for  $\text{Fe}_2\text{O}_3$  are somewhat high and variable, doubtless due to minor and unavoidable contamination by iron oxides. Silicon was determined by U.V. spectrophotometry following fusion in NaOH using nickel crucibles. Small corrections were made for Si in the crucibles and in the NaOH. Aluminium was determined by AC spark spectroscopy in solution. The analytical results lead to the formula  $\text{Cu}_2\text{Pb}_2(\text{Fe,Al})_2\text{Si}_5\text{O}_{17}\cdot 6\text{H}_2\text{O}$ .

In hot 1:1  $\text{HNO}_3$  creaseyite slowly turns white—this is a silica sponge showing optical properties similar to the original material but with vastly decreased birefringence and refractive indices; cations are released to the solution. The process occurs very slowly in cold 1:1  $\text{HNO}_3$ . Similar behaviour occurs in hot 1:1 HCl, but in cold 20 %  $\text{H}_2\text{SO}_4$  creaseyite is readily leached of cations. The mineral is soluble

in hot 1:1 aqua regia. It is unaffected by cold 40 % KOH but quickly turns brown when heated.

In the closed tube creaseyite turns brown, readily losing all water by 550 °C. Heated to ignition it fuses to a rusty brown slag stippled with minute beads of copper.

*Crystallography.* Little is known of the morphology of creaseyite except the information gleaned from thin-section study. Using the orientation of the X-ray cell, crystals are elongate on [001] and flattened on {010}, a plane of difficult cleavage. Viewed along [100], the terminations are blunt, implying the absence of any {*okl*}

TABLE I. *Chemical analyses of creaseyite*

	1	2	3	4	5	6	7	8		9	10
CuO	14.5	13.0	13.4	13.5	13.1	—	13.5	13.7	Cu	8.1	8
ZnO	—	—	1.5	0.9	1.6	0.9	1.2	—	Zn	0.7	—
PbO	37.9	38.5	—	25.8	35.8	—	37.0	38.4	Pb	7.9	8
Fe <sub>2</sub> O <sub>3</sub>	—	—	12.2	13.0	11.6	—	12.3	12.3	Fe <sup>3+</sup>	7.4	8
Al <sub>2</sub> O <sub>3</sub>	—	—	—	—	—	—	2.1†	1.8	Al	0.2	
SiO <sub>2</sub>	—	—	—	—	—	—	25.5*	25.8	Si	20.3	20
H <sub>2</sub> O	—	—	—	—	—	—	8.8‡	9.3	O	68.7	68
							100.4	100.0	H <sub>2</sub> O	23.4	24

1 and 2, on 199 and 191 μg by atomic absorption in 1:1 HNO<sub>3</sub>

3, on 140 μg leached in HF then run in 1:1 HNO<sub>3</sub> by atomic absorption

4 and 5, on 377 and 671 μg, leached in conc. HNO<sub>3</sub>, run in 1:1 HNO<sub>3</sub> by atomic absorption

6, on 295 μg, leached in cold 1:1 HNO<sub>3</sub>

7, mean of all analyses

8, calculated for Cu<sub>2</sub>Pb<sub>2</sub>(Fe,Al)<sub>2</sub>Si<sub>3</sub>O<sub>17</sub>·6H<sub>2</sub>O with Fe:Al = 4:1

9, empirical unit-cell contents

10, idealized unit-cell contents

\* 25.6 and 25.4 % on 226 and 603 μg by U.V. spectrophotometry after NaOH fusion.

† 1.9 and 2.3 % by AC spark spectrography on 570 μg leached in conc. HNO<sub>3</sub>.

‡ 8.6 and 8.9 % by Penfield method on 595 and 2474 μg at 550 °C; further ignition of the second sample gave an additional 1.2 % loss (see text).

Analyst, Miss M. Duggan, Phelps Dodge Corporation, except Al<sub>2</sub>O<sub>3</sub> H<sub>2</sub>O by L. A. Talley, Phelps Dodge Corporation.

forms, but viewed along [010] the terminations are steeply tapered, implying the presence of {*hol*} with  $h \gg l$ , probably as vicinal forms.

Creaseyite gives crisp X-ray powder patterns, sensibly identical for all three localities. Indexed patterns are presented in Table II.

Rotation and Weissenberg photographs established approximate cell dimensions that were refined from the indexed powder pattern. For Tiger material this gave  $a$  12.483 ± 0.006 Å,  $b$  21.395 ± 0.011,  $c$  7.283 ± 0.004; Potter-Cramer material gave  $a$  12.497,  $b$  21.375,  $c$  7.283. Owing to the minuteness of the single crystal used, single-crystal patterns were faint. The diffraction symbol in the orientation chosen (so  $c < a < b$ ) is *mmmCb*. The calculated density is 4.01 g/cm<sup>3</sup> for  $Z = 4$ .

*Optics.* In thin section creaseyite bears a resemblance to conichalcite although it is a bit more yellow in over-all colour. Fibres invariably exhibit parallel extinction and are length slow. The optic orientation is  $\alpha \parallel [100]$ ,  $\gamma \parallel [001]$ , and since the largest

cross-section is normal to [010] the only figures obtainable are flash figures. Indices of refraction determined for NaD light are  $\alpha$  1.737,  $\beta$  1.747,  $\gamma$  1.768 (all  $\pm 0.002$ ).  $2V_\gamma$  is  $69^\circ$  meas,  $70^\circ$  calc. Dispersion is weak with  $v > \rho$ . Pleochroism is in yellow-greens with  $\gamma$  a yellow-green,  $\alpha$  a similar but yellower colour, and  $\beta$  a clear watery green;  $\gamma = \alpha > \beta$ .

TABLE II. *Indexed X-ray powder data for creaseyite*

Tiger				Wickenburg			
<i>I</i>	<i>d</i> <sub>meas</sub>	<i>d</i> <sub>calc</sub>	<i>hkl</i>	<i>I</i>	<i>d</i> <sub>meas</sub>	<i>d</i> <sub>calc</sub>	<i>hkl</i>
10	10.726	10.782	110	10	10.755	10.788	110
		10.697	020			10.687	020
3	6.200	6.192	130	3	6.201	6.190	130
5	6.024	6.035	111	4	6.037	6.037	111
		6.020	021			6.019	021
4	5.352	5.349	040	2	5.352	5.344	040
3	4.720	4.718	131	2	4.723	4.717	131
2	4.327	4.333	221	1	4.320	4.335	021
5	4.067	4.061	240	3	4.075	4.061	240
		4.084	310			4.089	310
2	3.642	3.641	002	1/2	3.641	3.642	002
1/2	3.592	3.594	330				
5B	3.555*	3.566	060	4B	3.554	3.562	060
		3.562	311			3.565	311
		3.547	241			3.547	241
3	3.448	3.450	112	3	3.451	3.450	112
		3.447	022			3.447	022
4B	3.216	3.203	061	3B	3.213	3.200	061
		3.223	331			3.225	331
5	3.013	3.010	042	6	3.013	3.009	042
		3.018	222			3.018	222
5	2.982	2.983	350	5	2.989	2.983	350
2	2.761	2.760	351	1	2.764	2.761	351
5	2.696	2.695	440	5	2.696	2.697	440
4	2.674	2.674	080	2	2.670	2.672	080
2	2.557	2.558	332	2	2.560	2.559	332
	plus 22 additional lines to 1.686; none with $I_{\text{est}} > 3$				plus 12 additional lines to 1.712; none with $I_{\text{est}} > 3$		

Cr-K $\alpha$  radiation; 114 mm Straumanis camera; intensities estimated visually.

\* Almost resolved to two lines at 3.57 and 3.54 Å

*Additional comments.* All three creaseyite localities are characterized by the presence of oxide-zone silicates (other than chrysocolla) such as ajoite, diopside, wickenburgite, and willemite (not hemimorphite). The presence of willemite rather than hemimorphite in these localities probably indicates higher activities of SiO<sub>4</sub> species than normal, as suggested previously by Pough (1941), for clearly the temperature control found by Roy and Mumpton (1956) is not the factor favouring willemite in these occurrences. Additionally, the presence of other silicates, not usually found in oxide assemblages, again points to more abundant SiO<sub>4</sub> species during oxidation.

This is almost certainly the mineral described as beudantite in Peterson (1938b) as 'yellowish-green tufts of fibers associated with wulfenite and limonite . . . in the upper levels of the Collins mine'. Peterson (1938a) noted that 'the samples from Mammoth also gave a microchemical test for copper . . .'.

The specimens from Tiger, numbering 10, probably contain a gramme of creaseyite. Four specimens from the Potter-Cramer mine and one from Caborca combined add only a few tens of milligrammes to the world supply.

Type specimens will be deposited at the British Museum (Natural History) and with the collection of the Department of Geosciences, University of Arizona.

The species is named in honour of Dr. S. C. Creasey in recognition of his geological studies on Arizona localities, particularly the Mammoth-St. Anthony mine (Tiger).

We are grateful to Marjorie Duggan of Phelps Dodge Corporation for her efforts in the difficult analytical work. Our thanks to Richard L. Flagg for the opportunity to include two large and fine specimens of creaseyite in this study.

#### REFERENCES

- CREASEY (S. C.), 1950. Arizona Zinc and Lead deposits; Geology of the St. Anthony (Mammoth) area, Pinal County, Arizona. *Ariz. Bur. Mines Bull.* **156**, 63-84.
- PETERSON (N. P.), 1938a. *Geology and Ore Deposits of the Mammoth Mining Camp, Pinal County, Arizona*. Ph.D. dissertation, Univ. Ariz.
- 1938b. Geology and ore deposits of the Mammoth mining camp area, Pinal County, Arizona. *Ariz. Bur. Mines Bull.* **144**.
- POUGH (F. M.), 1941. Occurrence of Willemite. *Amer. Min.* **27**, 92-102.
- ROY (D. M.) and MUMPTON (F. A.), 1956. Stability of minerals in the system ZnO-SiO<sub>2</sub>-H<sub>2</sub>O. *Econ. Geol.* **51**, 432-43.

[Manuscript received 20 August 1974]