1896

UTAHITE, A NEW MINERAL AND ASSOCIATED COPPER TELLURATES FROM THE CENTENNIAL EUREKA MINE, TINTIC DISTRICT, JUAB COUNTY, UTAH

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ABSTRACT

Utahite, idealized as $Cu_5Zn_3(Te^{6+}O_4)_4(OH)_8 \cdot 7H_2O$, *is triclinic, space-group choices* $P1$ *or* $P\bar{1}$, *with refined unit-cell parameters from powder data:* $a = 8.794(4)$, $b = 9.996(2)$, $c = 5.660(2)$ Å, $\alpha = 104.10(2)°$, $\beta = 90.07(5)°$, $\gamma = 96.34(3)°$, $V = 479.4(3)$ Å^3, a:b:c = 0.8798:1:0.5662, Z = 1. *The strongest five reflections in the X-ray powder pattern are [dÅ(I)(hkl)]: 9.638(100)(010); 8.736(50)(100); 4.841(100)(020); 2.747(60)(002); 2.600(45)*$(\bar{3}01, \bar{3}1\bar{1})$. *The mineral is an extremely rare constituent on the dumps of the Centennial Eureka mine, Tintic district, Juab County, Utah, where it occurs both as isolated 0.6-mm clusters of tightly bound aggregates and as 0.2-mm sheaves. The former are found on drusy white quartz; the latter are on dark brown quartz. Associated minerals include cesbronite and two undefined Cu-Zn-Te-bearing secondary phases. Individual crystals of utahite are prismatic to thin tabular to blade-like, are subhedral to euhedral, and are elongate [001]. They are up to 0.3 mm in longest dimension, with a length-to-width ratio of approximately 20:1. Forms are {010} major and {001} minor. The mineral is transparent to translucent, pale blue to a deeper blue-green, with a pale blue streak and an uneven fracture. Utahite is vitreous, brittle and nonfluorescent; hardness (Mohs) 4–5; calculated density 5.33 g/cm*^{3} *(for empirical formula), 5.34 g/cm*^{3} *(for idealized formula). In polished section, utahite is slightly bireflectant and nonpleochroic. In reflected plane-polarized light in air it is very pale brown, with ubiquitous pale emerald-green internal reflections. The anisotropy is unknown because it is masked by the internal reflections. Averaged electron-microprobe analyses yielded* $CuO = 25.76$, $ZnO = 15.81$, $TeO_3 = 45.47$, H_2O *(by difference) [12.96], total = [100.00] weight %, corresponding to* $Cu_{4.98}Zn_{2.99}(Te^{6+}O_4)_{3.98}(OH)_{7.98} \cdot 7.1H_2O$, *based on O = 31. Both* H_2O *and (OH) were confirmed by infrared spectroscopy. The mineral name is for the state in which the Centennial Eureka mine is located.*

INTRODUCTION

Utahite, ideally $Cu_5Zn_3(Te^{6+}O_4)_4(OH)_8 \cdot 7H_2O$, is a newly recognized mineral species. It was first encountered during megascopic examination, scanning electron energy-dispersive study and routine X-ray powder diffraction characterization of a suite of secondary Cu-

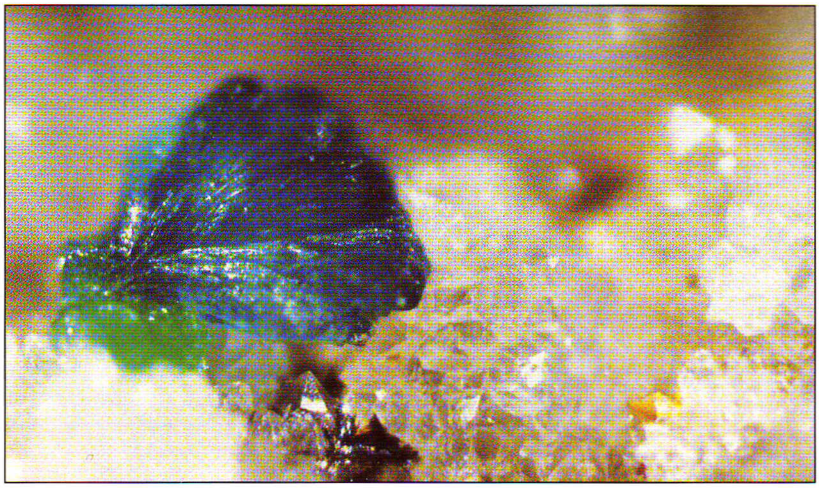


Figure 1. **Isolated compact cluster of utahite crystals in parallel to subparallel growth, associated with green cesbronite. The magnification is 17.4x and the utahite cluster is 0.4 mm in longest dimension.**

and Te-bearing minerals. These minerals were originally collected by one of us (MCJ) in July 1992 from the mineralized dumps adjacent to the Centennial Eureka mine, Tintic district, Juab County, Utah. Utahite is the fifth of at least seven new secondary Cu- and Te-bearing phases from this locality to be characterized thus far.

The mineral name is for Utah, the state in which the Centennial Eureka mine is located; the mineral and mineral name have been approved by the Commission on New Minerals and Mineral Names, I.M.A. Cotype material (three specimens and one SEM stub) are housed in the Systematic Reference Series of the National Mineral Collection at the Geological Survey of Canada, Ottawa, under catalogue number 67415. The polished section used for both the electron-microprobe analyses and the attempted reflectance study is preserved at the Natural History Museum, Great Britain, as BM 1994, 99.

THE LOCALITY

The Centennial Eureka mine is located at latitude 39°56′38″ N, longitude 112°07′18″ W, in the Tintic mining district about 1 mile southwest of the town of Eureka, which is situated about 70 miles south of Salt Lake City in Juab County, Utah. The main shaft and dumps are in the NW$\frac{1}{4}$ of Section 24, R3W, T10S, on the *Eureka, Utah* 7.5-minute quadrangle. The large and magnificent headframe, over 70 feet tall, was constructed from timbers reportedly imported from Norway.

The Centennial Eureka mine (originally known as the Blue Rock mine, probably because of the abundant copper minerals) was opened in 1876 and operated for over 50 years, until its closure in 1927. According to the Centurion Mines Corporation, the present lease-holder on the mine, it yielded a total of over 656,000 ounces of gold, 23.9 million ounces of silver, and 79.5 million pounds of copper, making it second in production among the district's mines (after the Chief Consolidated).

The large ore pipes in the mine are considered massive replacement deposits, and have been mined to a depth of 2,200 feet. The extensive workings cover 20 levels and consist of at least 20 miles of drifts, cross-cuts, raises and shafts. Some of the huge stopes are 125 feet wide and over 1,000 feet long. Ore still exists below the deep water table (about 2,000 feet below the surface), mining having ceased at an economic cut-off.

Most of the microminerals currently known from the mine were collected from the dumps, and precise original locations underground are unknown.

ASSOCIATED MINERALS

Utahite has been identified on five specimens collected from the dumps. The immense dumps of the mine were largely removed and processed for their low-grade concentrations of gold in late 1991. At this time, a wide variety of mineralized specimens were exposed, including several boulders which contain the new Cu- and Te-bearing assemblages. Additional information regarding the geology, mineralogy and history of the Centennial Eureka mine and surrounding environs can be found in Marty *et al.* (1993) and in Roberts *et al.* (1994).

Utahite was observed in two of these boulders and must be considered extremely rare; only about 10 µgm of the mineral is presently known. On the holotype material, the mineral occurs both as isolated clusters to 0.6 mm of tightly bound parallel to subparallel aggregates of numerous single crystals (Fig. 1), and as numerous 0.2-mm isolated and grouped sheaves in small vugs of crumbly, drusy white to colorless and dark brown quartz. These sheaves are, in turn, composed of numerous individual crystals that are in parallel growth (Fig. 2). Some of these sheaves are also found as bowtie-like divergent arrangements. Associated minerals are leaf-green crystals of cesbronite, UK-4 (Marty *et al.*, 1993) in spherules and botryoidal crusts, and an undefined Cu-Zn-Te-bearing pale green botryoidal crust. Additional Cu- and Te-bearing secondary minerals that have been identified by X-ray powder-diffraction methods on similar specimens include mcal-

Figure 2. **Scanning electron photomicrograph of sheaves of utahite.**

pineite (Roberts *et al.*, 1994), frankhawthorneite (Roberts *et al.*, 1995; Grice and Roberts, 1995), jensenite (Roberts *et al.*, 1996a; Grice *et al.*, 1996), leisingite (Roberts *et al.*, 1996b), xocomecatlite, dugganite, quetzalcoatlite and one additional Cu-Te-As-bearing phase which is currently under investigation. A listing of many primary and secondary minerals identified at the Centennial Eureka mine has been published by Marty *et al.* (1993). The copper minerals are listed here in Table 1. Utahite is a secondary mineral that formed from the breakdown of primary Cu-, Zn- and Te-bearing sulfides.

Table 1. **Copper-bearing minerals identified from the Centennial Eureka mine.**

Copper-Tellurates	
Cesbronite	$Cu_5^{2+}(Te^{4+}O_3)_2(OH)_6\cdot 2H_2O$
Dugganite	$Pb_3(Zn,Cu^{2+})_3(Te^{6+}O_6)(AsO_4)(OH)_3$
Frankhawthorneite	$Cu_2Te^{6+}O_4(OH)_2$
Jensenite	$Cu_3Te^{6+}O_6\cdot 2H_2O$
Leisingite	$Cu(Mg,Cu,Fe,Zn)_2Te^{6+}O_6\cdot 6H_2O$
Mcalpineite	$Cu_3^{2+}Te^{6+}O_6\cdot H_2O$
Quetzalcoatlite	$Zn_8Cu_4{}^{2+}(Te^{4+}O_3)_3(OH)_{18}$
Utahite	$Cu_5Zn_3(Te^{6+}O_4)_4(OH)_8\cdot 7H_2O$
Xocomecatlite	$Cu_3^{2+}Te^{6+}O_4(OH)_4$
UK-4 (Marty *et al.*, 1993)	$(Cu,Zn)(TeO)(AsO_4)Cl\cdot xH_2O$
Unnamed	Cu-Te-As
Unnamed	Cu-Te-Zn
Other Copper Minerals	
Antlerite	$Cu_3(SO_4)$
Aurichalcite	$(Zn,Cu)_5(CO_3)_2(OH)_6$
Azurite	$Cu_3(CO_3)_2(OH)_2$
Brochantite	$Cu_4(SO_4)(OH)_6$
Chalcocite	Cu_2S
Chalcopyrite	$CuFeS_2$
Chenevixite	$Cu_2^{2+}Fe_2^{3+}(AsO_4)_2(OH)_4\cdot H_2O$
Chrysocolla	$(Cu,Al)_2H_2Si_2O_5(OH)_4\cdot nH_2O$
Clinoclase	$Cu_3(AsO_4)(OH)_3$
Conichalcite	$CaCu^{2+}(AsO_4)(OH)$
Connellite	$Cu_{19}Cl_4(SO_4)(OH)_{32}\cdot 3H_2O$
Copper	Cu
Cornubite	$Cu_5(AsO_4)_2(OH)_4$
Cornwallite	$Cu_5(AsO_4)_2(OH)_4\cdot H_2O$
Covellite	CuS
Cuprite	Cu_2O
Duftite	$PbCu(AsO_4)(OH)$
Enargite	Cu_3AsS_4
Gartrellite	$Pb(Cu^{2+},Fe^{2+})_2(AsO_4,SO_4)_2(CO_3,H_2O)_{0.7}$
Jalpaite	Ag_3CuS_2
Malachite	$Cu_2(CO_3)(OH)_2$
Mixite	$BiCu_6(AsO_4)_3(OH)_6\cdot 3H_2O$
Olivenite	$Cu_2(AsO_4)(OH)$
Philipsburgite	$(Cu,Zn)_6(AsO_4,PO_4)_2(OH)_6\cdot H_2O$
Polybasite	$(Ag,Cu)_{16}Sb_2S_{11}$
Posnjakite	$Cu_4(SO_4)(OH)_6\cdot H_2O$
Rosasite	$(Cu,Zn)_2(CO_3)(OH)_2$
Strashimirite	$Cu_8(AsO_4)_4(OH)_4\cdot 5H_2O$
Tenorite	CuO
Tetrahedrite	$(Cu,Fe)_{12}(Sb,As)_4S_{13}$
Tyrolite	$CaCu_5(AsO_4)_2(CO_3)(OH)_4\cdot 6H_2O$
Zeunerite	$Cu(UO_2)_2(AsO_4)_2\cdot 10\text{–}16H_2O$

PHYSICAL PROPERTIES

Individual crystals are prismatic (in tightly bound aggregates) to thin tabular to blade-like (in sheaves), elongate [001], subhedral to euhedral, up to 0.3 mm in longest dimension (average about 0.2 mm), and have a length-to-width ratio of approximately 20:1. SEM study of several clusters of sheaves show that individual crystals average 0.5 x 15 x 75 microns in size. No obvious forms were observed megascopically; SEM photomicrographs of bladed crystals in sheaves show major {010} and minor {001}.

Single crystals are pale blue while clusters tend to be a deeper blue-green color. The streak is pale blue. Twinning was not observed megascopically, nor was it found in X-ray single-crystal studies. The mineral possesses a vitreous to pearly luster, is translucent, brittle, and is nonfluorescent under both longwave and shortwave ultraviolet light. The fracture appears to be uneven for single crystals; clusters tend to fracture parallel to the elongation of individuals. The Mohs hardness is estimated to be 4 to 5. Neither cleavage nor parting was observed megascopically. The density could not be measured owing to the small size of available specimens and the dearth of material.

X-RAY DIFFRACTION

Precession single-crystal studies, employing Zr-filtered Mo radiation, show that utahite is triclinic with space-group choices

Table 2. **X-ray powder diffraction data for utahite.**

*I*est.	$d\text{Å}_{(meas.)}$	$d\text{Å}_{(calc.)}$	*hkl*	*I*est.	$d\text{Å}_{(meas.)}$	$d\text{Å}_{(calc.)}$	*hkl*
100	9.638	9.631	010	5	2.272	2.277	$\bar{3}21$
50	8.736	8.737	100			2.276	$13\bar{2}$
40	6.862	6.873	$\bar{1}10$	3	2.241	2.239	$\bar{3}3\bar{1}$
40	6.172	6.132	110	3	2.206	2.212	$\bar{2}12$
30	5.488	5.487	001	* 40	2.165	2.166	022
100	4.841	4.816	020	5	2.116	2.109	212
20	4.380	4.368	200	* 20	2.081	2.080	410
40	4.152	4.161	$\bar{2}10$	* 10	2.048	2.050	$23\bar{2}$
20	3.995	4.002	$\bar{1}11$	1	2.006	2.008	$\bar{3}31$
* 40	3.822	3.818	210	* 25	1.969	1.970	$\bar{3}4\bar{1}$
10	3.203	3.211	030	10	1.927	1.928	$\bar{1}50$
		3.197	$\bar{2}11$			1.926	050
* 40	3.129	3.131	$\bar{1}30$	5	1.887	1.884	$15\bar{1}$
* 10	3.030	3.035	$\bar{1}3\bar{1}$	5	1.870	1.863	$\bar{1}32$
5	2.978	2.968	211	3	1.840	1.842	$\bar{2}50$
30	2.912	2.912	300	20	1.787	1.792	$\bar{1}5\bar{2}$
		2.908	130			1.781	$34\bar{1}$
* 20	2.827	2.828	$01\bar{2}$	* 5	1.755	1.755	$\bar{3}41$
* 60	2.747	2.744	002	20	1.720	1.722	$\bar{3}5\bar{1}$
* 30	2.681	2.684	$02\bar{2}$			1.717	430
45	2.600	2.604	$\bar{3}01$	5b	1.672	1.670	203
		2.598	$\bar{3}1\bar{1}$			1.669	232
*10b	2.520	2.523	$31\bar{1}$	* 15	1.623	1.623	042
* 40	2.478	2.477	$\bar{3}2\bar{1}$	* 10	1.605	1.605	060
* 20	2.409	2.408	040	* 30	1.586	1.587	341
* 20	2.348	2.347	$\bar{1}3\bar{2}$	* 30	1.563	1.563	$06\bar{2}$
* 25	2.307	2.304	$32\bar{1}$				

* = reflections used for unit-cell refinement
— 114.6 mm Debye-Scherrer powder camera
— Cu radiation, Ni filter (λCu*K*α = 1.54178 Å)
— intensities estimated visually; b = broad line
— not corrected for shrinkage and no internal standard
— indexed with *a* = 8.794, *b* = 9.996, *c* = 5.660 Å,
α = 104.10°, β = 90.07°, γ = 96.34°

$P1$ or $P\bar{1}$ (diffraction aspect $P*$). The refined unit-cell parameters: $a = 8.794(4)$, $b = 9.996(2)$, $c = 5.660(2)$ Å, $\alpha = 104.10(2)°$, $\beta = 90.07(5)°$, $\gamma = 96.34(3)°$, $V = 479.4(3)$ Å^3, $a{:}b{:}c = 0.8798{:}1{:}0.5662$ are based on 20 powder reflections representing d-values between 3.822 and 1.563 Å for which unambiguous indexing was possible, based on visual inspection of precession single-crystal films.

The powder data (Table 2) are unique and bear no resemblance to any other inorganic phase listed in the Powder Diffraction File. Other Cu-Zn-Te oxide-hydrates known to occur in nature are quetzalcoatlite and tlalocite. As mentioned earlier, the former is also found at the Centennial Eureka occurrence.

The crystal used for the aforementioned precession single-crystal study was also used in an attempt to do crystal-structure analysis. Unfortunately, the crystal proved too small to yield any meaningful statistics, even after prolonged exposure to the X-ray beam (L. A. Groat, personal communication, 1995). No larger single crystals are currently available for structure analysis.

CHEMISTRY

Utahite was analyzed chemically by means of a Cameca SX-50 electron microprobe, using a 20-kV operating voltage, a 20-nA beam current, a 10-second count rate, and a 5-micron beam diameter. The standards employed were synthetic Cu metal (for Cu), synthetic Zn metal (for Zn) and synthetic Te metal (for Te). A wavelength-dispersive microprobe scan indicated the absence of any elements with atomic number greater than 9 except those reported here. The paucity of pure material prevented the quantitative determination of water. However, its presence as both molecular H_2O and (OH) was confirmed by infrared spectroscopic analysis; H_2O was therefore calculated by difference. The valence state of tellurium was assumed to be Te^{6+}; no secondary Te-bearing mineral from this occurrence has been shown by crystal-structure analysis to possess Te^{4+} in its structure. Crystal-structure analysis of cesbronite from this locality indicates a probable revision of its chemical formula, symmetry and cell parameters will be required (T. S. Ercit, personal communication, 1995). These results indicate that cesbronite is most likely a tellurate.

The average result of six analyses gave CuO = 25.76 (range 24.21–26.51), ZnO = 15.81 (range 14.78–16.92), TeO_3 = 45.47 (range 44.16–46.42), H_2O (by difference) = [12.96], total = [100.00] weight %. The empirical formula, on the basis of O = 31, is $Cu_{4.98}Zn_{2.99}(Te^{6+}O_4)_{3.98}(OH)_{7.98}\cdot 7.1H_2O$. The ideal formula, $Cu_5Zn_3(Te^{6+}O_4)_4(OH)_8\cdot 7H_2O$, requires CuO = 25.78, ZnO = 15.83, TeO_3 = 45.54, H_2O = 12.85, total = 100.00 weight %. The density, calculated for the empirical formula with Z = 1, is 5.33 g/cm^3 and the calculated density for the idealized formula is 5.34 g/cm^3. Utahite is the third reported Cu-Zn-Te-bearing oxide hydrate, after quetzalcoatlite and tlalocite.

INFRARED-ABSORPTION STUDY

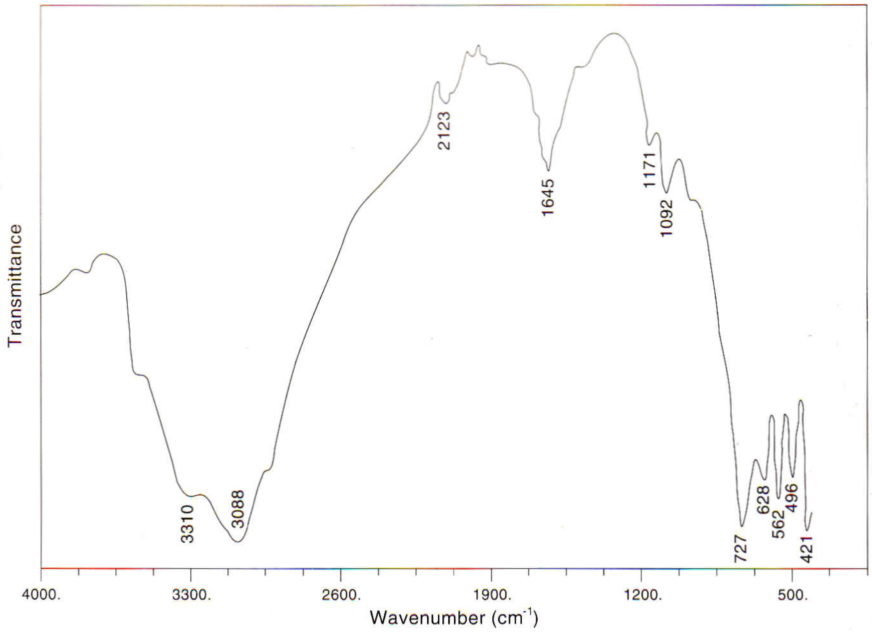
The equipment and procedures for acquiring the infrared-absorption spectrum for utahite are identical to those used to obtain the spectrum for mcalpineite (Roberts *et al.,* 1994) and need not be repeated here. The spectrum (Fig. 3) clearly shows absorption bands for both (OH) and H_2O. A very strong, broad absorption, which peaks at 3090 cm^{-1} with shoulders at about 3550, 3090 and 2925 cm^{-1}, is due to O-H stretching in both the (OH) groups and the H_2O molecules. A peak of medium intensity at 1645 cm^{-1} is due to H-O-H bending in the H_2O molecules.

OPTICAL PROPERTIES

A single grain of utahite, prismatic in habit and 70 by 220 microns in plane section, was polished with difficulty. Though prismatic, it appears that individual layers run diagonally across the length of the prism. In plane-polarized reflected light (in air) it is a very pale brown except where pale green internal reflections appear. The mineral is slightly bireflectant and nonpleochroic. Between crossed polarizers, it is clearly translucent and, in oil, its pale greenish brown surface color is obscured by pale emerald-green internal reflections. It does not extinguish, and rotation tints are imperceptible. The anisotropy is unknown; it is masked by the internal reflections.

The largest polished area sufficiently free from scratches for reflectance measurement was about 20 microns in diameter. However, part of this area contained internal reflections, and thus the reflectance spectra and refractive indices calculated from them must be considered as little more than approximate. These internal reflections contribute an unwanted component of diffuse reflectance to the spectral reflectance. In air, this would have a significant effect on the reflectance and on the refractive indices derived from them; in oil, this effect would be greater still. Measurements were made relative to a silicon carbide reflectance standard (Zeiss

***Figure 3.* Infrared-absorption spectrum for utahite.**



no. 472) and a secondary standard of cubic zirconia (polished and calibrated at the NHM) using a Zeiss microscope-spectrophotometer MPM 800. They have not been reported, since we feel, for the reasons noted above, they serve no useful purpose. Because the mineral did not extinguish, and because of the very low light levels reflected from its surface, measurements were made across and along the prism axis. The precision of the measured reflectances was reasonable: the refractive indices calculated relative to SiC at 590 nm were 1.84–1.90 and those relative to cubic zirconia were 1.83–1.88.

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