

Leisingite, $\text{Cu}(\text{Mg,Cu,Fe,Zn})_2\text{Te}^{6+}\text{O}_6 \cdot 6\text{H}_2\text{O}$, a new mineral species from the Centennial Eureka mine, Juab County, Utah

ANDREW C. ROBERTS

Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario, Canada K1A 0E8

LEE A. GROAT

Department of Geological Sciences, University of British Columbia, 6339 Stores Road, Vancouver, British Columbia, Canada V6T 1Z4

JOEL D. GRICE, ROBERT A. GAULT

Research Division, Canadian Museum of Nature, Ottawa, Ontario, Canada K1P 6P4

MARTIN C. JENSEN¹

Mackay School of Mines, University of Nevada, Reno, Nevada, USA 89557-0047

ELIZABETH A. MOFFATT

Canadian Conservation Institute, 1030 Innes Road, Ottawa, Ontario, Canada K1A 0M5

AND

JOHN A. R. STIRLING

Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario, Canada K1A 0E8

Abstract

Leisingite, ideally $\text{Cu}(\text{Mg,Cu,Fe,Zn})_2\text{Te}^{6+}\text{O}_6 \cdot 6\text{H}_2\text{O}$, is hexagonal, $P\bar{3}$ (143), with unit-cell parameters refined from powder data: $a = 5.305(1)$, $c = 9.693(6)$ Å, $V = 236.2(2)$ Å³, $c/a = 1.8271$, $Z = 1$. The strongest six reflections of the X-ray powder-diffraction pattern [d in Å (hkl)] are: 9.70 (100) (001), 4.834 (80) (002), 4.604 (60) (100), 2.655 (60) (110), 2.556 (70) (111) and 2.326 (70) (112). The mineral is found on the dumps of the Centennial Eureka mine, Juab County, Utah, U.S.A. where it occurs as isolated, or rarely as clusters of, hexagonal-shaped very thin plates or foliated masses in small vugs of crumbly to drusy white to colourless quartz. Associated minerals are jensenite, cesbronite and hematite. Individual crystals are subhedral to euhedral and average less than 0.1 mm in size. Cleavage {001} perfect. Forms are: {001} major; {100}, {110} minute. The mineral is transparent to somewhat translucent, pale yellow to pale orange-yellow, with a pale yellow streak and an uneven fracture. Leisingite is vitreous with a somewhat satiny to frosted appearance, brittle to somewhat flexible and nonfluorescent; $H(\text{Mohs})$ 3–4; $D(\text{calc.})$ 3.41 for the idealized formula; uniaxial negative, $\omega = 1.803(3)$, $\epsilon = 1.581$ (calc.). Averaged electron-microprobe analyses yielded CuO 24.71, FeO 6.86, MgO 6.19, ZnO 0.45, TeO₃ 36.94, H₂O (calc.) [21.55], total [96.70] wt.%, leading to the empirical formula $\text{Cu}_{1.00}(\text{Mg}_{0.77}\text{Cu}_{0.56}\text{Fe}_{0.48}\text{Zn}_{0.03})\Sigma_{1.84}\text{Te}_{1.06}^{6+}\text{O}_{6.02} \cdot 5.98\text{H}_2\text{O}$ based on O = 12. The infrared absorption

¹ Present address: 121–2855 Idlewild Drive, Reno, Nevada, USA 89509

Mineralogical Magazine, August 1996, Vol. 60, pp. 653–657

© Copyright the Mineralogical Society

spectrum shows definite bands for structural H₂O with an O—H stretching frequency centered at 3253 cm⁻¹ and a H—O—H flexing frequency centered at 1670 cm⁻¹. The mineral name honours Joseph F. Leising, Reno, Nevada, who helped collect the discovery specimens.

KEYWORDS: leisingite, new mineral, Centennial Eureka mine, Juab County, Utah, U.S.A., X-ray data, electron-microprobe analyses, optical data, infrared-absorption study.

Introduction

LEISINGITE, ideally Cu(Mg,Cu,Fe,Zn)₂Te⁶⁺O₆·6H₂O, is a newly recognised mineral species which was first encountered during megascopic examination, scanning electron energy-dispersion study and routine X-ray powder-diffraction characterisation of a suite of secondary Cu- and Te-bearing minerals. This suite of samples was collected in July, 1992 from dumps rich in ore-grade material adjacent to the Centennial Eureka mine, Tintic District, Juab County, Utah, U.S.A. This mineral is the fourth of at least eight new secondary Cu- and Te-bearing phases that will eventually be characterised. It was informally designated as UKCE-10 (Roberts *et al.*, 1996) during the course of the mineralogical investigation.

The mineral is named for Mr Joseph F. Leising of Reno, Nevada, U.S.A. He helped one of us (M.C.J.) collect the suite of secondary minerals from the Centennial Eureka mine dumps. Mr Leising is a registered geologist and is an active mineral collector. His current interests are mineral species and localities of the Great Basin region of the western United States. The mineral and mineral name have been approved by the Commission on New Minerals and Mineral Names, I.M.A. Holotype material, consisting of five specimens, an SEM stub and several single-crystal mounts, is preserved in the Systematic Reference Series of the National Mineral Collection, Geological Survey of Canada, Ottawa, Ontario, Canada, under the catalogue number NMC 67882.

Occurrence and associated minerals

Leisingite has been identified on eight specimens collected from the dumps of the Centennial Eureka mine, Tintic District, Juab County, Utah, U.S.A. (latitude 39° 56' 38" N, longitude 112° 07' 18" W), about 1.5 km southwest of the historic town of Eureka. This copper, gold and silver property, worked primarily from 1876 to 1927, was the most productive and profitable deposit in the district. 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 mineralised samples 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 on page 419 of the formal description of mcalpineite (Roberts *et al.*, 1994).

Leisingite was observed in two of these boulders and must be considered extremely rare; only about 2 µg of the mineral is presently known. On the holotype material, the mineral occurs as isolated, or rarely as clusters of, hexagonal-shaped very thin plates or foliated masses in small vugs of crumbly to drusy white to colourless quartz. Associated minerals are emerald-green rhombs of jensenite (Roberts *et al.*, 1996; Grice *et al.*, 1996), leaf-green crystals of cesbronite and tiny red spherules of hematite. Additional Cu- and Te-bearing secondary minerals that have been identified by X-ray powder-diffraction methods on similar specimens include mcalpineite (Roberts *et al.*, 1994), frankhawthorneite (Roberts *et al.*, 1995; Grice and Roberts 1995), xocomecatlite, dugganite, quetzalcoatlite and four additional crystalline unnamed Cu- and Te-bearing phases which are 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).

Leisingite is a secondary mineral that formed from the breakdown of primary Cu- and Te-bearing sulphides. Iron is locally abundant, but the primary source of the magnesium is more problematical; it may be derived from the decomposition of dolomite which is ubiquitous to the area. Marty *et al.* (1993) state: "The deep water table (about 2,000 feet below the surface) permitted significant oxidation of the original primary minerals and was the single most important factor in the formation of the large suite of secondary minerals that are now present". The altered enargite-rich boulders which contain the Cu- and Te-bearing mineralisation most probably were mined at depths in excess of 1,000 feet.

Physical and optical properties

Leisingite occurs as isolated, or rarely as clusters, of hexagonal-shaped very thin plates or foliated masses in small vugs of crumbly to drusy white to colourless quartz. An SEM photomicrograph of a typical crystal protruding out of a vug is presented in Fig. 1. Individual crystals are subhedral to euhedral with dominant {001} pinacoid which is brightly reflecting and very narrow {100} and {110} faces. Crystals are



Fig. 1. Scanning electron photomicrograph of a leisingite crystal protruding from a small cavity. Matrix is quartz. (Scale bar: 50 μm).

up to 0.2 mm in longest dimension, but most crystals are less than 0.1 mm in diameter. They are extremely thin; SEM study shows an average thickness between 1–2 μm . Twinning was not observed megascopically nor was it found in X-ray single-crystal studies. Leisingite crystals are pale yellow to pale orange-yellow and are, for the most part, transparent; the streak is pale yellow. The mineral is brittle to somewhat flexible, possesses an uneven fracture and a vitreous luster, and is nonfluorescent under both long- and short-wave ultraviolet radiation. The Mohs' hardness is estimated to be 3–4 and the mineral has a perfect {001} cleavage. The density could not be measured owing to the size of available specimens, size of crystals and dearth of pure material. The calculated density based on the simplified formula given in the chemistry section is 3.41 g/cm^3 for $Z = 1$. It should be noted that the colour, transparency and size of plates made them very difficult to recognise on the white to colourless quartz matrix.

Optically, leisingite is uniaxial negative. Grain mount studies in Na gel-filtered light (λ 589.9 nm) indicate that $\omega = 1.803(3)$ and is the maximum index of refraction. ϵ is in the plate and is unmeasurable due to extreme thinness; it was calculated as 1.581 from the Gladstone-Dale relationship, assuming a k for MgO of 0.225 (Mandarino, 1981), and the simplified formula.

X-ray powder and single-crystal study

Two crystals of leisingite were examined by single-crystal precession methods employing Zr-filtered Mo radiation. One crystal was mounted such that a^* , and the other crystal such that 110^* , was parallel to the

precession camera dial axis. The reciprocal lattice levels collected were: $hk0 \rightarrow hk2, h0l, h1l$ and $110^* \wedge c^*$. Leisingite is hexagonal with measured unit-cell parameters $a = 5.304$, $c = 9.61$ Å. The apparent diffraction symmetry is $3m$ with a pseudo-mirror plane parallel to 110^* . Therefore, the permissible pseudo-space-group choices are: $P\bar{3}m1(164)$, $P3m1(156)$ and $P321(150)$ (diffraction aspect $P3^*1$). However, crystal-structure analysis (Groat and Grice, in preparation) conclusively demonstrates that the true space group for leisingite is $P3(143)$.

The refined unit-cell parameters: $a = 5.305(1)$, $c = 9.693(6)$ Å, $V = 236.2(2)$ Å³, $c/a = 1.8271$, are based on 13 reflections, between 3.333 and 1.278 Å, in the X-ray powder pattern for which unambiguous indexing was possible. All possible reflections down to 1.26 Å were visually examined on single-crystal precession films. Fully indexed 114.6 mm Debye-Scherrer camera X-ray powder data are presented in Table 1. The data are unique and do not bear resemblance to any inorganic compound listed in the PDF up to and including Set 44.

Chemistry

A 20 μm -sized crystal of leisingite was analysed with a JEOL 733 electron microprobe using Tracor-Northern 5500 and 5600 automation. The wavelength-dispersion mode was used. Data reduction was done with a conventional ZAF routine in the Tracor-Northern TASK series of programs. The operating conditions were as follows: operating voltage of 15 kV, a beam current of 20 nA and a beam 10 μm in diameter. Data for the sample was collected for 25 seconds or 0.50% precision, whichever was obtained first; for the standards, 50 seconds or 0.25% precision, whichever was obtained first. A 100 second energy-dispersion scan indicated no elements with $Z > 8$ other than those reported here were present. The following standards were employed: natural paratellurite (Te- $L\alpha$), natural cuprite (Cu- $K\alpha$), synthetic $\text{FeTe}_2\text{O}_5(\text{OH})$ (Fe- $K\alpha$), synthetic ZnSeO_3 (Zn- $K\alpha$) and natural diopside (Mg- $K\alpha$). The valence states for both Cu and Te, as well as the number of O atoms, were determined by crystal-structure analysis (Groat and Grice, in preparation) prior to final interpretation of the electron-microprobe results. The paucity of pure uncontaminated material prevented the quantitative determination of H_2O by classical methods. However, its presence as bonded H_2O was confirmed by both crystal-structure analysis and powder infrared-absorption study; and the formula was therefore calculated to give $6\text{H}_2\text{O}$.

The average result of three analyses gave TeO_3 36.94 (range 36.49–37.61), CuO 24.71 (range

TABLE 1. X-ray powder data for leisingite

$I_{est.}$	$d \text{ \AA}_{(meas.)}$	$d \text{ \AA}_{(calc.)}$	hkl	$I_{est.}$	$d \text{ \AA}_{(meas.)}$	$d \text{ \AA}_{(calc.)}$	hkl
100	9.70	9.693	001	5	1.668	1.667	204
80	4.834	4.846	002	5	1.635	1.635	212
60	4.604	4.594	100	3	1.612	1.612	006
* 20	3.333	3.334	102	5	1.565	1.565	115
* 30	3.224	3.231	003	* 30	1.531	1.531	300
* 60	2.655	2.653	110	* 20	1.513	1.513	301
* 70	2.556	2.558	111	* 20	1.461	1.460	302
* 70	2.326	2.327	112	10	1.380	1.384	303
5	2.143	2.143	104	10	1.380	1.380	116
5	2.080	2.076	202	* 10	1.326	1.326	220
* 20	2.051	2.050	113	5	1.313	1.314	221
5	1.934	1.939	005	5	1.294	1.295	304
* 40	1.789	1.789	114	* 10	1.278	1.279	222
* 10	1.736	1.736	210				

114.6 mm Debye-Scherrer powder camera, Cu radiation, Ni filter (λ Cu-K α = 1.54178 Å), intensities estimated visually, corrected for shrinkage but no internal standard.

* = lines used for unit-cell refinement.

indexed with $a = 5.305$, $c = 9.693$ Å

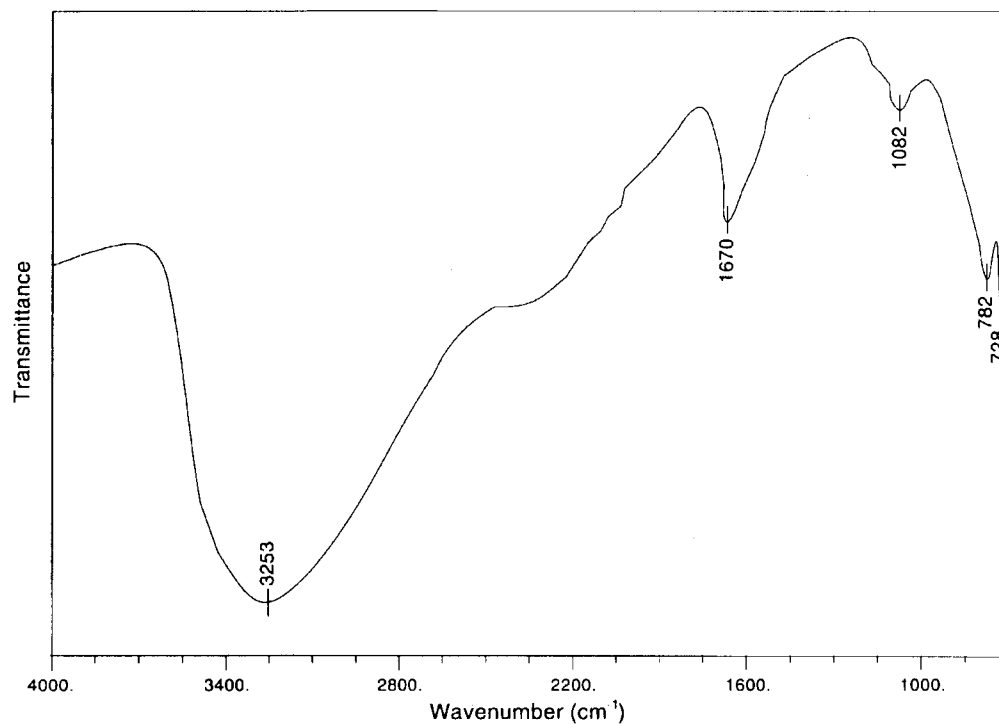


FIG. 2. Infrared-absorption spectrum for leisingite.

24.15–25.42), FeO 6.86 (range 6.75–6.96), ZnO 0.45 (range 0.32–0.64), MgO 6.19 (range 6.12–6.30), H₂O [21.55], total [96.70] wt.%. With O = 12, the empirical formula is $\text{Cu}_{1.00}(\text{Mg}_{0.77}\text{Cu}_{0.56}\text{Fe}_{0.48}\text{Zn}_{0.03})_{\Sigma 1.84}\text{Te}_{1.06}^{6+}\text{O}_{6.02}\cdot 5.98\text{H}_2\text{O}$. The ideal formula, $\text{Cu}(\text{Mg,Cu,Fe,Zn})_2\text{Te}^{6+}\text{O}_6\cdot 6\text{H}_2\text{O}$, with Mg:Cu:Fe:Zn = 0.84:0.61:0.52:0.03 requires TeO₃ 36.17, CuO 26.38, FeO 7.70, ZnO 0.50, MgO 6.98, H₂O 22.27, total 100.00 wt.%. This is yet another example of the use of crystal-structure analysis in order to determine the precise chemical formula of a complex mineral species (Hawthorne and Grice 1990).

The low analytical electron-microprobe total is due to several limiting factors: overall average size of individual crystals (50–100 μm); extreme thinness of crystals (1–2 μm); and dearth of pure material which we were able to extract from the mineral specimens and mount for probe study. All these factors combined to make it extremely difficult to obtain and mount sufficient material for an adequate electron-microprobe analysis. As previously mentioned, the grain used to finally yield the analyses presented above was no more than 20 μm in size. However, the analytical results are representative and are in fairly good agreement with bond-valence analysis derived from the crystal-structure study.

Infrared-absorption study

The equipment and procedures for acquiring the infrared-absorption spectrum for leisingite are identical to those used to obtain the spectrum for mcAlpineite (Roberts *et al.*, 1994) and need not be repeated here. The spectrum (Fig. 2) clearly shows absorption bands for structural H₂O. A very strong absorption band, which is broad and which peaks at 3253 cm⁻¹, is due to O–H stretching and a medium strong absorption band, which peaks at 1670 cm⁻¹, is due to H–O–H bending in the H₂O molecules.

Acknowledgements

The authors thank Armand C. Tsai (GSC) for the

SEM photomicrograph reproduced in Figure 1. The crystal-structure study was supported by an NSERC Research Grant to LAG.

References

- Grice, J.D. and Roberts, A.C. (1995) Frankhawthorneite, a unique HCP framework structure of a cupric tellurate. *Can. Mineral.*, **33**, 649–53.
- Grice, J.D., Groat, L.A. and Roberts, A.C. (1996) Jensenite, a cupric tellurate framework structure with two co-ordinations of copper. *Can. Mineral.*, **34**, 49–54.
- Hawthorne, F.C. and Grice, J.D. (1990) Crystal-structure analysis as a chemical analytical method: application to light elements. *Can. Mineral.*, **28**, 693–702.
- Mandarino, J.A. (1981) The Gladstone-Dale relationship. IV. The compatibility concept and its application. *Can. Mineral.*, **19**, 441–50.
- Marty, J., Jensen, M.C. and Roberts, A.C. (1993) Minerals of the Centennial Eureka mine, Tintic District, Eureka, Utah. *Rocks & Minerals*, **68**, 406–16.
- Roberts, A.C., Ercit, T.S., Criddle, A.J., Jones, G.C., Williams, R.S., Cureton, F.E. II and Jensen, M.C. (1994) McAlpineite, Cu₃TeO₆·H₂O, a new mineral from the McAlpine mine, Tuolumne County, California and from the Centennial Eureka mine, Juab County, Utah. *Mineral. Mag.*, **58**, 417–24.
- Roberts, A.C., Grice, J.D., Criddle, A.J., Jensen, M.C., Harris, D.C. and Moffatt, E.A. (1995) Frankhawthorneite, Cu₂Te⁶⁺O₄(OH)₂, a new mineral species from the Centennial Eureka mine, Tintic District, Juab County, Utah. *Can. Mineral.*, **33**, 641–7.
- Roberts, A.C., Grice, J.D., Groat, L.A., Criddle, A.J., Gault, R.A., Erd, R.C. and Moffatt, E.A. (1996) Jensenite, Cu₃Te⁶⁺O₆·2H₂O, a new mineral species from the Centennial Eureka mine, Tintic District, Juab County, Utah. *Can. Mineral.*, **34**, 49–54.

[Manuscript received 15 July 1995]