

## Cesbronite, a new copper tellurite from Moctezuma, Sonora

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**SUMMARY.** Cesbronite occurs at the Bambollita mine, near Moctezuma, Sonora, with a variety of other tellurites. The colour is 'green beetle' (R.H.S. 135-B) with a pale streak.  $H\ 3$ ;  $D_{\text{meas}}\ 4.45 \pm 0.2$ . Crystals are orthorhombic  $2\ mmm$  with  $a\ 8.624\ \text{\AA}$ ,  $b\ 11.878$ ,  $c\ 5.872$  (all  $\pm 0.016\ \text{\AA}$ ); space group  $Pbcn$ . For  $Z = 2$  the calculated density is  $4.455\ \text{g/cm}^3$ . The strongest powder lines are  $5.934$  (100),  $3.490$  (92),  $4.889$  (71),  $2.358$  (70),  $2.379$  (38),  $1.592$  (34),  $2.156$  (28), and  $1.698$  (27). Electron-probe analysis gave: CuO 50.3%, 50.3, 49.8, 49.4; TeO<sub>2</sub> 39.3%, 39.2, 38.6, 38.6. Water determined gravimetrically 11.0%. This gives  $\text{Cu}_6(\text{TeO}_3)_2(\text{OH})_6 \cdot 2\text{H}_2\text{O}$ .

Cesbronite is pleochroic with absorption  $\gamma \approx \beta \gg \alpha$ . Optically positive with  $2V_\gamma$ , calc.  $72^\circ$ ;  $\alpha\ 1.880$   $\parallel [100]$ ,  $\beta\ 1.928$   $\parallel [001]$ ,  $\gamma\ 2.029$   $\parallel [010]$ .

CESBRONITE was first collected by Peter Embrey and Pierre Bariand during a visit we made to the Bambollita (La Oriental) mine near Moctezuma, Sonora. The mineral is named in honour of Dr. Fabien Cesbron, French mineralogist. There are two thin veins exposed in this mine, and cesbronite occurs in only one. This vein is closer to the portal and is more severely oxidized than the other vein (where quetzalcoatlite occurs). The primary mineralogy of both veins is the same: hessite–bornite–galena.

Early oxidation products in the vein are electrum, teineïte, and carlfriesite. Cesbronite comes later, appearing when the primary ores are wholly decayed or are completely enveloped in secondary products. While cesbronite may occur on these relics, it usually is found filming fractures up to several inches away. Often it is found directly upon spherules of a dark-green Cu–Fe–Te mineral; just as commonly this unknown mineral has disappeared, leaving a hollow crystalline spherule of cesbronite. The last mineral in the sequence is a pea-green amorphous Cu–Fe–Te mineral that is ubiquitous in the vicinity of both veins.

Although the mineral is widely distributed along the vein walls, there is not very much. Perhaps a gramme of material is available.

*Physical properties.* Cesbronite is transparent when crystalline with a bright lustre. The colour is 'green beetle'<sup>1</sup> (R.H.S. 135-B) with a similar but paler streak. The mineral is brittle and cleavage occurs but cannot be seen during crushing owing to the small grain size. The Mohs hardness is 3. The specific gravity was determined as  $4.45 \pm 0.2$  on about 4.5 mg using the Berman balance with powder basket. Three trials were made at  $23.7^\circ\text{C}$  using toluene. No fluorescence was observed in long or short wave U.V.

*Chemistry.* Qualitative analysis showed only Cu and Te as well as water by the Penfield method. This was confirmed by qualitative electron-probe work prior to

<sup>1</sup> I was disappointed in the name and had guessed emerald green (R.H.S. 134-A).

quantitative analysis. Four polished grains were analysed for Cu and Te, 20 point counts each, using copper and tellurium as standards. The results appear in the first four columns of Table I.

The analyses lead to empirical cell contents (Table I) approximating closely to  $2[\text{Cu}_5(\text{TeO}_3)_2(\text{OH})_6 \cdot 2\text{H}_2\text{O}]$ .

Cesbronite is readily soluble in cold or warm 1:1  $\text{HNO}_3$  and 1:1  $\text{HCl}$ ; it turns  $\text{HCl}$  yellow upon dissolving. It is unaffected by 40 %  $\text{KOH}$ , warm or cold, and is insoluble in water. A microchemical test for tellurite was positive.

TABLE I. *Chemical analyses of cesbronite*

	1	2	3	4	5	6	7	8
CuO	50.3	50.3	49.8	49.4	—	49.95	49.28	Cu 10.14
TeO <sub>2</sub>	39.3	39.2	38.6	38.6	—	38.92	39.56	TeO <sub>3</sub> 3.94
H <sub>2</sub> O	—	—	—	—	11.0	11.00	11.16	OH 12.40
						99.87	100.00	H <sub>2</sub> O 3.66

1-4. Electron-probe analyses of 4 grains by R. F. Symes, British Museum (Natural History).

5. Determined gravimetrically, Penfield method on 0.52 mg.

6. Average of 1-5.

7. Theory for  $\text{Cu}_5(\text{TeO}_3)_2(\text{OH})_6 \cdot 2\text{H}_2\text{O}$ .

8. Empirical unit-cell contents.

*Crystallography.* Crystals of cesbronite up to 0.5 mm were readily found, usually occurring as radiating hollow crusts of sharp bipyramids that individually project above the crust for up to half their length. The crystals are orthorhombic, *mmm*. Often they are grouped in the crust as bundles of a few sub-parallel individuals each of which shows a sharp termination. The crystals are invariably elongate on the *a*-axis with chisel-shaped terminations bounded by  $d\{103\}$  and bevelled by  $n\{180\}$ . Small but brilliant  $c\{001\}$  and  $b\{010\}$  faces bound the girdle of the bipyramids. In the zone  $[010]$  *d* and *c* are usually striated giving a curved outline to the crystal. Faces *n* and *b* also mutually interfere but in visible steps rather than in vicinal striated faces. An idealized measured crystal is shown in fig. 1.

Pulverized crystals gave a clear X-ray powder pattern that is indexed in Table II. Because of the relatively small cell size and simplicity of the pattern most lines index unambiguously. Cell dimensions were verified by rotation patterns but were refined from the powder data and are: *a* 8.624 Å, *b* 11.878, *c* 5.872, all  $\pm 0.016$  Å. Weissenberg photographs indicate the space group *Pbcn*. If *Z* = 2 the calculated density is 4.455 g/cm<sup>3</sup>.

*Optics.* In thin section crystals are a rich green colour, resembling brochantite or atacamite but with higher birefringence. A poor cleavage is visible on  $\{010\}$  and a good

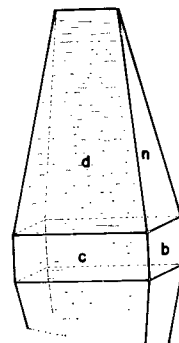


FIG. 1. A crystal of cesbronite, oriented with the *a*-axis vertical.

TABLE II. *Indexed powder data for cesbronite Cr-K $\alpha$  radiation, 114-mm camera*

<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>
100	5.934	5.934	020	70	2.358	2.358	032
71	4.889	4.888	120	28	2.156	2.156	400
13	4.317	4.312	200	16	2.026	2.028	142
92	3.490	3.488	220	—	—	2.024	312
13	2.964	2.967	040	—	—	2.026	420
11	2.850	2.850	012	15	1.979	1.978	060
11	2.706	2.706	112	19	1.847	1.846	052
21	2.589	2.587	320	20	1.806	1.805	152
25	2.446	2.444	240	27	1.698	1.697	252
38	2.379	2.378	212	34	1.592	1.591	432

Plus 19 additional lines to  $d = 1.180$ , none with  $I > 20$ .

cleavage follows {021}; some crystals diverge slightly on this plane along the  $a$ -axis in fan-shaped aggregates. Alteration to an amorphous pea-green compound commences as stippling or marginal corrosion until the cesbronite is a cavernous or hollow relict.

Pleochroism is marked with  $\gamma =$  deep emerald green,  $\beta =$  rich yellow-green, and  $\alpha =$  pale bluish green with  $\gamma \approx \beta \gg \alpha$ . Grains lying with their  $b$  axis vertical give a centred biaxial figure that exhibits moderate dispersion,  $\rho > v$ . The sign is positive with  $2V$  calc =  $72^\circ$ . Indices determined at  $22^\circ\text{C}$  for NaD are:  $\alpha$  1.880,  $\beta$  1.928,  $\gamma$  2.029 (all  $\pm 0.008$ ). The optic orientation is  $\alpha \parallel [100]$ ,  $\beta \parallel [001]$ ,  $\gamma \parallel [001]$ .

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