

Tlapallite, a new mineral from Moctezuma, Sonora, Mexico

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SUMMARY. Tlapallite is a new mineral found in 1972 at the Bambollita (La Oriental) mine near Moctezuma, Sonora. Also recently found in old specimens from Tombstone, Arizona. Data for type (Mexican) material: Colour viridian green RHS-128A with pale streak, $H = 3$, $D_{\text{calc}} = 5.05 \text{ g/cm}^3$. Crystals monoclinic, class unknown. Indexing based on Ito method gave a cell: $a = 11.97 \text{ \AA}$, $b = 9.11$, $c = 15.66$, $\beta = 90^\circ 36'$. Strongest lines: 11.972 \AA (10), 2.985 (10), 3.540 (6), 5.946 (5), 2.887 (5), 4.731 (4), 3.372 (4), 3.282 (4). Similar data obtain for Tombstone. Chemical analysis for type material yielded the formula $\text{H}_6\text{Ca}_2\text{Cu}_3(\text{SO}_4)(\text{TeO}_3)_4\text{TeO}_6$ with $\text{Te}^{4+}:\text{Te}^{6+} = 4:1$. However, analysis of the Tombstone material indicates a more general formula $\text{H}_6(\text{Ca}, \text{Pb})_2(\text{Cu}, \text{Zn})_3(\text{SO}_4)(\text{TeO}_3)_4\text{TeO}_6$. The better data from this material indicate $Z = 4$, $D_{\text{calc}} = 5.465$ vs $D_{\text{meas.}} = 5.38$. Characterized by extreme birefringence, $\alpha = 1.815$, $\beta = \gamma = 1.960$; for Tombstone $\alpha = 1.955$, $\beta = \gamma = 2.115$.

Named from the Nahua word *tlapalli*, meaning paint, in allusion to its mode of occurrence at the type locality.

TLAPALLITE is one of a myriad of tellurium oxysalts found recently at the Bambollita (La Oriental) mine near Moctezuma, Sonora. Although it is by far the most abundant of these unusual minerals at the mine, its characterization has been most difficult, delaying publication for several years. The chemical problems were not satisfactorily resolved until an old specimen from Tombstone, Arizona, was re-examined and proved to be the same.

At the type locality, tlapallite occurs as a thin paint-like film on the rock fracture surfaces in and adjacent to thin veins cutting intensely sericitized rhyolites. Tlapallite is perhaps the last of the tellurites/tellurates to form, and its mode of occurrence as a shiny botryoidal scum suggests that it has crystallized quickly from rapidly drying acid solutions. Almost invariably the crusts are plastered on a substratum of powdery or dust-like quartz, sericite, calcite, and baryte. Tlapallite often occurs alone but may associate with other minerals, particularly carlfreisite.

Just recently a specimen of tlapallite was brought to our attention by R. W. Thomssen. The specimen was originally in the University of Arizona museum and labelled as emmonsite from Tombstone, Arizona. Thin sections show that the piece is about half tlapallite cementing a calc-silicate tactite, and the gangue looks much like other specimens to be found at the Lucky Cuss mine in Tombstone.

Physical properties. The colour is remarkably uniform on all specimens collected and is a distinctive shade of green (viridian green) RHS-128A. The streak is similar but notably paler. The colour of the Tombstone material is quite different, RHS-140B (Cyprus green).

The Mohs hardness is 3, determined on compact botryoidal material. Crystals are minute, appearing as sheaves of radially arranged scales normal to the surface of botryoidal material. The spherules often have a smooth shiny surface and may break readily on concentric, curved surfaces.

Determination of specific gravity proved difficult. Measurement by Berman balance was out of the question for the Mexican material, and sink-float in Clerici solution was attempted. The value appeared to be just above 4.65, beyond the extreme range of the method. However, a sample of Tombstone tlapallite in excess of 9 mg gave a value of 5.38 ± 0.1 on the Berman balance in toluene (23.8 °C).

Tlapallite shows no response in long or short wavelength ultraviolet light.

Chemistry. An emission spectrogram of Mexican tlapallite showed very strong lines for calcium, copper, and tellurium. Tlapallite from Tombstone contained major amounts of copper, tellurium, calcium, and lead as determined by emission spectrography. Microchemical tests showed the presence of sulphate and the absence of chloride, bromide, and iodide in both varieties. Carbonate was present in Mexican tlapallite.

As the reader will note from Table I the analysis

TABLE I. *Chemistry of tlappallite*

	Bambollita mine, Mexico*				Tombstone, Arizona§		
	%	Ratio	Recalc.†	Theory	%	Ratio	Theory
CaO	8.3	0.148	8.6	8.64	4.3	0.077	4.34
PbO	—	—	—	—	13.6	0.061	13.58
CuO	15.6	0.196	18.5	18.37	15.8	0.199	16.50
ZnO	0.8	0.010	0.9	—	0.7	0.009	—
TeO ₂	41.4	0.260	49.0	49.15	44.3	0.279	44.15
TeO ₃	11.4	0.065	13.5	13.52	12.5	0.071	12.14
SO ₃	5.2	0.065	6.15	6.16	5.57	0.070	5.54
H ₂ O	—	—	4.16†	4.16	4.25	0.236	3.74
Total			100.81	100.00	101.02		99.99

* CaO, CuO, and ZnO determined by A.A. on three separate weighings of 906, 1104, and 1430 μg . CaO found: 8.8, 7.8, 8.3%; CuO 15.5, 15.3, 16.1%; ZnO 0.7, 0.7, 0.9%. TeO₂ and TeO₃ done on the 906 μg sample, SO₃ on a 2031 μg sample. Evolution of CO₂ was observed in all cases when samples were treated with nitric or hydrochloric acid.

† The mineral pickings were known to be contaminated with calcite, baryte, quartz, and sericite. After the lead-containing variety from Tombstone was analysed and its formula calculated, we knew the formula of this mineral had to be $\text{H}_6\text{Ca}_2\text{Cu}_3(\text{SO}_4)_2^{2-}(\text{TeO}_3)_2^{2-}(\text{TeO}_6)^{6-}$, which has a mol. wt. of 1299. The lowest ratio is 0.077 instead of 0.065 as calculated from our data. Therefore 84.5% is the average mineral content, the remainder being impurities as noted above. The CaO is also corrected to bring the ratio to 0.154, the amount of CaCO₃ in the sample being undetermined.

‡ Water calculated here as $0.077 \times 3 \times 18.015$.

§ CaO, PbO, CuO, and ZnO by A.A. on a 1112 μg sample; TeO₂ and TeO₃ on a 1110 μg sample. SO₃ by the Schwartzkopf Microchemical Laboratory. H₂O, average of 2 detns. by the Penfield method, which gave 4.23 and 4.27%, on 1454 and 1193 μg .

|| Proposed formula $\text{H}_6(\text{Ca}, \text{Pb})_2(\text{Cu}, \text{Zn})_3(\text{SO}_4)_2^{2-}(\text{TeO}_3)_2^{2-}(\text{TeO}_6)^{6-}$, with Ca 1.12, Pb 0.88.

was hampered by the inextricable admixture of varying quantities of calcite, baryte, sericite, and quartz in the Mexican materials. These impurities were too little to weigh accurately as 'insol.' and, furthermore, some calcium contamination was surely due to dissolved calcite. Only upon the discovery of better material from Tombstone was the analysis satisfactorily concluded.

Copper, lead, zinc, and calcium were quantitatively determined in both varieties by atomic absorption spectroscopy in 10% nitric acid, after decomposition with hot 1:1 nitric acid and evaporation. Tellurite was determined by decomposing the mineral in hot nitric acid, evaporating to dryness, and upon cooling, taking the residue up in 10.0 ml 3*N* hydrobromic acid. The solutions were read spectrophotometrically at 440 nm within 2 minutes of the addition of the hydrobromic acid, and then scanned from 540 nm to 400 nm to correct for copper interference. The solutions were completely reduced to tellurite by evaporation of the bromide solution, and re-read similarly. The difference in 440 nm peak intensity before and after reduction is a function of the tellurate originally present.

The quantitative determination of sulphate was done on the Mexican tlappallite by the indirect ultraviolet spectrophotometric method developed by R. A. Jones and W. I. Stephen (1973). The insolubility of lead sulphate in neutral solution prevented a successful determination of sulphate in the Tombstone mineral, which was sent to Schwartzkopf Microanalytical Laboratory for determination of total sulphur. To determine the sulphate content of the Mexican tlappallite, a 2031 μg sample was decomposed with cold 3*N* hydrochloric acid, and evaporated to dryness. The residue was leached with warm deionized water and brought to a volume of 10.0 ml. The pH of the resulting solution was about 4.5. Following the procedure of Jones and Stephen, aliquots of up to 1.9 ml were transferred to 2 ml centrifuge tubes, and the volumes adjusted to 1.9 ml with deionized water. Then 0.10 ml 0.5% aqueous 2-amino-perimidine was added. After centrifuging, a 1.0 ml aliquot of the supernatant solution was diluted to 10.0 ml and read spectrophotometrically at the 305 nm peak. A calibration curve of 0 to 30 μg SO₃ was prepared using K₂SO₄. In addition, synthetic mixtures containing amounts of calcium, copper,

tellurite, and tellurate known to be present in the sample, plus varying amounts of sulphate were also prepared and analysed as the mineral was. Even though the residue after evaporation was not all soluble in water, the sulphate was recovered. The precision of the entire procedure was about $\pm 5\%$ relative. Tellurate did not interfere, because it was probably converted to tellurite during evaporation from the hydrochloric acid solution.

Water was determined on 1454 and 1193 μg of Tombstone tlapallite by the Penfield method. The results were about 15% high, probably because of some loss of TeO_2 . There was insufficient Mexican tlapallite for a reasonably precise water determination.

Tlapallite is easily soluble in cold 1:1 HCl, but slowly so in 1:1 HNO_3 unless heated. It is unaffected by cold KOH (20%) but decomposes readily upon heating. The mineral fuses readily to a yellow-brown slag in the Penfield tube, slowly evolving a white sublimate of TeO_2 .

Crystallography. Finding a single crystal of tlapallite proved fruitless. Tombstone material, especially, held out some hope, but the tiny flakes isolated were invariably badly dished or curved.

Powder data (Table II) were examined by the Ito method, and a cell quickly found because the mineral can be nearly indexed as orthorhombic. It is monoclinic, however, and powder data were refined to give the following cells:

$$a = 11.97 \text{ \AA}, b = 9.11, c = 15.66, \beta = 90^\circ 36' \text{ (Mexico),}$$

$$a = 12.07 \text{ \AA}, b = 9.13, c = 15.94, \beta = 90^\circ 27' \text{ (Tombstone).}$$

Because of the large cell and β nearly 90° , the indexed powder lines rapidly degenerated into a multiplicity of possible hkl values. There are no data available to indicate the class of symmetry.

Using the cell data, for Mexico $V = 1707 \text{ \AA}^3$, $M = 1299$, hence D_{calc} is 5.05 (as opposed to

TABLE II. X-ray powder data for tlapallite. Cr-K α radiation, 114 mm camera

Bambollita mine, Mexico				Tombstone, Arizona			
$I/I_{0\text{est}}$	d_{meas}	d_{calc}	hkl	$I/I_{0\text{est}}$	d_{meas}	d_{calc}	hkl
10	11.972	11.970	100	10	12.074	12.073	100
5	5.946	5.936	012	1	7.909	7.923	011
4	4.731	4.731	202	1	6.607	{ 6.612	{ 111
3	4.553	4.553	020			{ 6.627	{ 102
3	4.248	{ 4.256	{ 120	3	6.027	{ 6.037	{ 200
		{ 4.248	{ 113			{ 6.004	{ 012
2b	3.937	3.936	022	3½	4.794	4.794	202
4	3.732	{ 3.732	{ 104	3	4.573	4.565	020
		{ 3.733	{ 122	1	4.261	{ 4.270	{ 120
2	3.622	{ 3.627	{ 213	2	4.203	4.024	300
		{ 3.624	{ 220	1	3.955	3.962	022
		{ 3.540	{ 302			{ 3.775	{ 104
6	3.540	{ 3.535	{ 221	3	3.765	{ 3.768	{ 122
		{ 3.551	{ 311			{ 3.760	{ 122
4	3.282	{ 3.292	{ 123	4	3.584	{ 3.581	{ 302
		{ 3.281	{ 222			{ 3.582	{ 311
10	2.985	{ 2.980	{ 313			{ 3.318	{ 222
		{ 2.985	{ 223	3	3.311	{ 3.314	{ 204
		{ 2.893	{ 131			{ 3.324	{ 123
5	2.887	{ 2.890	{ 131			{ 3.018	{ 400
		{ 2.881	{ 115	8	3.019	{ 3.010	{ 015
		{ 2.886	{ 124			{ 3.010	{ 223
		{ 2.787	{ 205			{ 3.019	{ 320
2	2.785	{ 2.786	{ 402	5	2.906		
		{ 2.792	{ 411	3	2.820		
		{ 2.795	{ 322	4	2.683		
4	2.663	numerous		4	2.640		
4	2.624	numerous					

Film degenerates rapidly, with an additional dozen or so faint lines to c. 1.3 Å.

Plus thirty-one faint lines to c. 1.3 Å.

$D > 4.65$ meas). For Tombstone, $V = 1756.5 \text{ \AA}^3$, $M = 1445$, D_{calc} is 5.465 vs. $D = 5.38$ meas.

Optics. In thin-section tlapallite could be mistaken for duftite or conichalcite although its extreme birefringence contrasts with those two minerals. Tlapallite from both localities appears as sheaves or rosettes of tabular or bladed crystals and α , the acute bisectrix, is normal to the plane of flattening. Since $2V_{\alpha}$ is sensibly 0° , plates seen on edge are always length slow and show extreme birefringence. Extinction is parallel in this orientation no matter what position γ and β assume. Pleochroism is modest in bottle green with $\gamma = \beta > \alpha$.

Indices were measured for NaD and are $\alpha = 1.815$, $\beta = \gamma = 1.960$ (Mexico); $\alpha = 1.915$, $\beta = \gamma = 2.115$ (Tombstone). The first three values given are determined in oils (± 0.010), the value 2.115 was extrapolated between 2.110 and 2.125 using S-Se melt for the higher end. The melt was checked by the Brewster method.

Discussion. It was noted from study of mine occurrences and hand specimens that tlapallite appears as a transitory phase when the destruction of other tellurium oxysalts begins. Species such as tlalocite, cesbronite, xocomecatlite, quetzalcoatlite, teineite, and carlfriesite clearly have formed in acid waters. As oxidation progresses downwards, waters equilibrated with atmospheric CO_2 attack the top

of the Te-bearing oxide zone, and supergene calcite begins to appear. The dissolved Te-species may be dumped from solution if it simply dries up, and tlapallite may be the result.

Tlapallite does not compare with other tellurites or tellurates known and is clearly unique. Type specimens will be given to the British Museum and University of Arizona. The University of Arizona already has a fine Tombstone specimen (U.A. Te-21) from the Razor Collection.

The Nahuatl word tlapalli means paint, and the mineral is named in allusion to the fact that it films rocks as though painted on. It should be pronounced TLA-PA-LAIT or TLA-PA-LÍ-TA in Spanish. The mineral and name were approved prior to publication by the Commission on New Minerals and Mineral Names of the I.M.A.

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REFERENCE

- Jones (P. A.) and Stephen (W. I.), 1973. The indirect spectrophotometric determination of the sulphate ion with 2-Aminoperimidine. *Anal. Chim. Acta*, **64**, 85-92.

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