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MOCTEZUMITE, A NEW LEAD URANYL TELLURITE

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ABSTRACT

A new mineral whose composition is lead uranyl tellurite has been found at La Moctezuma mine, Moctezuma, Sonora, Mexico. The mineral occurs as minute blades and rosettes in cracks and vugs in the oxidized zone of a tellurium—gold deposit. Dimensions of the largest crystal observed are 3×1×0.2 mm, but most crystals are much smaller. Associated minerals are barite, pyrite, limonite, emmonsite, zinc tellurite, a new dark-red lead tellurite or tellurate, and a new uranium tellurite or tellurate occurring as straw colored micaceous aggregates, which is presently being studied.

The color is bright to dark orange. Cleavage (100) is perfect, hardness is about 3, and specific gravity, measured by pycnometer, is 5.73. Most crystal faces are curved and give unsatisfactory reflections on the goniometer, but *x*-ray studies proved the mineral to be monoclinic, with elongation parallel to *b*. Crystals tend to be multiple, with nearly parallel growth and other structural imperfections, resulting in spots on the level photographs being smeared out as long lines rather than sharp dots. Best results were obtained with the Buerger precession camera. Cell dimensions are: $a=7.82$, $b=7.07$, $c=13.84$ Å, and $\beta=93°$ 37.5′. Principal powder lines are 3.156, 3.492, 2.997, 3.088, and 3.385 Å, in decreasing order of intensity. Composition by wet chemical analysis is $PbO \cdot UO_3 \cdot 2TeO_2$, anydrous. Proportions of Pb:U:Te were confirmed by *x*-ray fluorescence analysis comparing the natural mineral with an artificial mixture. Optically the mineral is biaxial (−), with all indices above 2.11. The name moctezumite is proposed, in allusion to the locality.

INTRODUCTION

The Moctezuma mine, widely known locally as "La Bambolla," is 12 km south of the town of Moctezuma, in east-central Sonora. It is in some rather rugged foot hills 4 km west of the Moctezuma River, at about 900 m above sea level. The geographical coordinates are 29°41′N latitude and 109°43′W longitude.

The deposit was discovered in 1937 and was mined from that year until 1946, yielding gold ore which was shipped to the smelter at El Paso, Texas. Unusually large amounts of native tellurium and other tellurium minerals were noted in the ore, but no attempt was made to recover this element, or even to analyze and record the Te content of the lots of ore that were shipped. More recently, exploration has been in progress to see if the orebody can be mined commercially for tellurium.

In specimens obtained from the mine and studied at the Royal Ontario Museum in 1961 five new tellurium minerals were noted: denningite (Mandarino, 1963), spiroffite (Mandarino, 1962b), zinc-iron tellurite or tellurate, calcium tellurite or tellurate, and an amorphous iron tellurite or tellurate (Mandarino, 1962a). In the course of investigating the minerals from the oxidized zone of the mine, the writer noted a mineral in small orange colored blades and rosettes which he at first thought to be tellurite. *X*-ray fluorescence analysis, however, showed that the principal chemical constituents of the mineral were lead, uranium, and tellurium, and subsequent investigation has confirmed that the mineral is a new species, for which the name "Moctezumite" is here proposed. Other material being studied by the writer at the Instituto de Geología of the Universidad Nacional Autónoma de México has shown the presence of at least four more new species.

Geology

The tellurium-gold ore is in a series of sub-parallel quartz veins in a highly altered bedded rock which probably corresponds to a tuff, although the original character of the rock is obscured by hydrothermal alteration. This tuff has been folded and faulted, and bedding attitudes within the mine range from horizontal to vertical or overturned. The age of this rock is probably Late Cretaceous. Other rocks of volcanic origin, which appear to be andesitic flows and are younger, can be seen in the near vicinity. They also have been disturbed by faulting and folding. In and east of the valley of the Moctezuma River there is a flow of basalt covering at least 100 square kilometers, the age of which is Pleistocene (Gaines, 1965).

Mineralogy

The deepest workings in the mine are at 84 m, which is about 25 m below the water table. Even at this depth there is some evidence of oxidation in the ore. The metallic minerals present in the least oxidized ore consist principally of native tellurium and pyrite. Locally small grains of native gold are seen, but as these seem always to be associated with partial oxidation of the tellurium to paratellurite, it is not known whether the gold may also be an oxidation product of some gold telluride. However, no gold tellurides have as yet been identified in the ore.

Apart from tellurium, pyrite and gold, there are numerous minerals formed during oxidation of the ore. These include tellurite, paratellurite (Switzer, 1960), emmonsite, denningite, spiroffite, moctezumite, a calcium tellurite and a new zinc-iron tellurite mentioned by J. A. Mandarino, a new ferric tellurite or tellurate, a new uranium tellurite, chalcomenite, a red-violet lead and iron tellurite or tellurate, wulfenite, hydrated iron oxides, and manganese oxides. Among the non-metallic minerals are quartz, barite, fluorite and kaolin.

Very minor quantities have also been noted of native selenium, tetradymite, altaite, cinnabar, a copper selenide (possibly kockmanite), and at least three other new tellurium minerals. An attempt is being made to secure sufficient amounts of these to permit identification and description.

The moctezumite itself is found in crystals coating fractures in the oxidized portion of the vein material, associated principally with uranium tellurite, limonite, the red-violet lead-iron tellurite, and emmonsite. Barite is also commonly present. Some of the moctezumite is found as rosettes of crystals radiating from an empty core, suggesting that the oxidation and leaching of a preexisting uranium mineral may have been responsible for the moctezumite halos. Maximum observed size of the crystals was 3 mm long by 1 mm wide and about 0.2 mm thick; the habit is blade-like. Crystals have dull and commonly curved faces, which do not give satisfactory reflections on the two-circle goniometer.

Properties

Physical and optical properties. Moctezumite is bright orange in color, varying to dark orange and brownish orange in crystals that have been slightly altered. Hardness is about 3 and cleavage (100) is perfect. Specific gravity, measured by pycnometer, was 5.77. Taking into account that the sample contained 10.72% scheelite with a specific gravity of 6.10, the corrected measured specific gravity of moctezumite is 5.73.

All indices of moctezumite are higher than the highest liquid available to the writer, which has an index of 2.11. The mineral is biaxial (−) and has parallel extinction. 2V is small, in the range of 5°–10°.

Chemical tests. Moctezumite is readily soluble in dilute hydrochloric acid and in dilute sodium hydroxide, the resulting solutions giving tests for lead, uranium, and tellurium.

Concentration and analysis. About 800 mg of nearly pure moctezumite were concentrated and separated, using heavy liquids, a Frantz Isodynamic Separator, and an electrostatic separator to remove pyrite. The principal impurities remaining were scheelite and barite, with a little emmonsite and traces of pyrite. The scheelite was not in the original sample, but was introduced inadvertently when the impure moctezumite sample was treated in the electrostatic separator to remove pyrite. The separator had previously been utilized to perform a similar operation on scheelite concentrates, and in spite of careful cleaning before use, some scheelite remained and became mixed with the small amount of moctezumite recovered. Subsequently it could not be removed from the sample except by hand sorting, since its density and electrical and magnetic properties were too close to those of moctezumite to permit mechanical separation.

A small sample of pure moctezumite grains was hand picked from this concentrate for *x*-ray fluorescence analysis. This showed lead, tellurium, and uranium to be the only heavy elements present. Subsequently two

250-mg samples were analyzed by wet chemical methods (Table 1—average of two determinations).

If one adds to the total (Table 1) 2.09 per cent CaO, the theoretical quantity of lime required to make scheelite with the amount found of WO_3, the total becomes 99.40 per cent.

Composition. After deducting 1.23 percent of emmonsite, the remaining lead, uranium, and tellurium are found to be present in the molecular ratio:

$$PbO:UO_3:TeO_2 - 0.98:1.02:2.08$$

Thus, moctezumite has the formula $PbO \cdot UO_3 2TeO_2$, or $PbUTe_2O_8$.

This ratio was confirmed by preparing an artificial mixture of PbO, UO_3 and TeO_2 and comparing the *x*-ray fluorescence diagram of this mixture with that of the natural mineral. They gave essentially identical results.

TABLE 1. QUANTITATIVE CHEMICAL ANALYSIS OF MOCTEZUMITE

PbO	21.80%
UO_3	29.10
TeO_2	34.18
Fe_2O_3	0.29
Insoluble	3.26
Loss on heating to 500° C.	0.05
WO_3	8.63
Total	97.31

CRYSTALLOGRAPHY

Morphology. Crystals of moctezumite are elongated parallel to *b*, and flattened parallel to (201). Only four faces were observed: (100), (201), (110) and (021). Indices of the last two listed are uncertain as these two faces were too curved to give reflections on the goniometer.

X-ray powder diffraction data. Powder photographs of moctezumite give a pattern in which the three strongest lines correspond to 3.156, 3.492, and 2.997 Å. A complete list of d values is given in Table 2.

Crystal structure. Single-crystal *x*-ray studies were made using both Weissenberg and Buerger precession cameras. Considerable difficulty was experienced in securing suitable crystals for this work because of the tendency of the mineral to form sub-parallel, radiating groups of two or more crystals, in place of individual crystals. Even when simple crystals

TABLE 2. *X*-RAY POWDER PATTERN FOR MOCTEZUMITE

Basis: *a* 7.819, *b* 7.070, *c* 13.836 Å, *β* 93°37.5′
Cu radiation, Ni filter

Intensity	hkl	d (meas)	d (calc)
1	002	6.92	6.904
½	011	6.31	6.293
3	$\bar{1}02$	5.34	5.341
1	012	4.95	4.940
2	111	4.81	4.831
2	200	3.900	3.902
9	020	3.492	3.535
	$\bar{2}02$		3.493
6	113	3.385	3.387
10	$\bar{1}21$	3.156	3.154
7	014	3.088	3.102
8	212	2.997	2.997
1	114	2.818	2.819
3	$\bar{1}15$	2.488	2.487
2	311	2.384	2.385
½	006	2.288	2.301
1	032	2.227	2.230
1	$\bar{3}04$	2.141	2.144
1	$\bar{3}21$	2.090	2.087
5	133	2.012	2.011
4	400	1.949	1.951
2	232	1.920	1.920
3	410	1.882	1.881
1	035	1.791	1.793
2	040	1.763	1.768
	$\bar{1}35$		1.763
2	$\bar{4}04$	1.747	1.746
3	008	1.722	1.726
2	404	1.656	1.654
1	316	1.627	1.627
1	$\bar{2}18$	1.578	1.576
1	511	1.504	1.505
1		1.339	
3		1.302	

were found, these gave results difficult to interpret because of mosaic structure and other internal defects which resulted in the spots on Weissenberg level photographs being smeared out into lines which often reached 2 cm or more in length. This resulted in uncertainties in the location and measurement of the centers of the spots, and hence in their plotting and identification on rectangular coordinates. Best results were ob-

TABLE 3. CRYSTALLOGRAPHIC DATA FOR MOCTEZUMITE

Monoclinic a 7.819± .007, b 7.070± .003, c 13.836± .013 Å, β 93°37.5′

$a{:}b{:}c$	1.105:1:1.957
Volume	763.37 Å^3
Unit cell contents	$Pb_3U_3Te_6O_{24}$
Space group	$P\,2_1/c$
Density	
Calculated from $Pb_3U_3Te_6O_{24}$	5.41 g cm^3
Measured	5.73 g cm^3

tained with the precession method, where the smearing was considerably less pronounced.

NAME

The name moctezumite is proposed for this mineral in allusion to the name of the mine, La Moctezuma, and the nearest town, Moctezuma, Sonora.

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