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CLIFFORDITE—A NEW TELLURITE MINERAL FROM MOCTEZUMA, SONORA, MEXICO

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ABSTRACT

This new mineral occurs along joint surfaces in the oxidized zone of the San Miguel mine, a tellurium-gold-silver prospect near Moctezuma, Sonora, associated with mackayite, barite, quartz, and limonite. It has also been found in very small quantities at the Moctezuma mine in the same district, associated with native tellurium and paratellurite in small vugs.

The small octahedrons are bright yellow with adamantine luster. The mineral is isotropic and index of refraction is higher than 2.11. Insufficient natural material was available for quantitative analysis or specific gravity determination, but X-ray fluorescence analysis showed only uranium and tellurium in material from the San Miguel mine, and uranium, tellurium, and a small amount of lead in material from the Moctezuma mine. Synthetic material was identical in color, habit, and powder pattern with the natural material, and gave 31.3 percent U and 52.6 percent Te, which corresponds closely to the formula UTe_3O_8. Specific gravity, measured on synthetic material, was 6.57, and calculated specific gravity is 6.76.

Single crystal precession photographs showed $a = 11.371$ Å and space group $Pa3$, $Z = 8$. The principal powder lines with corresponding intensities are 3.273 (10): 2.844 (8): 2.007 (8): 2.755 (7): and 1.712 (7).

Cliffordite from the Moctezuma mine contains a little lead and is identical with the supposed lead oxy-fluoride from this mine described by Mandarino and Williams in 1961. The lead oxy-fluoride is therefore not a valid species.

The name is for Clifford Frondel, in recognition of his many contributions to the study of the mineralogy of uranium.

INTRODUCTION

In 1963 the writer noticed crusts of bright yellow microscopic crystals on some mackayite specimens from the San Miguel Mine, Moctezuma, Sonora, Mexico. Subsequent investigations established that these crystals consisted of uranium tellurite, a new mineral. Later on it was found that this mineral is identical with a substance from the Moctezuma Mine which had been first observed in 1961 and mistakenly identified as lead oxy-fluoride. The name cliffordite is proposed for this mineral.

OCCURRENCE

The San Miguel Mine is about 10 km northwest of the Moctezuma Mine in an environment of tertiary andesite porphyrys and altered tuffs. Quartz veins cutting these rocks sometimes contain substantial amounts of barite and pyrite, and in local shoots may be mineralized with native tellurium and other tellurides including gold and silver minerals. Oxidation of these veins has given rise to a number of oxidized tellurium minerals, especially mackayite, besides abundant jarosite and limonite and other iron oxides coating fractures.

Minerals recognized in very minor amounts include tetrahedrite, rickardite, emmonsite, tellurite, schmitterite (a new uranyl tellurite, the description of which is in preparation), cliffordite, and cerargyrite. The cliffordite is rare and because of the small size of the crystals and druses is not easy to find in spite of its bright color. Only about ten specimens altogether have been found so far. It occurs typically on oxidized joint surfaces in druses and scattered about between larger mackayite crystals which are thickly disseminated on the same surfaces. Sometimes the mackayite is yellowish, and since it has a crystal habit in some respects similar to the cliffordite and both minerals tend to give triangular adamantine reflections, this further tends to make recognition of the cliffordite difficult at a quick glance. The crystals are always small, the largest observed being about 0.2 mm across, and the majority are much smaller.

Physical and Optical Properties

Cliffordite is a bright sulphur-yellow color, with an adamantine luster. Its hardness is 4, and its density, measured by pyknometer on synthetic UTe_3O_8, is 6.57. Cliffordite is optically isotropic, and the index of refraction is greater than 2.11, the highest liquid available to the writer.

Chemical Tests

Cliffordite is soluble in concentrated hydrochloric acid but insoluble in dilute acid. It also dissolves slowly in solutions of the alkali hydroxides. By X-ray fluorescence analysis specimens from the San Miguel Mine were shown to contain only uranium and tellurium.

Composition

The first analysis made on cliffordite was done by Dr. Kurt Fredriksson of the Smithsonian Institution with the electron microprobe there. Using as standards grains of moctezumite, tellurite, and other tellurium minerals, the percentages of U and Te were found to be 24 ± 1 and 54 ± 1 respectively.

Since insufficient natural material was available for a wet chemical analysis, it was decided to try to synthesize the mineral. Preliminary efforts based on uranyl salts and tellurium dioxide were unsuccessful, but when a quadrivalent uranium salt (UF_4) was substituted for the uranyl salts in the raw material, crystals were produced which were identical in powder pattern, crystal habit, color and qualitative composition to natural cliffordite, hence the crystals were assumed to be synthetic cliffordite. Considerable experimentation was required before the optimum conditions for synthesis were established; it was found for instance, that a moderate oxidizing environment (using hydrogen peroxide) was very helpful, probably in causing the $Te_3O_8^{-4}$ complex to form. An excess of oxidizer resulted in the formation of uranyl tellurite plus tellurium dioxide. Natural uranyl tellurite has also been found at both the San Miguel and the Moctezuma Mines; its description is in preparation.

The synthesis was carried out in pyrex and in vycor tubes in a stainless steel bomb. The best results and largest crystals were obtained at about 360°C and 184 bars.

The synthetic product was analyzed by standard wet procedures. The results of analysis are given in Table 1. The resulting formula, UTe_3O_8, makes cliffordite the second tellurium compound found in nature having the $Te_3O_8^{-4}$ radical, the first one being spiroffite, $(Mn, Zn)_2 Te_3O_8$, which was found at the Moctezuma Mine.

TABLE 1. QUANTITATIVE CHEMICAL ANALYSIS OF CLIFFORDITE

	UTe_3O_8	Natural cliffordite microprobe analysis	Synthetic cliffordite
U	31.79	24±1	31.25
Te		54±1	
Te_3O_8	68.21	(72±1.3)	70.25
Total	100.00		101.50

MORPHOLOGY

Crystals of cliffordite are isometric, and the only form observed in natural material is the octahedron. Synthetic material, while dominantly octahedral, also showed the cube.

X-RAY POWDER DIFFRACTION DATA

Powder photographs of cliffordite gave a pattern in which the three strongest lines are 3.273, 2.844 and 2.007. Table 2 gives a complete list of *d* values with corresponding *hkl* indices. Since sharp lines were observed even in the back reflection region, it was possible to use these for a refinement of the cell dimensions.

CRYSTAL STRUCTURE

Buerger precession photographs were made of the *h*00, *h*10, *h*20 planes, and also of *hh*0 and *hhh* planes. These established the symmetry as cubic, space group *Pa*3. The value of *a* is 11.371 Å, and the cell volume is 1470.3

TABLE 2. INDEXED X-RAY POWDER PATTERN FOR CLIFFORDITE

Basis: $a=11.371$ Å
Cu radiation, Ni filter

I	d(obs.)	d(calc.)	hkl
1	6.52	6.565	111
4	5.66	5.686	200
1	5.07	5.085	210
6	4.63	4.642	211
6	4.02	4.020	220
3	3.80	3.790	221
2	3.423	3.428	311
10	3.273	3.283	222
2	3.159	3.154	320
3	3.037	3.039	321
8	2.844	2.843	400
7	2.755	2.758	410, 322
4	2.683	2.680	411, 330
5	2.537	2.543	420
2	2.479	2.481	421
4	2.322	2.321	422
1	2.270	2.274	430
4	2.226	2.230	431
1	2.110	2.112	520, 432
8	2.007	2.010	440
2	1.981	1.979	522, 441
2	1.953	1.950	530, 433
5	1.894	1.895	600, 442
3	1.845	1.845	611, 532
6	1.796	1.798	620
4	1.778	1.776	621, 540, 443
2	1.756	1.755	541
7	1.712	1.714	622
4	1.696	1.695	630, 542
1	1.677	1.677	631
3	1.640	1.641	444
5	1.625	1.624	632
1	1.608	1.608	710, 550, 543
2	1.575	1.577	640
6	1.518	1.520	642
2	1.505	1.506	722, 544
2	1.457	1.456	650, 643
2	1.446	1.444	732, 651
1	1.421	1.421	800
1	1.408	1.410	810, 740, 652
2	1.401	1.400	811, 741, 554
5	1.379	1.379	820, 644
1	1.358	1.359	653
3	1.341	1.340	822, 660
3	1.322	1.322	831, 750, 743
2	1.305	1.304	662
2	1.272	1.271	840
6	1.241	1.241	842
1	1.225	1.226	921, 761, 655
3	1.212	1.212	664
2	1.204	1.205	922, 850, 843, 762
1	1.161	1.161	844
1	1.149	1.149	941, 853, 770
2	1.138	1.137	10.0.0, 860
1	1.131	1.131	10.1.0, 942, 861, 764
6	1.1154	1.1150	10.2.0, 862
1	1.0938	1.0942	10.2.2, 666
3	1.0554	1.0558	10.4.0, 864
3	1.0386	1.0380	10.4.2
2	.9890	.9897	10.4.4, 882
2	.9741	.9751	10.6.0, 866
1	.9605	.9610	10.6.2
1	.9476	.9476	12.0.0, 884
2	.9342	.9347	12.2.0
3	.9221	.9223	12.2.2, 10.6.4
1	.8960	.8962	12.4.1, 11.6.2, 10.6.5, 984
5	.8875	.8879	12.4.2, 10.8.0, 886
3	.8771	.8773	10.8.2
4	.8476	.8475	12.6.0, 10.8.4
3	.8385	.8383	12.6.2
1	.8341	.8338	13.4.1, 11.8.1, 11.7.4
4	.8121	.8122	14.0.0, 12.6.4
5	.8042	.8041	14.2.0, 10.10.0, 10.8.6
2	.7961	.7961	14.2.2, 10.10.2
2	.7941	.7942	14.3.0, 13.6.0, 12.6.5
2	.7922	.7923	14.3.1, 13.6.1, 11.9.2, 11.7.6, 10.9.5
2	.7862	.7865	14.3.2, 13.6.2, 12.8.1, 12.7.4, 10.10.3, 988
4	.7809	.7810	14.4.0, 12.8.2
3	.7737	.7737	14.4.2, 12.6.6, 10.30.4

$Å^3$. $Z=8$, and the calculated specific gravity is 6.766, in reasonable agreement with the measured value of 6.57.

During the course of this investigation, a sample was borrowed from the mineral collection of the American Museum of Natural History of a mineral which had been found at the Moctezuma Mine in 1961 and tentatively identified by Mandarino and Williams (1961) as lead oxy-fluoride, a new mineral. This mineral occurs as a bright yellow crystalline coating in cavities in native tellurium, associated with quartz and paratellurite.

Because the color is identical with cliffordite, and some minute octahedral crystals were visible, cliffordite was suspected. X-ray fluorescence analysis showed tellurium and uranium as major constituents, with a minor quantity of lead also present. The powder photograph of this substance is identical with that of cliffordite, with the exception that $a = 11.47$ Å. This slightly larger cell is probably due to the presence of 2 to 3 percent lead in substitution for some of the uranium. The three strongest lines of lead oxy-fluoride are 3.33, 2.88 and 2.04. On the basis of these data, there can be no doubt that the mineral found at the Moctezuma Mine is plumbian cliffordite and the lead oxy-fluoride as a natural mineral has yet to be found.

Name

The name cliffordite is proposed for this mineral in honor of Professor Clifford Frondel of Harvard University in recognition of his many contributions to the science of mineralogy and in particular in the field of the mineralogy of uranium. Cliffordite has been approved by the Committee on New Minerals and New Mineral Names of the I.M.A.

Type Material

Specimens of "lead oxy-fluoride", now known to be plumbian cliffordite, are to be found in a number of museums. A specimen of cliffordite from the San Miguel Mine has been deposited in the mineral collection of the Smithsonian Institution, U.S. National Museum, Washington, D.C.

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References

Gaines, R. V. (1965) Mineralizacion de telurio en la mina Moctezuma, cerca de Moctezuma, Sonora. *Univ. Nac. Auton., Mex., Inst. Geol. Bol.* **75,** (pt. 1.)

——— (1967) Nuevos datos sobre mackayita. *Univ. Nac. Auton., Mex., Inst. Geol. Bol.* **82,** (pt. 2).

Mandarino, J. A., and S. J. Williams (1961) Five new minerals from Moctezuma, Sonora, Mexico. *Science,* **133,** 2017.

———, S. J. Williams and R. S. Mitchell (1963) Spiroffite, a new tellurite mineral from Mexico. *Mineral Soc. Amer. Spec. Pap.* **1.**

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