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STUDIES OF URANIUM MINERALS (XXIII): TORBERNITE,
ZEUNERITE AND URANOSPHERITE.¹ROBERT BERMAN, *Harvard University Cambridge, Mass., and U. S.
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TORBERNITE

An attempt was made to synthesize the fully hydrated (8–12 H₂O) form of torbernite, as no account of its synthesis could be found in the literature. Two solutions were made: 4.83 g. of Cu(NO₃)₂·3H₂O and 21.68 g. of (UO₂)(NO₃)₂·6H₂O were dissolved in 500 ml. of water; 5.52 g. of NaH₂PO₄·H₂O was dissolved in another 500 ml. of water. Both solutions were chilled with distilled-water ice cubes before and during mixing. The two solutions were combined, and the mixture was stored in a refrigerator at 5° C. A green precipitate formed in the course of several days. It was kept in the refrigerator as a damp slurry and was used in that form as far as possible.

Under the petrographic microscope the precipitate was seen to be microcrystalline, with low birefringence and extinctions visible on some of the grains. Only a mean index of refraction could be obtained; it was measured as 1.590.

The *d*-spacings were obtained on an *x*-ray spectrometer and are given in Table 1. They are analogous to the spacings of fully hydrated zeunerite and autunite and bear the same relationship to the less hydrated forms as do the other species of the torbernite group. The cell dimensions are $a_0 = 7.025 \text{ \AA} \pm 0.005$, $c_0 = 20.63 \text{ \AA} \pm 0.02$.

ZEUNERITE

Zeunerite is the arsenate analogue of torbernite. Fully hydrated zeunerite was synthesized by J. W. Frondel (1951) but hitherto has not been reported with certainty in nature.

Some specimens with transparent green crystals were obtained from the Natural History Museum of Vienna. The labels identified the specimens as zeunerite from the Weisser Hirsch mine, Schneeberg, Saxony. The indices of refraction are as follows: $n_O = 1.610$, $n_E = 1.582 (\pm 0.001, 25^\circ \text{ C})$. The specific gravity was measured on the Berman Balance. Several grains gave values close to 3.47.

The zeunerite occurs as orthogonal crystals as much as 2 mm. in diameter, bounded by prisms and basal planes. Some of the rectangular

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TABLE 1. INTERPLANAR SPACINGS FOR TORBERNITE, ZEUNERITE AND URANOSPHERITE. Cu $K\alpha$ RADIATION, Ni FILTER

Torbernite, artificial $a_0=7.025 \text{ \AA}$, $c_0=20.63$			Zeunerite, Schneeberg $a_0=7.18 \text{ \AA}$, $c_0=21.06$			Uranospherite, Schneeberg	
d (\AA)	I	hkl	d (\AA)	I	d (\AA)	I	
10.30	10	002	10.20	10	5.25	8	
6.61	4	101	6.75	5	4.74	3	
5.17	3	004	5.25	1	4.37	4	
4.94	9	110	5.06	8	4.15	1	
4.476	4	112	4.606	2	3.87	7	
3.674	4	114			3.47	7	
3.578	9	200	3.611	9	3.16	10	
3.512	8	202	3.384	7	3.05	3	
3.097	1	211	3.167	2	2.71	1	
		212	3.064	1	2.60	1	
2.904	3	204	2.946	4	2.54	1	
2.853	2	213	2.885	4	2.46	2	
2.731	1	214	2.753	3	2.39	2	
2.665	1	205			2.35	1	
2.477	1	220	2.533	4	2.16	2	
2.412	2	222	2.457	4	2.08	2	
2.237	1	224			2.03	1	
			2.366	1	1.97	8	
			2.321	2	1.90	7	
			2.263	3	1.83	8	
			2.201	4	1.80	1	
			2.075	5	1.73	2	
			1.978	1	1.66	4	
			1.932	6	1.59	1	
			1.870	1	1.56	1	
			1.795	5	1.52	1	

blocks are truncated by the (011) form; on some of the larger crystals these pyramids result in a lozenge shape. The pyramids are striated parallel to the base. There are good cleavages parallel to the base and prisms. The basal cleavage is by far the best. The crystals typically break into rectangular tabular fragments. Incipient dehydration, presumably due to metazeunerite, has taken place along some of the rectangular edges of the base, outlining the crystals with light-green matte material. The unaffected material gives an x -ray pattern virtually identical with that of fully hydrated zeunerite. The spacings of the natural material are listed in Table 1. The unit cell dimensions are $a_0=7.18 \pm 0.01 \text{ \AA}$, $c_0=21.06 \pm 0.02 \text{ \AA}$.

Miss M. E. Thompson (personal communication) states that a copper uranyl arsenate having similar indices of refraction occurs as a coating on

black coaly material from the Dexter Mine, Calf Mesa, San Rafael Swell, Utah. When the samples were first studied, the optical properties were as follows: $n_O = 1.610 \pm 0.002$, $n_E = 1.583 \pm 0.002$. Pleochroism $O =$ pale blue-green, $E =$ very pale green. No pleochroism was observed in the Schneeberg samples. The Calf Mesa material dehydrated very quickly. The x -ray pattern, obtained a few weeks later, matches meta-zeunerite, and the indices changed to $n_O = 1.642$, $n_E = 1.610$.

URANOSPHERITE

Uranospherite was described by Weisbach (1873) from the Walpurgis vein of the Weisser Hirsch mine at Neustädtl, near Schneeberg, Saxony. It is a secondary mineral, formed with various arsenates in the oxidized zone of a vein carrying uraninite, native bismuth, and cobalt-nickel arsenides. It is associated with walpurgite, uranospinite, troegerite, zeunerite, erythrite, and black cobalt oxide. It is known only from the original locality. Very few authentic specimens appear to be extant, and x -ray powder data have not been available.

Uranospherite is a hydroxide or hydrated oxide of bismuth and hexavalent uranium. The formula is uncertain, perhaps $\text{Bi}_2\text{O}_3 \cdot 2\text{UO}_3 \cdot 3\text{H}_2\text{O} = (\text{BiO})(\text{UO}_2)(\text{OH})_3$. The only reported analysis is given in Table 2.

TABLE 2. ANALYSIS OF URANOSPHERITE

	Bi_2O_3	UO_3	H_2O	Total
1.	42.66	52.39	4.95	100.00
2.	44.34	50.88	4.75	99.97

1. Theoretical weight percentage, $\text{Bi}_2\text{O}_3 \cdot 2\text{UO}_3 \cdot 3\text{H}_2\text{O}$.
 2. Uranospherite, Schneeberg, Saxony; Winkler, analyst, in Weisbach (1873).

The mineral is orange in color, and occurs as drusy, radial aggregates up to 0.5 mm. in diameter. When these are broken apart, the radial laths of the material almost always rest on a cleavage. The laths usually have somewhat irregular terminations, giving the drusy appearance to the exterior of the radial group. Occasionally, the laths are terminated by one or two small oblique edges. The edges make angles of 40° and 140° with the sides of the lath. In the cases where two terminal edges meet, forming an arrowlike point on the lath, the angle of the point is 80° . Faint striations can be observed parallel to the direction of the lath. Spectrographic and thermal analyses are lacking. On heating, the mineral decrepitates and falls to pieces composed of brown, silky needles.

An authentic specimen was obtained from the Natural History Museum, Vienna, through the courtesy of Dr. A. Schiener, curator. The

TABLE 3. OPTICAL PROPERTIES OF URANOSPHERITE

	Orientation	New data	Larsen (1921)
X	<i>a</i>	1.959	1.955
Y	<i>b</i>	1.981	1.985
Z	<i>c</i>	2.060	2.05

optics were measured, using phosphorus and Larsen-Meyrowitz index liquids, and the results are in agreement with those reported by Larsen (1921) on a specimen from the Roebbling collection. The values obtained are given in Table 3.

Z is parallel to the elongation of the laths and X is normal to the cleavage. The optic sign is positive, and $2V$ is calculated as 56° . Larsen observed strong dispersion, $r < v$. There is no marked absorption or pleochroism. The mineral is probably orthorhombic. A U. S. National Museum specimen, no. R-5892, labelled uranospherite, was examined optically and its identity was verified. The x-ray diffraction pattern of the Vienna specimen is given in Table 1.

Fletcher (1913) attempted to measure the melting point of supposed uranospherite from Sabugal, Portugal. He states that small particles "lose body" at 1170°C ., and that larger particles melt with iridescence at 1320°C . His material is from an undescribed locality for this mineral, and its authenticity is very doubtful.

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IDENTITY OF PILBARITE WITH THOROGUMMITE AND KASOLITE

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Pilbarite was described by Simpson (1910) from the Wodgina area of the Pilbara goldfields, Western Australia. The mineral occurs as small nodules enclosed in albite in weathered outcrops of tantalite-rich pegmatites. Occasional residual cores of thorogummite indicate that the

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