

NEW DATA ON BOLTWOODITE, AN ALKALI
URANYL SILICATE

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ABSTRACT

Boltwoodite is an alkali uranyl silicate with the composition $K(H_2O)UO_2(SiO_4) \cdot nH_2O$ where n is zero to one. Chemical analysis, recalculated after deducting impurities, gives SiO_2 -14.8, UO_3 -68.5, K_2O -9.4, Na_2O -0.4, H_2O -6.9, total 100.0 per cent. The proposed formula is supported by infra-red data, and the formula and other lines of evidence are shown to indicate a relationship to kasolite. Strongest lines of the x-ray powder pattern are 6.81 (10), 3.40 (9), 2.95 (8), 3.54 (7), and 2.91 (7). Optically biaxial negative with $nX=1.668$ -1.670, $nY=1.695$ -1.696, $nZ=1.698$ -1.703; 2V large, anomalous blue interference color, parallel extinction. Color pale yellow. Habit: radiating acicular to fibrous, and dense microcrystalline pseudomorphic aggregates. Hardness $3\frac{1}{2}$ to 4. Perfect (010) and imperfect (001) cleavage. Symmetry orthorhombic on basis of optical study, but may be monoclinic with b -axis elongation. Boltwoodite occurs as a secondary mineral coating fractures and cavities, and as pseudomorphs after uraninite. Twenty one localities representing a variety of geological environments are listed. Data are presented on the hydrothermal synthesis of the potassium, potassium plus sodium, sodium, and ammonium analogues of the mineral.

INTRODUCTION

Boltwoodite was described from the Delta mine, Emery County, Utah, by Frondel and Ito (1956). It was the first of the alkali uranyl silicates to be noted, and with gastunite (Honea, 1959) is one of two such minerals now known. Since the original description, many additional widely scattered localities with different geological environments have been noted. The new material available has allowed the compiling of additional data concerning properties and occurrence, and has permitted infra-red analysis to determine the structural relationship of boltwoodite to other members of the uranyl silicate group. This new information concerning the natural mineral is presented herein, along with data on the hydrothermal synthesis of the potassium, potassium plus sodium, sodium, and ammonium analogues.

PHYSICAL PROPERTIES

In general aspect, boltwoodite is very similar to both sklodowskite and uranophane, but is somewhat paler in color than the latter. At the Delta mine, Utah, and the Lookout No. 22 mine, Colorado, the mineral occurs as yellow wartlike aggregates of fibers. Specimens from Myponga South Australia, and Quebrada del Tigre, Argentina, are pale yellow in color and contain boltwoodite in flattened radial aggregates between grains and along cleavage surfaces. Pseudomorphic aggregates from Alto Boqueirao, Brazil, and the Little Indian mine, Colorado, are dense mi-

microcrystalline and pale straw yellow in color. Specific gravity about 3.6 (Fron del and Ito, 1956). Hardness $3\frac{1}{2}$ to 4. Perfect (010) and imperfect (001) cleavage. Luster of crystals pearly on cleavage surfaces, of radial aggregates vitreous to silky, depending on crystal size. Dull to earthy in microcrystalline pseudomorphs. The mineral fluoresces dull green under both long- and shortwave ultraviolet excitation.

CHEMICAL ANALYSIS

The only available chemical analysis of boltwoodite is listed below in Table 1. As indicated in column E of the table, the analysis is in good agreement with the originally proposed formula $K_2(UO_2)_2(SiO_3)_2(OH)_2 \cdot 5H_2O$ except for the low water content. However, more recent data

TABLE 1. CHEMICAL ANALYSIS OF BOLTWOODITE

	A	B	C	D	E	F
SiO ₂	12.74	14.8	0.246	2	13.44	14.29
UO ₃	58.68	68.5	0.243	2	63.96	68.07
K ₂ O	8.03	9.4	0.100	} 1	10.52	11.21
Na ₂ O	0.33	0.4	0.006			
CuO	9.61	—	—	—	—	—
SO ₃	2.12	—	—	—	—	—
H ₂ O	7.33	6.9	0.373	3	12.08	6.43
Insol.	0.19	—	—	—	—	—
Rem.	0.34	—	—	—	—	—
Total	99.37	100.0			100.00	100.00

A. Boltwoodite, Delta mine, Emery County, Utah. Remainder includes Al₂O₃, CaO, MgO, PbO, and V₂O₅. Analyst Jun Ito in Fron del and Ito, 1956.

B. Analysis recalculated after deducting brochantite, Cu₄SO₄(OH)₆, insoluble, and undetermined portions.

C. Molecular amounts calculated from B.

D. Molecular proportions from B.

E. Ideal composition of $K_2(UO_2)_2(SiO_3)_2(OH)_2 \cdot 5H_2O$.

F. Ideal composition of $K_2O \cdot 2UO_3 \cdot 2SiO_2 \cdot 3H_2O$ or $K(H_3O)UO_2(SiO_4) \cdot nH_2O$ where $n=0$.

from infra-red analysis indicates that the water as determined is correct and that the mineral has a nesosilicate structure. The formula proposed on the basis of this new data is $K(H_3O)(UO_2)(SiO_4) \cdot nH_2O$, in which n designates zeolitic water which on the basis of limited analytical data varies from zero through one. The ideal composition for the newly proposed formula is listed in column F, and is seen to be in even closer agreement than the above. The formula here proposed is close to that of

kasolite, a relationship discussed more fully in a following section of this paper. The analysis sample of Frondel and Ito contained brochantite and small amounts of unidentified materials, which are deducted in the recalculated analysis in column B.

OPTICAL DATA

As shown in Table 2 there is close agreement between optical constants for boltwoodite from the several natural occurrences. It is worthy

TABLE 2. OPTICAL DATA FOR NATURAL AND SYNTHETIC BOLTWOODITE

	1	2	3	4	5	Pleochroism	
nX	1.668	1.669	1.670	1.670	1.661-1.671	Colorless	Biaxial neg.
nY	1.696 (?)	1.695	1.695		1.682-1.694	Pale ylw	Anomalous blue
nZ	1.703	1.698	1.702	1.70	1.689-1.702	Pale ylw	Parallel extinction Z = elongation
<ol style="list-style-type: none"> 1. Boltwoodite, Delta mine, Emery County, Utah (Frondel and Ito, 1956). 2. Boltwoodite, La Chiquita mine, Quebrada del Tigre, Cordoba Province, Argentina. 3. Boltwoodite, Myponga, South Australia. 4. Unknown type 1b, Bad Gastein, Salzburg (Haberlandt and Schiener, 1951). 5. Beta-uranophane, <i>n</i> for yellow light, (Steinocher and Novacek, 1939). 							
	6	7	8	9	10		
Average <i>n</i>	1.695	1.61	1.61	1.62	1.642		
<ol style="list-style-type: none"> 6. Boltwoodite, Alto Boqueirao, Brazil. Dense, microcrystalline aggregate. 7. Synthetic potassium boltwoodite containing amorphous silica. 8. Synthetic potassium plus sodium boltwoodite containing amorphous silica. 9. Synthetic sodium boltwoodite containing amorphous silica. 10. Synthetic ammonium boltwoodite containing amorphous silica in lesser amount than above, and coarser grained. 							

of note that the indices of refraction of boltwoodite are in close agreement with those of the upper range for beta-uranophane as determined by Steinocher and Nováček (1939). Because of this similarity, it is believed that *x*-ray examination of specimens labelled beta-uranophane will add to the number of occurrences listed in this paper. Two of the localities herein noted have previously had beta-uranophane identified on the basis of optical data. Indices of refraction for beta-uranophane are presented for comparison in Table 2.

Haberlandt and Schiener (1951) list an unknown uranyl silicate from Bad Gastein, Salzburg, with optics identical to those determined by the writer. Since the *x*-ray powder pattern of this unknown did not check with that of beta-uranophane, which is present in the same suite, the unknown mineral is here tentatively identified as boltwoodite.

The synthetic products, and dense pseudomorphs after uraninite from

natural occurrences, were too fine-grained to yield complete optical data. In such instances only an average index of refraction is reported. It is immediately obvious that the values obtained for most of the fine-grained synthetic products are lower than expected. This is the result of the presence of both adsorbed water and excess amorphous silica in the sub-microscopically crystallized aggregates. Although too fine-grained for optical data, these products give good x-ray powder diffraction patterns in which the only effect of grain size is a very slight broadening of lines.

X-RAY AND CRYSTALLOGRAPHIC DATA

The small size of available crystals precluded the use of morphologic or single crystal x-ray methods. Optical study indicates orthorhombic symmetry, but like most of the other acicular uranyl silicates, boltwoodite may be monoclinic with *b*-axis elongation. Measured *d*-spacings

TABLE 3. X-RAY POWDER DIFFRACTION DATA FOR BOLTWOODITE FROM THE DELTA MINE, EMERY COUNTY, UTAH. COPPER RADIATION, NICKEL FILTER, WAVELENGTH 1.5418A

d	I	d	I	d	I
7.53	2	1.994	2	1.335	2
6.81	10	1.983	2	1.311	2
6.40	5	1.950	3	1.297	4b
5.45	5	1.935	1	1.270	$\frac{1}{2}$
4.74	4	1.900	6b	1.242	2b
4.32	4	1.874	1	1.211	1
4.11	2	1.820	2	1.196	1
3.91	1	1.780	1	1.174	2
3.75	1	1.764	6	1.149	2b
3.54	7	1.700	3	1.122	1b
3.40	9	1.658	3	1.112	2
3.13	5	1.627	2	1.087	1b
3.07	1	1.602	2b	1.072	1
2.95	8	1.580	2	1.053	2
2.91	7	1.566	1	1.041	1
2.69	1b*	1.550	1	1.023	1b
2.53	3	1.530	2	1.000	1
2.45	5	1.515	3b	0.980	1b
2.34	4	1.502	3b	0.971	1
2.26	5	1.487	1b	0.963	2b
2.21	4	1.455	1	0.928	1b
2.16	2	1.438	1	0.915	1b
2.13	3	1.411	3	0.884	1b
2.11	2	1.393	1	0.876	1
2.08	1	1.378	2	0.845	$\frac{1}{2}$
2.05	3	1.356	1b		

* b = broad.

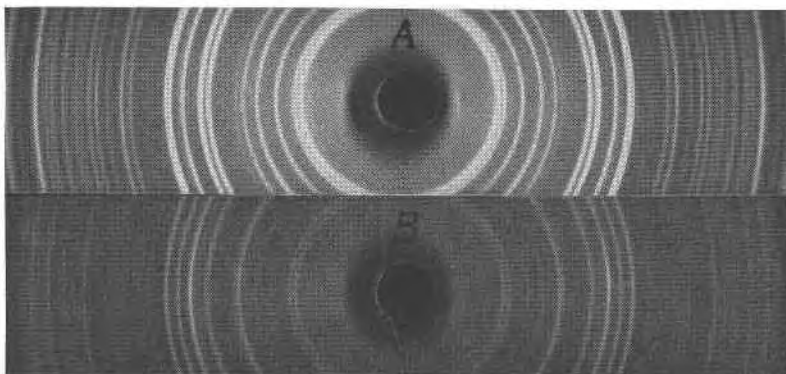


FIG. 1. X-ray powder diffraction patterns of: A. Boltwoodite, Delta mine, Emery County, Utah, and B. Kasolite, Shinkolobwe, Belgian Congo. Copper radiation, nickel filter. Contact print.

from an x-ray powder diffraction pattern corrected for film shrinkage are listed in Table 3. These spacings are in close agreement with the spacings for the first ten lines given in the preliminary description of Frondel and Ito (1956).

Figure 1 shows powder patterns for both boltwoodite and kasolite. Similarities in the general configuration of the patterns are seen to be present, and coupled with other lines of evidence, to be discussed later, are taken to indicate a structural relationship between the two phases.

INFRA-RED ABSORPTION SPECTRUM

Infra-red absorption spectra were made of both the natural and synthetic mineral, the curves for which are reproduced below as Fig. 2A and B. Analyses were made on a Perkin-Elmer instrument with sodium chloride analyzing prism. Samples were prepared for analysis by mixing two mg. of the very finely ground mineral (minus 325 mesh) with 0.5 grams of specially dried potassium bromide, and pressing the mixture into a thin wafer. Since not enough material was available from the type specimen, the absorption curve for the natural mineral was prepared with material from the locality in Cordoba Province, Argentina.

Absorption maxima appearing on all curves near 3.0 and 6.2 microns correspond to the stretching and bending vibrations respectively of the hydroxyl (or HOH) bond (Randall, *et al.*, 1949). The additional low wavelength maxima at 3.2 and 7.15 microns on curve B mark the stretching and bending vibrations of the ammonium bond. Stronger absorption peaks in the region from 10.1 to 11.7 microns result from silicate bonding, and are within the region from 9.7 to 12.2 microns shown by

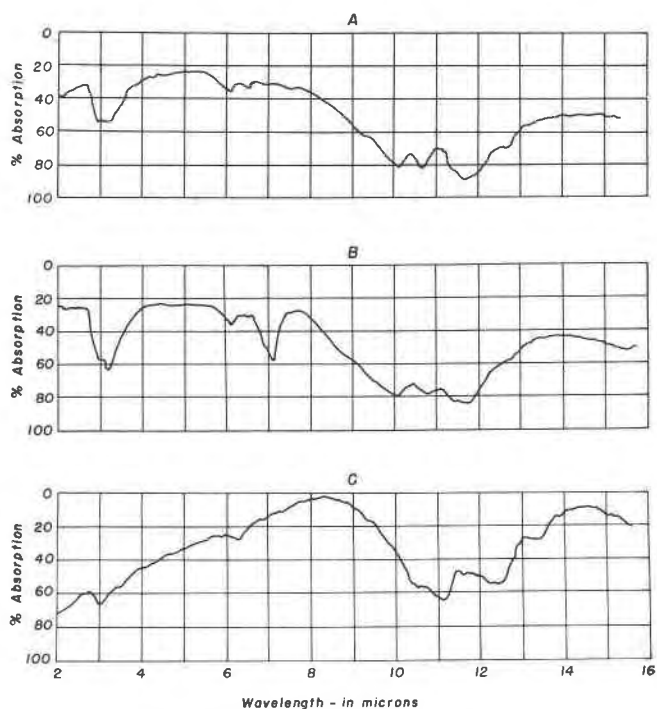


FIG. 2. Infra-red absorption spectra of natural and synthetic boltwoodite, and kasolite. A. Boltwoodite, La Chiquita mine, Quebrada del Tigre, Cordoba Province, Argentina, B. synthetic ammonium boltwoodite, C. kasolite, Shinkolobwe, Belgian Congo.

Launer (1952) to be typical of minerals having nesosilicate structures. On the basis of this evidence it is proposed that boltwoodite, like uranophane (Smith, Gruner, and Lipscomb, 1957), contains independent silicate tetrahedra as basic structural units.

The infra-red spectral curve for kasolite is included as Figure 2C for purposes of comparison. It is shown in the following discussion that boltwoodite most closely approaches the kasolite nesosilicate formula early proposed by Billiet and de Jong (1936), and since supported by Gorman (1957) on the basis of single crystal x -ray study. It is noted that the strong absorption maxima of kasolite are also present in the range typical of minerals with the nesosilicate structure, and thus that both minerals are comprised of the same basic silicate structural units.

COMPARISON WITH KASOLITE

Boltwoodite is found to be quite similar to kasolite on the basis of molecular ratios from chemical analyses, a conclusion supported by

x-ray powder diffraction patterns, infra-red data, and optical data. Both minerals show a much lower water content than the other uranyl silicates, containing respectively one (kasolite— $\text{PbO} \cdot \text{UO}_3 \cdot \text{SiO}_2 \cdot \text{H}_2\text{O}$) and three (boltwoodite— $\text{K}_2\text{O} \cdot 2\text{UO}_3 \cdot 2\text{SiO}_2 \cdot 3\text{H}_2\text{O}$) molecules of water in the oxide formulas derived from analyses. Further, the three water molecules in the boltwoodite formula are required to occupy cation positions as hydronium ions to balance the electrostatic charge demanded by the nesosilicate structure indicated by infra-red analysis. A lower water content for boltwoodite is also suggested by the significantly higher indices of refraction as compared to gastunite- $(\text{K}, \text{Na})_2(\text{UO}_2)_3(\text{Si}_2\text{O}_5)_4 \cdot 8\text{H}_2\text{O}$, which is also a potassium uranyl silicate.

The ionic radii of the principal cations ($\text{K}^+—1.33\text{A}$, $\text{H}_3\text{O}^+—1.33\text{A}(?)$, $\text{Pb}^{++}—1.20\text{A}$) indicates that these cations are well within the size range that would allow the formation of similarly coordinated structures. The similarities in line configuration and *d*-spacings of *x*-ray powder diffraction patterns of the two minerals, previously pointed out in Fig. 1, suggests this similarity in structure. It is not suggested that the minerals are isostructural, but rather that their structures are similar and closely related. The mechanism of positioning the monovalent potassium and hydronium ions for divalent lead ions is not known.

It is felt that though there is a superficial resemblance of the *x*-ray powder pattern to that of sklodowskite, as suggested in the original description, there is more similarity of boltwoodite to kasolite. This similarity is indicated in the above discussion, and is strongly favored over resemblances to other uranyl silicates by the low water content.

THERMAL BEHAVIOR

A study of the thermal behavior of boltwoodite was carried out on material pseudomorphic after uraninite from Quebrada del Tigre, Cordoba Province, Argentina. The material used contains about two per cent impurities and is extremely fine-grained, but was the only material available in sufficient amount for such a study. The differential thermal analysis curve for boltwoodite is reproduced as Fig. 3, and a weight loss curve is shown as Fig. 4. Distinct endothermic peaks are present at 170° , 708° , and 906° C., and a single exothermic reaction at 1010° C. The low temperature peak results from expulsion of capillary and adsorbed water, and possibly from the loss of small amounts of zeolitic water. The most rapid water loss is seen in Fig. 4 to take place below 100° C., and optical and *x*-ray powder studies of material heated to 100° C. shows no change in optical constants or *d*-spacings. Material heated to 200° C. shows an increase in indices of refraction, and a very slight change in line intensities on *x*-ray patterns. When the heated sample is placed over

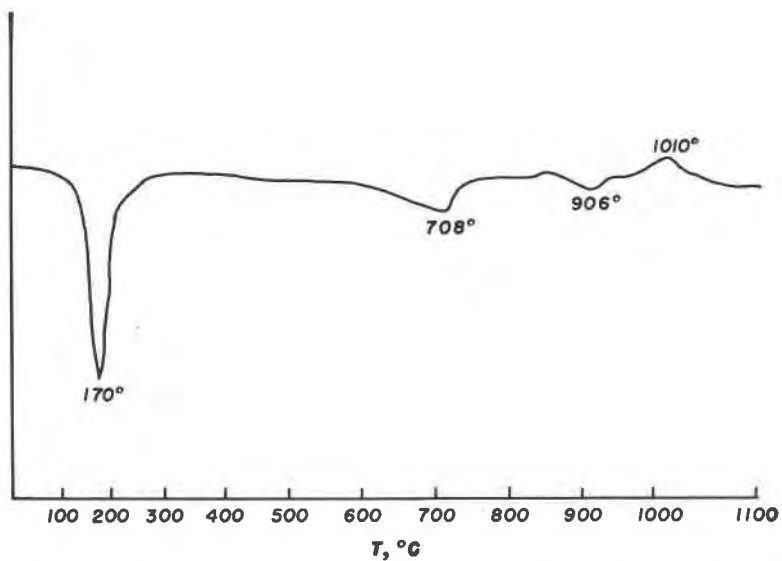


FIG. 3. Differential thermal analysis curve for boltwoodite from the La Chiquita mine, Quebrada del Tigre, Cordoba Province, Argentina.

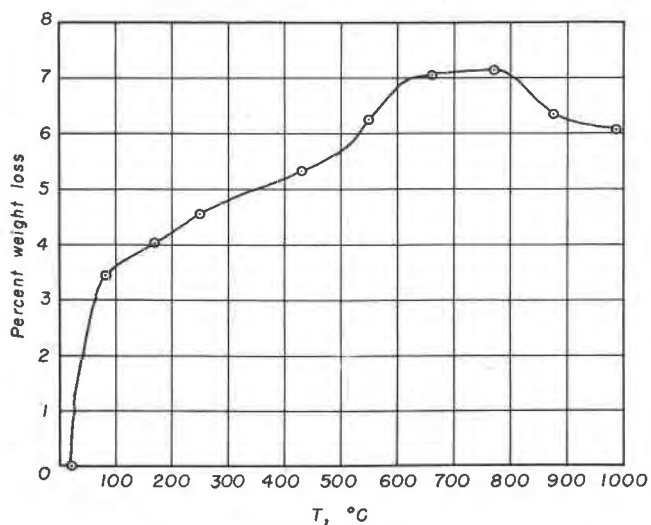


FIG. 4. Weight loss curve for boltwoodite from the La Chiquita mine, Quebrada del Tigre, Cordoba Province, Argentina.

water in a sealed container it regains normal optical constants in 48 hours. Above 100° C. weight loss continues at a lesser rate to approximately 500° C., at which temperature the curve steepens to slightly above 600° C. This final loss of weight corresponds to the broad exothermic reaction beginning at 600° C. and culminating at 708° C., and marks the final loss of water bonded as hydronium ions. X-ray patterns of material heated between 200° and 750° C. show a gradual collapse of the boltwoodite structure, and the appearance of small amounts of uraninite and U₃O₈ above 550° C. Total collapse of the boltwoodite structure has occurred at 750° C., and very broad and diffuse lines of a new phase appear. The gain of weight above 800° C. results from oxidation of the partially reduced uranium, and is expressed on the differential thermal analysis curve as an endothermic trough near 906° C. X-ray study indicates the appearance of a new phase at 875° C., the powder pattern of which resembles the x-ray pattern of clarkeite. This phase is stable to the highest temperature attained in the study (1100° C.), and at temperatures above 1000° C. is accompanied by an additional phase. The exothermic reaction at 1010° C. marks the appearance of this new phase, which could not be identified in the present study.

HYDROTHERMAL SYNTHESIS

Boltwoodite is readily synthesized by hydrothermal techniques in both low temperature runs and in higher temperature bomb runs. The method of synthesis used consists of coprecipitation of the essential ions in a gel from the soluble acetates. In all cases a 0.01 molar solution containing the essential ions was precipitated by raising the pH with a strong base. Bomb runs were made by heating the product of the low temperature precipitation in distilled water in a teflon-lined steel bomb. The potassium, potassium plus sodium, sodium, and ammonium analogues of boltwoodite were prepared. Results of the various syntheses are summarized in Table 4.

Although no attempt was made to systematically test complete solid solution between the several cations, the similarity in ionic radii and the isostructural character indicated by powder diffraction photographs indicate the probability that such is the case. The x-ray patterns of all synthetic products are essentially identical in both *d*-spacings and line intensities with each other and with the natural mineral (see Table 5). Slight broadening of the lines is evident in most of the synthetic products, and results from the microcrystalline nature of the precipitates. This is further shown on optical examination by the appearance as masses of extremely small, intergrown fibers which yield only an average index of refraction.

TABLE 4. SYNTHESIS OF BOLTWOODITE

Reagents	pH	Temp.	Product	Bomb Run	pH	Product
Potassium acetate Ammonium silicofluoride Uranyl sulfate Ammonium hydroxide	8½	90°	Ammonium boltwoodite	48 hrs. @ 246°	8	Boltwoodite
Potassium silicofluoride Uranyl acetate Potassium hydroxide	8	95	Boltwoodite	46 hrs. @ 235	7	Boltwoodite gastunite
Potassium silicofluoride Uranyl acetate Sodium hydroxide	7½	85	(K, Na) boltwoodite	46 hrs. @ 243	6½	(K, Na) boltwoodite
Sodium metasilicate Uranyl acetate Sodium hydroxide	10½	85	Na bolt- woodite	42 hrs. @ 242	8	Na bolt- woodite
Ammonium silicofluoride Uranyl acetate Ammonium hydroxide	7	95	Ammonium boltwoodite	48 hrs. @ 152	6	Ammonium boltwoodite soddyite

TABLE 5. COMPARISON OF X-RAY POWDER SPACINGS OF SYNTHETIC BOLTWOODITE WITH THOSE FOR THE NATURAL MINERAL

Natural (K, Na) boltwoodite		Synthetic K boltwoodite		Synthetic (K, Na) boltwoodite		Synthetic Na boltwoodite		Synthetic NH ₃ boltwoodite	
d	I	d	I	d	I	d	I	d	I
7.53	2								
6.81	10	6.84	10	7.03	10	6.81	10	6.89	10
6.40	5	6.35	5	6.51	4			6.42	5
5.45	5	5.47	4	5.54	4			5.43	1
4.74	4	4.74	3	4.71	1	4.75	5	4.74	6
4.32	4	4.35	2	4.35	1			4.33	3
4.11	2	4.11	1	4.11	1			4.11	1
3.91	1	3.88	2	3.91	1			3.93	1
3.75	1	3.75	1	3.79	2			3.75	1
3.54	7	3.55	8	3.53	9			3.55	9
3.40	9	3.41	6	3.38	3	3.45	7	3.44	5
3.13	5	3.16	8	3.16	8			3.15	6
3.07	1	3.09	1	3.08	1			3.09	3
2.95	8	2.96	7	2.98	6	2.97	6	2.96	7
2.91	7	2.91	6	2.91	7	2.93	8	2.91	6

Ammonium boltwoodite appears in the low temperature product in the synthesis of all the other uranyl silicates. With ammonium gastunite, it is the stable phase in the presence of high concentrations of ammonium ion. In all instances where there is no other monovalent cation of similar radius, the ammonium boltwoodite is destroyed in bomb runs above 200° C. and either a hydrated uranyl oxide or other uranyl silicate formed. The formation of soddyite as shown in Table 4 is an example of this breakdown. The presence of ammonium ion in the low temperature precipitates is shown by characteristic absorption maxima for the ammonium ion on infra-red spectra, by the ammonia odor emitted on heating in an open tube, and by the high pH of water condensing on the walls of closed tubes.

Boltwoodite is relatively unstable in bomb runs above 200° C. This is indicated by more diffuse lines on *x*-ray patterns of the bomb products, and by conversion of boltwoodite from low temperature runs to soddyite and uranyl oxides in bomb runs. Stability relations between boltwoodite and gastunite are indicated in Table 4. Boltwoodite is consistently the stable phase at higher pH values, and is in some instances broken down in higher temperature runs to gastunite. Synthesis of boltwoodite has been reported in a brief note by Pommer and Chandler (1958), and Pommer (1958, personal communication) by the action of uranyl carbonate solutions on glass.

OCCURRENCE

Boltwoodite is a moderately common secondary uranium mineral, and has been recognized from twenty one localities representing a variety of geological associations. Of the localities noted since the description of the mineral, one is described in the literature, six were noted by the writer, seven are listed by J. W. Gruner (personal communication, 1958), five have been noted by the U. S. Geological Survey (Daphne Ross, personal communication, 1959), and one is proposed on the basis of optical constants of an unknown uranium silicate from the literature (Haberlandt and Schiener, 1951).

The mineral occurs in the outer silicate zone of alteration surrounding the zone of hydrated uranyl oxides, which encrust primary uraninite. Boltwoodite is also found filling fractures and interstitial openings some distance from primary uraninite. Frondel and Ito (1956) describe boltwoodite from the type locality at the Delta mine, Emery County, Utah, as occurring in yellow wartlike aggregates of radial fibers coating fractures in sandstone. Other specimens from the same locality show small radial aggregates associated with uranyl sulfates which surround bec-

querelite and fourmarierite altering from uraninite. Other minerals present include brochantite, gypsum, and an unidentified uranyl silicate.

Boltwoodite is present in the outer alteration rims of "gummite" pseudomorphs after uraninite from pegmatite occurrences at the La Chiquita mine, Quebrada del Tigre, Cordoba Province, Argentina; and Alto Boqueirao, Brazil. In both instances boltwoodite appears as dense microcrystalline aggregates with a pale straw-yellow color. In the La Chiquita mine, boltwoodite is also present as radial aggregates along cleavage planes and fractures in microcline and muscovite several inches from the pods of altered uraninite. Phosphuranylite is present as fracture coatings at both localities.

Montgomery (1957) mentions boltwoodite as pseudomorphs after high-thorian uraninite in serpentine at the Williams quarry, near Easton, Pennsylvania. The mineral is present in pseudomorphic aggregates with a dull luster, rough granular appearance, and pale translucent-yellow color. As in the other localities listed, boltwoodite also occurs as finely fibrous material and as thin coatings on fracture surfaces. Uranophane is closely associated, and other minerals present include thorigummite and "Mineral C" of Frondel (1956). Montgomery proposes late-stage hydrothermal metamorphism of the thorian uraninite as an origin for the pseudomorphous material, and supergene alteration for the origin of the fracture coatings and efflorescences on exposed surfaces.

At the Little Indian No. 36 mine and the Lookout No. 22 mine of the Marshall Pass area, Gunnison County, Colorado, boltwoodite is present as small wartlike aggregates on becquerelite and as dense earthy aggregates pseudomorphic after uraninite. Occurrences at the Little Indian mine are restricted to a shear zone near the fault contact between the Ordovician Harding quartzite and Precambrian gneiss, schist, and migmatite (R. Malan, U. S. Atomic Energy Commission, oral communication). The boltwoodite is secondary in origin, and is present in the oxidized zone along with uranophane, goethite, schoepite, ianthinite, and residual cores of uraninite. Uraninite is the only ore mineral, and sulfides are only sparsely present. Surface ore from the nearby Lookout No. 22 mine also contains soddyite, metazeunerite, and becquerelite.

Alteration of zirconian uraninite from the Sonia mine, near Guandacol, La Rioja Province, Argentina, has produced boltwoodite as small botryoidal aggregates of fibrous crystals intimately associated with cuprosklodowskite, and as interstitial filling in sandstone country rock surrounding lenticular pods of uraninite. Becquerelite is also present as a secondary mineral, and veins and encrusts uraninite.

Highly argillized granitic gneiss from Myponga, South Australia, con-

tains boltwoodite as coatings and interstitial fillings in the friable rock. The mineral here has an earthy luster, is very pale yellow in color, and is intimately intermixed with clay minerals. Under the microscope the coatings are seen to consist of minute radial fibrous aggregates. Boltwoodite is present with "gummite," uranophane, kasolite, and uranospinite, as a secondary alteration product of uraninite; and has been transported short distances from its primary source before deposition in the argillized gneiss. According to W. C. Woodmansee of the U. S. Atomic Energy Commission (oral communication), the Myponga deposit was a small but rich concentration of uranium minerals in the faulted crest of a small, tightly folded anticlinal structure. The oxidized uranium minerals of the surface zone do not persist with depth, and as ore is followed down the plunge of the fold relatively unaltered uraninite becomes the dominant mineral. Brannerite has also been identified from the mine.

Gruner (personal communication, 1958) has noted several additional localities in the Colorado Plateau and adjoining areas. These include: the Happy Jack mine, White Canyon district, San Juan County, Utah; the Pay Day mine, San Rafael Swell, Emery County, Utah; the Jerry group, Red Canyon, Utah; Seven Mile Canyon, Grand County, Utah; in the Todilto formation, Grants, New Mexico; the Moore claim, Niobrara County, Wyoming; and the Big Hill claim, Big Horn County, Wyoming.

Daphne Ross of the U. S. Geological Survey (personal communication, 1959) lists other localities in the Colorado Plateau at: the Pete No. 6 claim, San Juan County, Utah; Julia claims, San Juan County, Utah; Blue Jay mine, San Juan County, Utah; and the Huskon Nos. 17 and 20 mines, Cameron, Coconino County, Arizona. Mrs. Ross points out that these samples show variation both in chemical composition and x-ray pattern, and thus do not yield patterns that are identical in all respects with that of material from the Delta mine, which is used here as a standard for the natural mineral.

Optical data for an unknown uranium silicate mineral (Unknown, type 1*b*) listed by Haberlandt and Schiener (1951) are identical with those of boltwoodite, and indicate a probable occurrence with associated gastunite, uranophane, beta-uranophane, and other secondary uranium minerals at Bad Gastein, Salzburg.

NAME

The mineral was named after Bertram B. Boltwood (1870-1927), radiochemist of Yale University, who provided evidence that lead was the first disintegration product of uranium and devised the very fruitful

method of measuring geologic time on the basis of lead content of uranium minerals.

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