ABERNATHYITE, A NEW URANIUM MINERAL OF THE METATORBERNITE GROUP*

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Abstract

Abernathyite, a new uranium mineral from the Fuemrol No. 2 mine, Emery County, Utah, has the formula $K(UO_2)(AsO_4) \cdot 4H_2O$. The mineral occurs as transparent, yellow, fluorescent, thick tabular crystals belonging to the tetragonal system, ditetragonal-dipyramidal class $(4/m\ 2/m\ 2/m)$. The space group is $P4/nmm$; $a_0 = 7.17 \pm 0.01$ Å; $c_0 = 9.08 \pm 0.01$ Å; $a:c = 1:1.266$; $Z = 2$. Optically, the mineral is uniaxial negative, $\epsilon = 1.570 \pm 0.003$, $\omega = 1.597 \pm 0.003$. The hardness is between 2 and 3. The calculated specific gravity is 3.74. The chemical analysis shows, in per cent: K_2O, 9.5; UO_3, 57.7; As_2O_5, 21.6; P_2O_5, 1.5; H_2O-, 4.6; H_2O+, 9.9; total, 104.8. Abernathyite is named for the finder, Jess Abernathy, operator of the Fuemrol mine.

Introduction and Acknowledgments

In the summer of 1953, Jess Abernathy, operator of the Fuemrol mine, Emery County, Utah, noticed some yellow crystals in his ore. Realizing that they might be of mineralogic importance, he gave the several pieces of sandstone which were coated with crystals to E. B. Gross, mineralogist for the U. S. Atomic Energy Commission in Grand Junction, Colo. Mr. Gross was unable to find in the literature any mineral with corresponding optical properties, and, not having the facilities in Grand Junction for further work, he gave the specimens to A. D. Weeks and M. E. Thompson, mineralogists for the U. S. Geological Survey in Washington, D.C. The study of the mineral was continued in the U. S. Geological Survey, as a part of the Survey's program conducted on behalf of the Raw Materials Division of the U. S. Atomic Energy Commission.

The authors wish to express their appreciation to F. S. Grimaldi, of the U. S. Geological Survey, for his advice and assistance with the problems arising in the course of the chemical analysis. The authors are pleased to name this mineral for the person who found it, Jess Abernathy; without his interest in and appreciation of the mineralogy of his ore, the mineral might have remained undiscovered.

Occurrence and Associated Minerals

The Fuemrol No. 2 mine is on a lower slope of Temple Mountain, on the southeast flank of the San Rafael swell, Emery County, Utah, about 47 miles southwest of Green River, Utah (Fig. 1). Mining in the

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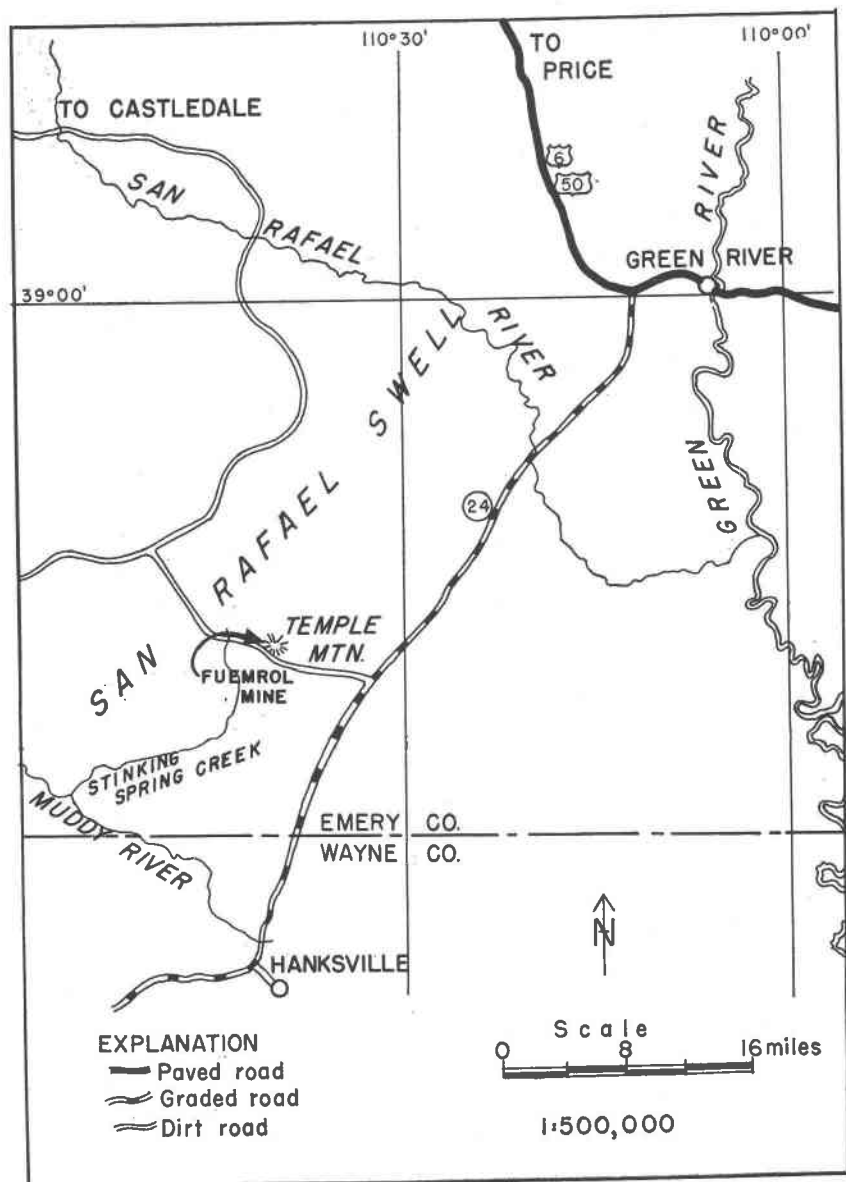* Publication authorized by the Director, U. S. Geological Survey.

Fig. 1. Index map of locality of abernathyite.

area is in vanadiferous and uraniferous asphaltic sandstones in the Shinarump conglomerate.

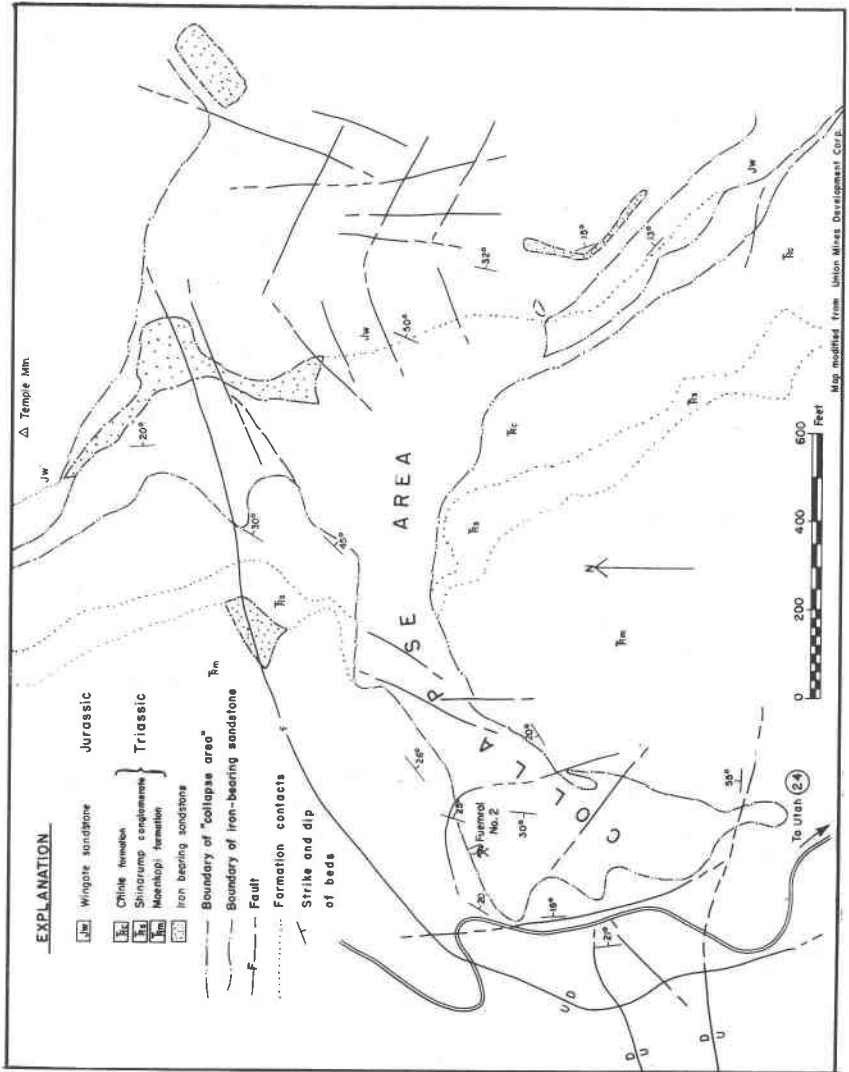Temple Mountain, a small elongate mountain, is capped by Wingate

FIG. 2. Geology of the "collapse" area at Temple Mt., Emery County, Utah.

sandstone. Beneath the Wingate sandstone, in descending order, are red standstones of the Chinle formation, gray Shinarump conglomerate, and red shales and sandstones of the Moenkopi formation. A "collapse" zone (Fig. 2) about 1,800 feet long and 400 feet wide extends below the Wingate sandstone near the central part of the mountain. The area of disturbed rocks has been called the "flop over" or the "tongue."

Within the disturbed area the sandstone has bleached white or gray,

lacks bedding features, and is much fractured. In the upper portions of the flop over, large masses of goethitic and hematitic sandstone are exposed.

At the Fuemrol No. 2 mine near the lower end of the flop over, the sandstone is light to dark gray and contains nodular masses ranging in diameter from 1 to 5 inches. The nodules are composed of sand grains cemented by asphaltite and pyrite. The outer layers of some nodules contain native arsenic, sphalerite, and metazeunerite. The gray to greenish-gray fine-grained sandstone of the Fuemrol mine is composed of poorly sorted subangular grains. Quartz grains make up 65 to 70 per cent of the sandstone; other major constituents are asphaltite and pyrite. Minor constituents are chert, plagioclase, zircon, and muscovite. The cementing material (15 to 20 per cent) is a microcrystalline brownish-gray clay aggregate.

Abernathyite occurs as a crystalline coating lining a fracture in the sandstone and is associated with yellow-brown earthy scorodite. No other minerals were found associated with the new mineral in the samples that were available for this study, but other specimens from the mine contain native arsenic, orpiment, and realgar (T. W. Stern, oral communication). Jarosite, pitticite, metazeunerite, and two other uranyl arsenates of uncertain composition have also been found.

Physical and Optical Properties

The crystals of abernathyite are unusually clear and transparent for a mineral of the metatorbernite group. They are yellow, have vitreous luster, and fluoresce moderately a yellow-green color in both long (3660 Å) and short (2537 Å) wavelength ultraviolet light. The streak is pale yellow.

The crystals are thin to thick tabular in habit and occur singly and in groups. Prominent forms are {001} and {110}. They show a perfect basal cleavage, but the cleavage is not micaceous as is typical of other minerals of the metatorbernite group.

The hardness is between 2 and 3. As the largest of the crystals is only about 0.5 mm. on an edge, it was necessary to observe the scratch tests for hardness with a binocular microscope.

An insufficient amount of the mineral was available for a direct measurement of the specific gravity, but the crystals sink in methylene iodide of specific gravity 3.32. The specific gravity is calculated as 3.74 for the pure $K(UO_2)(AsO_4) \cdot 4H_2O$ compound.

Abernathyite is uniaxial negative, $\omega = 1.597 \pm 0.003$, yellow, and $\epsilon = 1.570 \pm 0.003$, pale yellow to colorless. A few of the crystals are anomalously biaxial negative, with 2 V less than 5 degrees.

CHEMICAL ANALYSIS

A qualitative spectographic analysis by K. E. Valentine, of the Geological Survey, showed U, As, P, and K present in amounts more than 1 per cent and trace amounts of Fe, Al, and Si. Only about 25 mg. of material was available for the chemical analysis, and therefore only the principal components as indicated by the spectrographic analysis were determined in the chemical analysis. Standard macroanalytical procedures were followed; that is, H_2O- was determined by heating the sample to constant weight at 110° C., and H_2O+ by heating it to constant weight at 800° C.; arsenic was precipitated with H_2S and weighed as As_2S_5; uranium was determined colorimetrically by the $NaOH-H_2O_2$ method; potassium was weighed as K_2PtCl_6, and the purity of this precipitate was checked by a spectrographic analysis by H. W. Worthing, of the Geological Survey; phosphorus was determined colorimetrically using the molybdenum-blue reaction.

Because questions might be raised about the value of a chemical analysis for which such a small amount of material was available, some of the precautions taken in the analysis are stated here. These precautions consisted mainly of duplicate analyses and of "trial runs" on artificial mixtures. It was possible to make up artificial mixtures containing nearly the correct proportions of As, K, U, and P in advance of the chemical analysis, because the spectrographic analysis, the x-ray powder pattern,

TABLE 1. CHEMICAL ANALYSIS OF ABERNATHYITE

Analyst: Blanche Ingram, U. S. Geological Survey

	Analysis of abernathyite	Analysis recalculated to 100 per cent	$K(UO_2)(AsO_4) \cdot 4H_2O$
K_2O	9.5[1]	9.1	9.0
UO_3	57.7[2]	55.1	55.0
As_2O_5	21.6	20.6	22.2
P_2O_5	1.5	1.4	—
H_2O+	(9.9)	(9.4)	—
H_2O-	(4.6)	(4.4)	—
Total H_2O	14.5[3]	13.8	13.8
	104.8	100.0	100.0

[1] A value of 8.8 per cent K_2O was obtained in the first analysis. The analysis was then repeated on a larger sample, taking advantage of the information obtained from the first determination. The value of 9.5 per cent K_2O is considered more accurate.

[2] Average of 57.6, 57.6, 57.9.

[3] Average of 14.5, 14.4.

TABLE 2. MOLECULAR RATIOS OF COMPONENTS OF ABERNATHYITE

	Analysis	Molecular weight	Molecular ratios
K_2O	9.5	94	0.102
UO_3	57.7	286	0.202
As_2O_5	21.6	230	0.094 ⎫ 0.105
P_2O_5	1.5	142	0.011 ⎭
H_2O+	9.9	18	0.550 ⎫ 0.806
H_2O-	4.6	18	0.256 ⎭

and the physical properties of the new mineral made it fairly certain that the mineral was a member of the metatorbernite group and that its formula was probably $K(UO_2)[(As,P)O_4] \cdot nH_2O$.

The uranium determination was repeated three times; total H_2O was determined twice. Potassium was determined gravimetrically twice, the first time on a sample of 5 mg. original weight after H_2O-, H_2O+, As_2O_5, and UO_3 had been determined. A second analysis for potassium was made by F. S. Grimaldi, of the Geological Survey, on a 10-mg. sample which was treated with HCl and HBr to remove the arsenic. The potassium was then precipitated directly. These repeat analyses gave consistent results.

The results of the chemical analysis total 104.8 per cent. No explanation for this high total is offered. The analysis, when recalculated to 100 per cent, agrees very closely with the theoretical composition (Table 1).

The molecular ratios obtained from the analysis are very close to ideal proportions (Table 2). The simplest formula to be obtained from these ratios is $K(UO_2)(AsO_4) \cdot 4H_2O$. A small amount of phosphorus substitutes for arsenic in the ratio of one part P_2O_5 to 14.4 parts As_2O_5 by weight.

X-RAY DATA

An *x*-ray diffraction powder pattern was taken by D. D. Riska, of the Geological Survey, with a Debye-Scherrer camera (114.59-mm. diameter) using Ni-filtered Cu radiation. The pattern of abernathyite very closely resembles the patterns of several other members of the metatorbernite group—synthetic hydrogen-autunite, metatorbernite, and metazeunerite. The pattern was easily indexed by comparing it with a pattern of another member of the group whose cell dimensions were known (Table 3).

The cell dimensions of abernathyite and several other minerals and artificial compounds that are generally considered to belong to the meta-

TABLE 3. X-RAY DIFFRACTION POWDER DATA AND UNIT-CELL
CONSTANTS OF ABERNATHYITE

Space group: $P4/nmm$; $a_0 = 7.17 \pm 0.01$ Å; $c_0 = 9.08 \pm 0.01$ Å;
$a_0 : c_0 = 1 : 1.266$; $Z = 2$

I	$d_{(meas)}$	$d_{(calc)}$	hkl
10, broad	9.14	9.08	001
7	5.63	5.63	101
4	5.11	5.07	110
4	4.58	4.54	002
4	4.43	4.43	111
8, broad	3.84	3.84	102
7	3.59	3.59	200
8	3.34	3.38	112
		3.34	201
1	3.16		
5	3.02	3.03	003
		3.02	211
6, broad	2.79	2.81	202
		2.79	103
5, broad	2.61	2.63	113
		2.62	212
3	2.54	2.54	220
5	2.45	2.44	221
3	2.32	2.31	203
		2.31	301
6	2.28	2.27	004
		2.27	310
6	2.21	2.21	222
		2.21	213
		2.20	311
2	2.17	2.16	104
6	2.12	2.12	302
6	2.07	2.07	114
		2.03	312
3	1.948	1.943	321
		1.943	223
1	1.919	1.918	204
3	1.879	1.876	303
1	1.855	1.853	214
5	1.822	1.822	322
		1.816	005
		1.815	313
3	1.797	1.793	400
		1.760	104
3	1.780		
		1.759	401
6	1.712	1.710	411
		1.710	115

TABLE 3—(*continued*)

I	$d_{(meas)}$	$d_{(calc)}$	hkl
		1.691	224
3	1.667	$\begin{cases}1.667 \\ 1.667\end{cases}$	402 330
		1.662	331
		1.662	323
		1.646	304
		1.641	420
3	1.625	1.624	412
		1.620	205
6	1.606		
3	1.582	$\begin{cases}1.584 \\ 1.580 \\ 1.579\end{cases}$	332 215 421
		1.542	403
3	1.514	1.512	422
		1.508	413
3	1.482		
3	1.458		
6	1.421		
3	1.372		
1	1.359		
1	1.300		
5	1.280		
4	1.261		
1, broad	1.240		
1, broad	1.212		
3	1.206		
3	1.198		
1	1.187		

torbernite group are listed in Table 4 for comparison. We are grateful to Gabrielle Donnay, of the Geological Survey, for the measurement of the

TABLE 4. COMPARISON OF UNIT-CELL DIMENSIONS OF ABERNATHYITE WITH THOSE OF OTHER MEMBERS OF THE METATORBERNITE GROUP

Mineral or compound	$a_0(\text{Å})$	$c_0(\text{Å})$	Reference
Abernathyite $K(UO_2)(AsO_4) \cdot 4H_2O$	7.17	9.08	[2]
Synthetic troegerite $H(UO_2)(AsO_4) \cdot 4H_2O$	7.16	8.80	[1]
Synthetic $Na(UO_2)(AsO_4) \cdot 4H_2O$	7.12	8.70	[1]
Synthetic $NH_4(UO_2)(AsO_4) \cdot 4H_2O$	7.21	8.85	[1]
Meta-autunite I $Ca(UO_2)_2(PO_4)_2 \cdot 2\frac{1}{2}-6\frac{1}{2}H_2O$	6.98	8.42	[2]
Metatorbernite $Cu(UO_2)_2(PO_4)_2 \cdot 8H_2O$	6.95	2×8.70	[2]

[1] Mrose, M. E., 1953.

[2] Donnay, Gabrielle (oral communication).

lattice constants of abernathyite from Buerger precession photographs. The constants are given as follows: $a_0 = 7.17 \pm 0.01$ Å; $c_0 = 9.08 \pm 0.01$ Å; space group $P4/nmm$ ($D_4{}^7h$); cell contents 2 formula units $K(UO_2)(AsO_4) \cdot 4H_2O$. The calculated density is 3.74.

Beintema (1938) assigned meta-autunite to the space group $P4/nmm$, but he had to postulate a statistical distribution of Ca over half the symmetrically equivalent sites in the crystal structure in order to account for this high symmetry. Recently, G. Donnay (oral communication) found that this mineral and others in the group actually have lower symmetries as well as true cells which are multiples of Beintema's cell, so that the cations are in reality in ordered arrangement. On the other hand, her measurements indicate that the true symmetry of abernathyite is $P4/nmm$ with all the cation sites occupied by K ions, of which there are twice as many as there are Ca ions in meta-autunite.

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