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DEPARTMENT OF THE INTERIOR  
GEOLOGICAL SURVEY  
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Dr. Phillip L. Merritt, Assistant Director  
Division of Raw Materials  
U. S. Atomic Energy Commission  
16th St., and Constitution Avenue, N. W.  
Washington 25, D. C.

Dear Phil:

Transmitted herewith are three copies of TEI-454, "Abernathyite,  
a new uranium mineral of the metatorbernite group," by M. E. Thompson,  
Blanche Ingram, and E. B. Gross, August 1954.

We are asking Mr. Hosted to approve our plan to publish this  
report in American Mineralogist.

Sincerely yours,

*Andrew R. ...*  
for W. H. Bradley  
Chief Geologist

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Geology and Mineralogy

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UNITED STATES DEPARTMENT OF THE INTERIOR  
GEOLOGICAL SURVEY

ABERNATHYTE, A NEW URANIUM MINERAL OF THE METATORBERNITE GROUP 1/

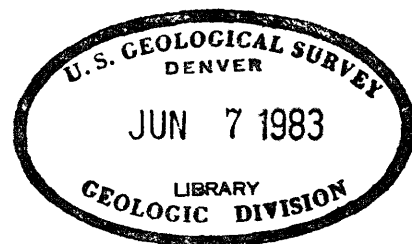
By

M. E. Thompson,2/ Blanche Ingram,2/ and E. B. Gross 3/

August 1954

Trace Elements Investigations Report 454

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1/ This report concerns work done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

2/ U. S. Geological Survey.

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## GEOLOGY AND MINERALOGY

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## ABERNATHYITE, A NEW URANIUM MINERAL OF THE METATORBERNITE GROUP

By M. E. Thompson, Blanche Ingram, and E. B. Gross

## ABSTRACT

Abernathyite, a new uranium mineral from the Fuehrol 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  $P4/nmm$ ;  $a_0 = 7.17 \pm 0.01$  A,  $c_0 = 9.08 \pm 0.01$  A;  $a:c = 1:1.266$ ;  $Z = 2$ . Optically, the mineral is uniaxial negative,  $\mathcal{E} = 1.570 \pm 0.003$ ,  $\omega = 1.597 \pm 0.003$ . The hardness is between 2 and 3. The calculated specific gravity is 3.74.

The chemical analysis shows, in percent:  $K_2O$  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 Fuehrol mine.

## INTRODUCTION AND ACKNOWLEDGMENTS

In the summer of 1953, Jess Abernathy, operator of the Fuehrol 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., who was present at the time. 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 whose interest in and appreciation of the mineralogy of his ore the mineral might have remained undiscovered.

#### OCCURRENCE AND ASSOCIATED MINERALS

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

Temple Mountain, a small elongate mountain, is capped by Wingate sandstone. Beneath the Wingate sandstone, in descending order, are red sandstones 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 been 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

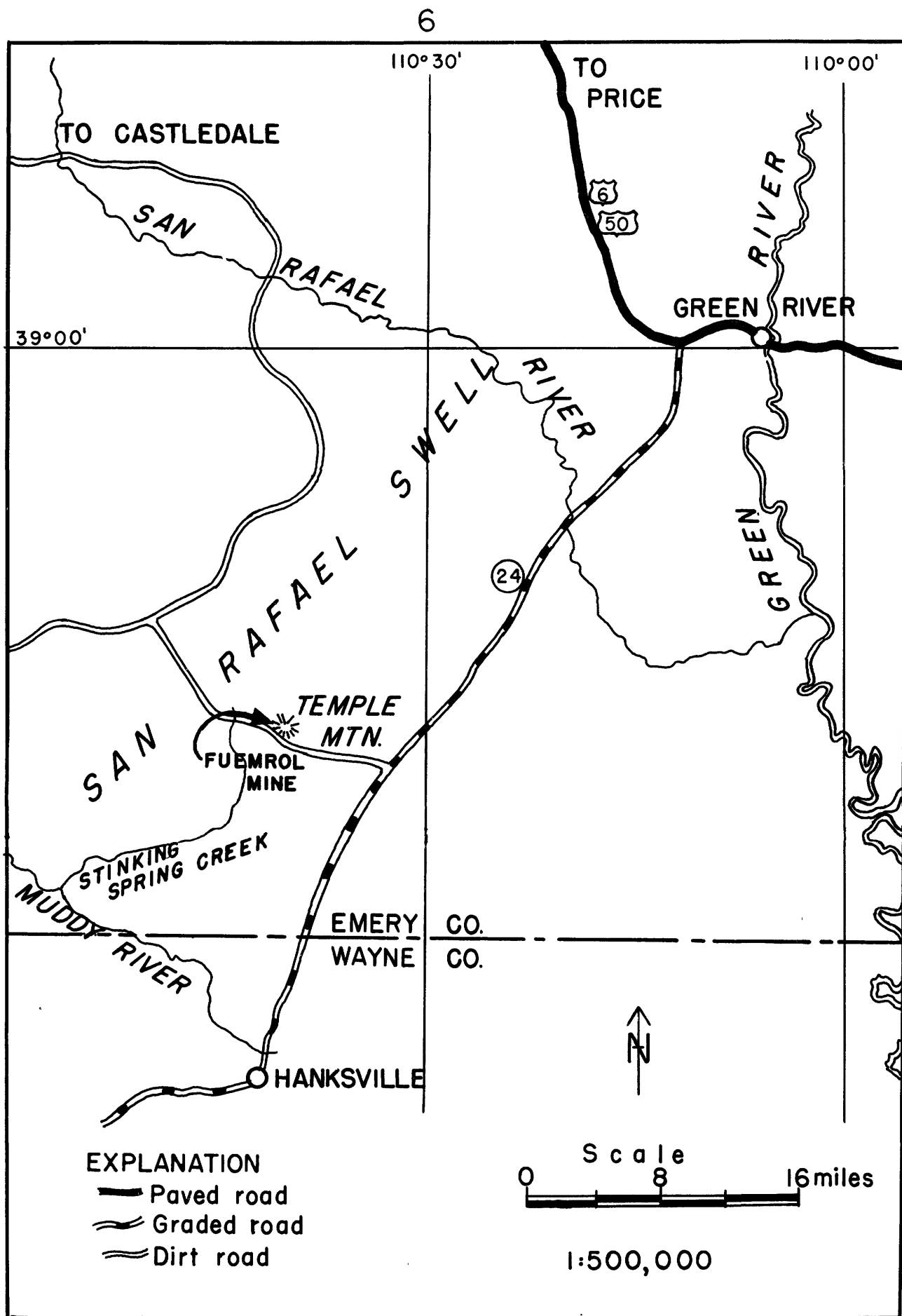


Figure 1. Index map of locality of abernathyite

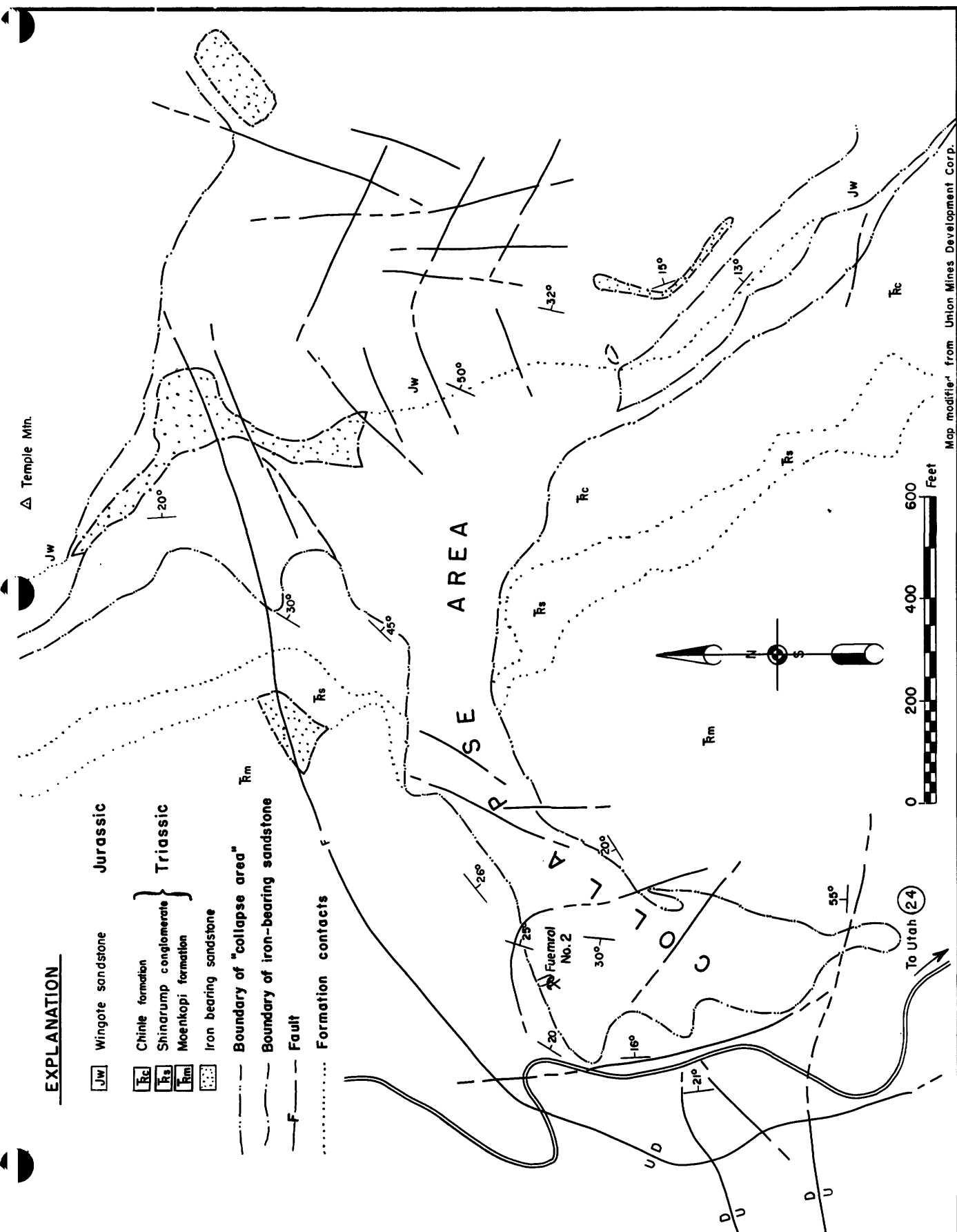


Figure 2. Geology of the "collapse" area at Temple Mt., Emery County, Utah



sandstone are exposed.

At the Fuenrol No. 2 mine near the lower end of the "tongue", 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 Fuenrol mine is composed of poorly sorted subangular grains. Quartz grains make up 65 to 70 percent of the sandstone; other major constituents are asphaltite and pyrite. Minor constituents are chert, plagioclase, zircon, and muscovite. The cementing material (15 to 20 percent) 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 a 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  $\text{K}(\text{UO}_2)(\text{AsO}_4) \cdot 4\text{H}_2\text{O}$  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  $2V$  less than 5 degrees.

#### CHEMICAL ANALYSIS

A qualitative spectrographic analysis by K. E. Valentine of the Geological Survey showed U, As, P, and K present in amounts over 1 percent, 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 macro-analytical procedures were followed, that is,  $\text{H}_2\text{O}^-$  was determined by heating the sample to constant weight at 110 C, and  $\text{H}_2\text{O}^+$  by heating it to constant weight at 800 C; arsenic was precipitated with  $\text{H}_2\text{S}$  and weighed as  $\text{As}_2\text{S}_5$ ; uranium was determined colorimetrically by the  $\text{NaOH-H}_2\text{O}_2$  method; potassium was weighed as  $\text{K}_2\text{PtCl}_6$ , 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, 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 percent. No explanation for this high total is offered. The analysis, when recalculated to 100 percent, 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.

Table 1.--Chemical analysis of abernathyite.

Analyst: Blanche Ingram.

	Analysis of abernathyite	Analysis recalcu- lated to 100 percent	$K(UO_2)(AsO_4) \cdot 4H_2O$
$K_2O$	<u>1/</u> 9.5	9.1	9.0
$UO_3$	<u>2/</u> 57.7	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 $H_2O$	<u>3/</u> 14.5	13.8	13.8
	104.8	100.0	100.0

1/ A value of 8.8 percent  $K_2O$  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 percent  $K_2O$  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
$P_2O_5$	1.5	142	0.011
$H_2O+$	9.9	18	0.550
$H_2O-$	4.6	18	0.256
			0.105
			0.806

## 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 metatorbernite group are listed in table 4 for comparison. We are grateful to Gabrielle Donnay of the Geological Survey for the measurement of the lattice constants of abernathyite from Buerger precession photographs. They are given as follows:  $a_0 = 7.17 \pm 0.01$  Å,  $c_0 = 9.08 \pm 0.01$  Å; space group  $P4/nmm$  ( $D_{4h}^{7h}$ ); 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) has 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.

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;  
 $a_0:c_0 = 1:1.266$ ;  $Z = 2$

<u>I</u>	<u>d(meas)</u>	<u>d(calc)</u>	<u>hkl</u>
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
		3.38	112
8	3.34 .....	3.34	201
1	3.16		
		3.03	003
5	3.02 .....	3.02	211
		2.81	202
6, broad	2.79 .....	2.79	103
		2.63	113
5, broad	2.61 .....	2.62	212
3	2.54	2.54	220
5	2.45	2.44	221
		2.31	203
3	2.32 .....	2.31	301
		2.27	004
6	2.28 .....	2.27	310
		2.21	222
6	2.21 .....	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
		1.943	321
3	1.948 .....	1.943	223
1	1.919	1.918	204
3	1.879	1.876	303
1	1.855	1.853	214
		1.822	322
5	1.822 .....	1.816	005
		1.815	313

Table 3.--X-ray diffraction powder data and unit-cell constants  
of abernathyite--Continued.

<u>I</u>	<u>d(meas)</u>	<u>d(calc)</u>	<u>hkl</u>
3	1.797	1.793	400
		1.760	104
3	1.780		
		1.759	401
		1.710	411
6	1.712 .....	1.710	115
		1.691	224
		1.667	402
3	1.667 .....	1.667	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 .....	1.584	332
		1.580	215
		1.579	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		

Table 4.--Comparison of unit-cell dimensions of abernathyite with those of other members of the metatorbernite group.

Mineral or compound	$a_0(\text{\AA})$	$c_0(\text{\AA})$	Reference
Abernathyite $\text{K}(\text{UO}_2)(\text{AsO}_4) \cdot 4\text{H}_2\text{O}$	7.17	9.08	<u>2</u> /
Synthetic troegerite $\text{H}(\text{UO}_2)(\text{AsO}_4) \cdot 4\text{H}_2\text{O}$	7.16	8.80	<u>1</u> /
Synthetic $\text{Na}(\text{UO}_2)(\text{AsO}_4) \cdot 4\text{H}_2\text{O}$	7.12	8.70	<u>1</u> /
Synthetic $\text{NH}_4(\text{UO}_2)(\text{AsO}_4) \cdot 4\text{H}_2\text{O}$	7.21	8.85	<u>1</u> /
Meta-autunite I $\text{Ca}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 2\frac{1}{2} - 6\frac{1}{2}\text{H}_2\text{O}$	6.98	8.42	<u>2</u> /
Metatorbernite $\text{Cu}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$	6.95	2 x 8.70	<u>2</u> /

1/ Mrose, M. E., 1953.

2/ Donnay, Gabrielle (oral communication).

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