UMOHOITE FROM THE LUCKY MC MINE, FREMONT COUNTY, WYOMING

By Robert G. Coleman and Daniel E. Appleman

Trace Elements Investigations Report 657

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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IN REPLY REFER TO:

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DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON 25, D. C.

April 10, 1957

AEC-431/7

Mr. Robert D. Nininger
Assistant Director for Exploration
Division of Raw Materials
U. S. Atomic Energy Commission
Washington 25, D. C.

Dear Bob:

Transmitted herewith are three copies of TEI-657, "Umohoite from the Lucky Mc mine, Fremont County, Wyoming," by Robert G. Coleman and Daniel E. Appleman, February 1957.

We plan to submit this report for publication in American Mineralogist.

Sincerely yours,

John H. Eric

for W. H. Bradley
Chief Geologist

Geology and Mineralogy

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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This preliminary report is distributed without editorial and technical review for conformity with official standards and nomenclature. It is not for public inspection or quotation.

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

USGS - TEI-657

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By Robert G. Coleman and Daniel E. Appleman

ABSTRACT

A new occurrence of the hydrous uranium-molybdenum mineral umohoite is described from the Lucky Mc mine, Wyoming. X-ray investigation shows that umohoite is monoclinic, $P2_1$ (C_2^2) or $P2_1/m$ (C_{2h}^2), a = 14.30 A, b = 7.50, c = 6.38, $\beta = 99^{\circ}05'$. Optically umohoite is biaxial negative with α(calc.) 1.66 ± 0.01, β 1.831 ± 0.005, and γ 1.915 ± 0.005, 2V(Na) $65^{\circ} \pm 2^{\circ}$; pleochroism X dark blue, Y light blue, Z olive green; dispersion $r > v$, strong. The strongest lines of the X-ray powder pattern are 7.31-6.96 (broad) (100), 3.22 (50), 14.10 (25), and 3.18 (25). Indexed X-ray powder diffraction data are listed.

INTRODUCTION

The uranium deposits of the Gas Hills area in Fremont County, Wyo., contain a complex suite of uranium minerals. More than twenty distinct species have been identified from this area. These deposits are localized in coarse arkosic sandstones and conglomerates of the upper part of the Wind River formation (Eocene). Mudstones and siltstones are also mineralized to a lesser extent.

The abundant molybdenum in these deposits has given rise to uranium molybdates in the early stages of oxidation. The unoxidized ore contains uraninite, coffinite, iron sulfides, and "jordisite" as an interstitial cement in the sediments. The fine-grained nature of these minerals and the high porosity of the sediments allow rapid oxidation by moist air above the water table. Umohoite, as described by Brophy and Kerr,1/ is present in limited amounts at the Lucky Mc mine where it crystallizes in the early stages of oxidation. The umohoite is commonly intergrown with gypsum in juxtaposition with iron sulfides and uranium oxides. At this stage of oxidation, secondary uranium minerals containing UO_2^{+2} have not yet formed; however, this stage must be transitory, as schoepite and uranophane may be found within several inches of the umohoite.

1/ Brophy, G. P., and Kerr, P. F., 1953, Hydrous uranium molybdate in Marysvale ore, in Annual Report for June 30, 1952 to April 1, 1953: U. S. Atomic Energy Comm. RME-3046, p. 26-44, issued by U. S. Atomic Energy Comm. Tech. Inf. Service Extension, Oak Ridge, Tenn.

The umohoite forms delicate rosettes of tabular plates terminated by rather sharply angled points. These rosettes are rarely more than 2 mm across and the individual crystals are all less than 0.5 mm in their longest dimension. The unaltered crystals are splendent blue black or in some cases dark green. In the areas where the secondary uranyl minerals have begun to form the umohoite is seen to alter to an undefined yellow uranium molybdate.

UNIT CELL AND SPACE GROUP

X-ray examination of the crystalline umohoite described above reveals that most of the material is not suitable for single-crystal studies. The typical "crystal" of umohoite is composed of many extremely thin, platy individuals stacked in disordered aggregates. Efforts to separate the plates cause bending, cleaving, and fracturing of the fragile crystals. Fairly good precession photographs were obtained with MoKα radiation from a small specimen, with approximate dimensions 97 x 85 x 2 μ, comprising only two or three individual plates.

Umohoite is monoclinic, with space group $\underline{P}2_1$ ($\underline{C}_2^2$) or $\underline{P}2_1/\underline{m}$ ($\underline{C}_{2\underline{h}}^2$). The cell dimensions of the crystals studied are:

$$\underline{a} = 14.30 \pm 0.05 \text{ A}$$

$$\underline{b} = 7.50 \pm 0.03$$

$$\underline{c} = 6.38 \pm 0.03$$

$$\beta = 99^{\circ}05' \pm 10'$$

There is a prominent pseudo-rhombohedral multiple cell; the $\underline{c}$-axis of the pseudo-$\underline{R}$ cell is parallel to $\underline{a}^*$ of the monoclinic cell and has a spacing of 42.36 A.

OPTICAL PROPERTIES

Umohoite is biaxial (-), with the following optical properties:

	$\underline{n}$	Pleochroism
α (calc.)	1.66 ± 0.01	dark blue
β	1.831 ± 0.005	light blue
γ	1.915 ± 0.005	olive green

$2V(Na) = 65^\circ \pm 2^\circ$; dispersion $r > v$, strong. Different plates show inclined or symmetrical extinction, depending on the face development; in a few cases (010) is present. The optic orientation is:

$$\underline{X} \approx \underline{a}^* \; (\underline{X} \wedge \underline{a} \approx 9^\circ 05')$$

$$\underline{Y} = \underline{b}$$

$$\underline{Z} \approx \underline{c}$$

CHEMICAL FORMULA

Brophy and Kerr (op. cit.) give the tentative chemical formula of umohoite as $UO_2MoO_4 \cdot 4H_2O$, and the observed specific gravity as 4.55 to 4.66. If this formula is correct, the cell contains $4[UO_2MoO_4 \cdot 4H_2O]$ and the calculated specific gravity is 4.93. An analysis of the Lucky Mc material by X-ray fluorescence spectroscopy, made by I. Adler of the U. S. Geological Survey, confirms the U:Mo ratio of 1:1. However, the following observations cast doubt on the formula as given: (1) umohoite occurs with partly oxidized ore at the Lucky Mc mine, at a stage at which typical secondary uranium minerals have not yet formed; (2) umohoite has a dark bluish color, whereas uranyl or molybdate compounds are characteristically brightly colored; (3) umohoite alters in the totally oxidized part of the ore to a yellow uranyl molybdate similar to synthetic uranyl molybdates. It therefore seems probable that the uranium or the molybdenum or both in umohoite are in an oxidation state lower than hexavalent.

X-RAY POWDER DIFFRACTION DATA

Umohoite has a variable lattice spacing normal to the perfect cleavage, as noted by Brophy and Kerr. If the mineral is prepared for X-ray powder photography by the usual grinding technique, the cell dimensions are altered, possibly due to a change in water content. In addition, the stacking of the layers in the structure is apparently disrupted, causing the virtual disappearance of the (h00) reflections. To overcome this difficulty F. A. Hildebrand of the U. S. Geological Survey prepared a sample of umohoite by fine chopping, rather than grinding; this process left the crystallographic characteristics of the mineral relatively unaltered. The powder-diffraction data listed in table 1 are corrected for film shrinkage and are indexed on the basis of the single-crystal measurements. The following lines could not be indexed on the umohoite cell:

I	$d_{obs.}$ (A)
2	8.24
9	6.02
3	5.74
1	2.15
6	2.07

The authors express their thanks to H. T. Evans, Jr., U. S. Geological Survey, for helpful advice. This work is part of a program being conducted by the U. S. Geological Survey on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

Table 1.--X-ray powder-diffraction data for umohoite.

CuKα radiation, $\lambda = 1.5418$ A, camera diameter 114.59 mm.
Corrected for film shrinkage. Cutoff at 15 A.

hkl	$d_{calc.}$(A)	$d_{obs.}$(A)	I	hkl	$d_{calc.}$(A)	$d_{obs.}$(A)	I
100	14.12	14.10	25	$\bar{2}12$	2.84	2.85-2.83b 1/	18
200	7.06	7.31-5.96b 1/	100	$\bar{3}02$	2.83		
110	6.62			500	2.82		
001	6.30	6.31	9	112	2.77		
$\bar{1}01$	6.12			$\bar{3}21$	2.77	2.77	2
101	5.44	5.44	4	$\bar{5}01$	2.76		
210	5.14			202	2.72		
$\bar{2}01$	5.12	5.11	2	411	2.70		
011	4.82	4.82	4	$\bar{3}12$	2.65		
$\bar{1}11$	4.74	4.74	18	510	2.64	2.64	1
300	4.71			$\bar{5}11$	2.59		
111	4.41	4.41	1	420	2.57	2.57	6
201	4.37			321	2.56		
$\bar{2}11$	4.23	4.23	2	$\bar{4}02$	2.56		
$\bar{3}01$	4.09			212	2.56		
310	3.99	3.96	1	$\bar{4}21$	2.48	2.48	4
211	3.78			130	2.46		
020	3.75	3.74	4	302	2.45		
120	3.62			501	2.44		
$\bar{3}11$	3.59			$\bar{1}22$	2.43		
400	3.53	3.54	9	$\bar{4}12$	2.42	2.42	2
301	3.52			022	2.41		
220	3.31	3.32	3	$\bar{2}22$	2.37	2.37	1
$\bar{4}01$	3.30			230	2.36		
021	3.22	3.22	50	600	2.35		
$\bar{1}21$	3.20			122	2.33		
410	3.20			$\bar{6}01$	2.33	2.33	2
$\bar{1}02$	3.18	3.18	25	312	2.33		
311	3.18			031	2.32		
002	3.15			511	2.32		
121	3.09	3.10	12	$\bar{1}31$	2.31		
$\bar{2}02$	3.06	3.06	3	$\bar{5}02$	2.29		
$\bar{4}11$	3.03	3.03	18	421	2.29	2.28	1
$\bar{2}21$	3.02			131	2.27		
102	2.98	2.98	12	$\bar{3}22$	2.26		
320	2.93	2.93	3	520	2.26		
$\bar{1}12$	2.93			610	2.25		
012	2.90			$\bar{2}31$	2.25		
401	2.89	2.88	2	$\bar{5}21$	2.23		
221	2.85			$\bar{6}11$	2.22		

Table 1.--X-ray powder-diffraction data for umohoite--Continued.

hkl	$d_{calc.}$(A)	$d_{obs.}$(A)	I	hkl	$d_{calc.}$(A)	$d_{obs.}$(A)	I
330	2.21			013	2.02		
222	2.20			611	2.02		
$\bar{5}12$	2.19			700	2.02		
402	2.19			$\bar{7}01$	2.02		
231	2.17			$\bar{4}31$	2.00		
$\bar{3}31$	2.13					1.97	4
$\bar{1}03$	2.13					1.92	1
$\bar{4}22$	2.12					1.88	9
$\bar{2}03$	2.11					1.85	6
003	2.10					1.82	3
601	2.10	2.10	1			1.79	6
412	2.10					1.72	1
322	2.05					1.66	2
$\bar{6}02$	2.05					1.64	2
$\bar{1}13$	2.05					1.62	6
521	2.04					1.59	2
$\bar{3}03$	2.04	2.04	18			1.57	1
430	2.04					1.55	2
331	2.04					1.54	2
103	2.03					1.23	2
$\bar{2}13$	2.03						

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[1] b = broad.