(Ito and Mori, 1951; Mori and Ito, 1950) is 2.02 Å, whereas the average Al-O in octahedral coordination is 1.9 Å. This difference could very well account for the larger cell presented by chalcosiderite.

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RHABDOPHANE FROM THE CHAMPION PEGMATITE, AMELIA COUNTY, VIRGINIA

RICHARD S. MITCHELL, *University of Virginia.*

Rhabdophane has been identified by *x*-ray diffraction in a rock specimen from the abandoned Champion pegmatite, Amelia County, Virginia. The mineral, hexagonal $(RE)PO_4 \cdot H_2O$, also occurs at Cornwall, England, and Salisbury, Connecticut (Hildebrand *et al.*, 1957). Although rhabdophane is apparently rare, there has been much interest in it recently because of the discovery of several related minerals. Brockite, $(Ca,Th)PO_4 \cdot H_2O$, recently described by Fisher and Meyrowitz (1962) is probably isostructural with rhabdophane. Impure thorium phosphates, probably related to brockite, have been reported by Dooley and Hathaway (1961).

Some very similar pseudohexagonal (orthorhombic) minerals are ningyoite, hydrated Ca-U phosphate (Muto *et al.*, 1959), and grayite, hydrated Ca-Th phosphate (Bowie, 1957, 1959; Fisher and Meyrowitz, 1962). Several other materials related to rhabdophane, under investigation by various workers, have been mentioned by Fisher and Meyrowitz (1962) and Semenov (1959).

The Virginia material is soft, earthy, dull, and yellowish gray. It appears to be pseudomorphic after a completely altered mineral which occurred as a blade 2 mm by 7 mm and at least 5 cm long. Several euhedral fergusonite crystals, about 1 cm long and 2 mm across, touch this blade at intervals along its length in a somewhat oblique manner, resembling branches. The fergusonite is metamict, but not altered in any other way. This assemblage is enclosed in a larger cleavable plagioclase mass closely associated with quartz. The rock is stained with secondary iron oxide, but the feldspar is not appreciably weathered. Only one specimen has been observed.

X-ray diffraction powder patterns show the material is a mixture of rhabdophane with considerable montmorillonite. The montmorillonite diffraction pattern is nearly identical to one reported by Kerr *et al.* (1950) for material from Polkville, Mississippi. An additional reflection at 4.16 Å indicated goethite. The data, compared in Table 1 with those for rhabdophane from Connecticut, represent the averaged values obtained from seven films made in two cameras with 11.46 cm diameters (CuKα radiation). The possibility that this mineral might have an orthorhombic (pseudohexagonal) symmetry similar to ningyoite and grayite was considered, but no diffraction lines suggesting this lower symmetry were encountered. Because of inaccuracies in measurement, due to line broadening from the very fine-grained nature of the mineral, the unit cell values derived from these data are not very accurate, but they approximate $a=7.06$ Å, $c=6.39$ Å. The cell parameters seem to be slightly larger than those for rhabdophane from Connecticut ($a=6.98$ Å; $c=6.39$ Å) (Muto *et al.*, 1959). A sample heated in air at 850° C. for three hours gave an *x*-ray powder pattern of the monazite type, with spacings and intensities close to monazite (ASTM powder data card 11-556). A few weak impurity lines, including hematite, were also noted.

A semiquantitative spectrographic analysis was made of an untreated sample. Examination of this analysis (Table 2) shows a composition consistent with a mixture of montmorillonite and rhabdophane. Probably most of the Si, Al, Mg, and Ca, and some of the trace elements, are from the clay. The Fe is mainly from goethite and perhaps clay. No doubt the rare earths, Th, and P, as well as many of the other trace elements, are from the rhabdophane. Some Ca may also be from the rhabodphane. The

TABLE 1. X-RAY POWDER DIFFRACTION DATA FOR RHABDOPHANE

hk·l	Virginia		Salisbury, Conn.[1]		
	d (obs.)	I (obs.)	d (obs.)	I (obs.)	d (calc.)
10·0	6.12	vw	6.07	m	6.05
10·1	4.40	vs[2]	4.40	s	4.39
11·0	3.48	mw	3.49	m	3.49
11·1	—	a	—	a	3.06
20·0	3.07	s	3.02	vs	3.02
10·2	2.85	ms	2.83	s	2.82
20·1	2.71	vw	—	a	2.73
11·2	2.38	w	2.36	w	2.36
21·0	2.25	vvw	2.28	vw	2.29
21·1	2.16	m	2.15	s	2.15
00·3	2.13	vw	—	a	2.13
30·0	—	a	2.02	vvw	2.02
30·1	1.93	vw	1.920	w	1.923
21·2	1.87	mw	1.859	m	1.859
20·3 22·0	1.76	vw	1.743	vw	1.741 1.746
30.2	1.71	vw	1.704	vw	1.705
31·0	1.68	vw	1.675	vw	1.678

[1] Data from Muto *et al.* (1959).

[2] This intensity probably should be rated less. Montmorillonite reflections, 110 and 020, fall nearly at same position.

possibility that some of the P is replaced by Si to form a "silicorhabdophane" (Semenov, 1959) cannot be excluded, but there is no reason to believe this is the case. The data at hand indicate this is a thorium-rich rhabdophane in which Ce, Nd and La are the major rare earths. Although considerable Th is present, the relatively large amounts of rare earths and small amount of Ca eliminate the possibility that this is brockite or similar minerals.

The mineralogy and structure of the Champion (Jefferson No. 4, Bland) pegmatite have been described in detail by Lemke *et al.* (1952, p. 114) and Brown (1962, p. 66). The pegmatite body, a discordant irregular lens in mica schist and gneiss, is about 80 feet long, 20 feet wide, and extends approximately 110 feet in depth. It is distinctly zoned with a quartz core from 2 to 10 feet thick. In addition to rhabdophane and fergusonite, discovered by the writer, pyrochlore, microlite, columbite-tantalite, allanite, zircon, and typical pegmatite silicate minerals have been reported from there. Considerable muscovite has been mined from the pegmatite.

TABLE 2. SEMIQUANTITATIVE SPECTROGRAPHIC DATA ON VIRGINIA RHABDOPHANE-MONTMORILLONITE MIXTURE

Element (as oxide)	Per cent
Si, Al, P	>10
Th, Fe	7.5
Ce	6
Nd	5
La	3.5
Mg	1.75
Ca	1.5
Pb	1.25
Pr, Sm, Zr	.75
Y	.5
Nb	.4
Dy, Mn	.25
Ti	.2
Gd	.15
Sn (?)	.05
Yb	.04
Ba	.02
Cu (?)	.01
V, Ni (?)	.005
Ga	.002

Analyst: F. W. Barley, American Spectrographic Laboratories, San Francisco.

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PHASE TRANSFORMATIONS AND CRYSTAL CHEMISTRY OF SCHOEPITE[1]

C. L. CHRIST, *U. S. Geological Survey, Washington, D. C.*

Recently, Evans (1963) presented an excellent review of the known crystal structures containing the uranyl ion, and drew certain general conclusions regarding the stability of the several types of uranyl ion coordination from a study of these structures. As an important feature of his paper, Evans (1963) discusses the possible structures of the natural uranium oxide hydrates and their salts, and presents compelling arguments for considering that the uranyl groups in these compounds have pentagonal coordination. These minerals include becquerelite, $CaO \cdot 6UO_3 \cdot 11H_2O$; billietite, $BaO \cdot 6UO_3 \cdot 11H_2O$; fourmarierite, $PbO \cdot 4UO_3 \cdot 4H_2O$; masuyite, formula uncertain; schoepite, $UO_3 \cdot 2H_2O$ (phases I, II, and III); and vandendriesscheite, formula uncertain (phases I and II); the detailed crystallography of these has been given by Christ and Clark (1960). Evans considers that the very large crystal unit cells of these pseudohexagonal minerals, containing from 12 to 432 uranium atoms, result essentially from the problem of packing pentagonal units into a layer arrangement that is consistent with crystal symmetry. A proposed structure is illustrated for billietite and becquerelite (Evans' Fig. 4); the structure leads to the corresponding chemical formulas $Ba[(UO_2)_6O_4(OH)_6] \cdot 8H_2O$ and $Ca[(UO_2)_6O_4(OH)_6] \cdot 8H_2O$. This structure, with a planar layer of charge -2, is most attractive in explaining the stability, as well as the complexity, of this kind of salt; it seems much more likely than the one resulting from a puckered-hexagon OH^- coordination, with a neutral $UO_2(OH)_2$ layer, that was originally proposed by Christ and Clark (1960).

In the study reported by Christ and Clark (1960), a number of crystals of the several uranium oxide hydrates were examined optically and by *x*-ray precession camera techniques from time to time over a period of months. It was found that becquerelite, billietite, fourmarierite, and masuyite were completely stable, but that schoepite and vandendriesscheite altered spontaneously and continuously to form crystallographically distinct phases in parallel intergrowth. These alterations in schoep-

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[1] Publication authorized by the Director, U. S. Geological Survey.