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### *Bassetite and uranospathite.*<sup>1</sup>

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[Read by Dr. A. F. Hallimond, March 25, 1954.]

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#### INTRODUCTION.

**B**ASSETITE and uranospathite were described as new uranium minerals from Cornwall in 1915 by A. F. Hallimond, to whose paper<sup>2</sup> reference should be made to supplement the descriptions given here. The position of both minerals as relatives of autunite was recognized by Hallimond. Unfortunately, chemical analyses could not be obtained and the composition of these minerals has remained uncertain. No further information has been published about uranospathite. In 1940 Meixner<sup>3</sup> reported that microchemical tests of an apparently authentic specimen of bassetite from Cornwall indicated that the mineral was a hydrated iron uranyl phosphate. Later George<sup>4</sup> briefly described under the name 'iron uranite' a more or less altered mineral from New Mexico that also appeared from qualitative tests to be an iron member of the autunite family. The colour and indices of refraction of this material were so different from those given by Hallimond for bassetite, however, that both it and the material examined by Meixner were considered to represent a different species. Recently, Branche, Chervet, and Guillemin<sup>5</sup> have referred a mineral from the Puy-de-Dôme district,

<sup>1</sup> Contribution from the Department of Mineralogy and Petrography, Harvard University, no. 346. Studies on uranium minerals, no. 17.

<sup>2</sup> A. F. Hallimond, *Min. Mag.*, 1915, vol. 17, p. 221.

<sup>3</sup> H. Meixner, *Chemie der Erde*, 1940, vol. 12, p. 433. [M.A. 7-529.]

<sup>4</sup> d'A. George, *Mineralogy of uranium and thorium*. U.S. Atomic Energy Comm., 1949, RMO-563.

<sup>5</sup> G. Branche, J. Chervet, and C. Guillemin, *Bull. Soc. Franç. Min. Crist.*, 1951, vol. 74, p. 457. [M.A. 11-542.]

France, to bassetite on the basis of optical characters, although they note that qualitative tests showed the presence of only traces of iron.

Several years ago, Dr. Hallimond kindly forwarded to the writer authentic specimens of both bassetite and uranospathite. Examination of this material led to the recognition of additional specimens in the Harvard collection, and a fuller description of both minerals can now be given.

#### BASSETITE.

Semi-quantitative spectrographic analyses<sup>1</sup> showed that type bassetite contained only Fe, U, and P as major constituents, together with traces of Mg, Cu, Al, and Si. X-ray powder patterns proved to be virtually identical with that of fully-hydrated saléeite, the Mg member of the torbernite group, and resembled, although less closely, the patterns of the other members of this group. The X-ray powder spacing data are given in table I. There is no similarity to the general type of pattern afforded by the lower hydrates of the metatorbernite group. Bassetite thus appears to be the ferrous iron member of the torbernite group, as was indicated by Meixner, but the original description, as well as optical and X-ray single-crystal study of the new crystals described below, indicates that the true symmetry is not tetragonal but monoclinic. Kahlerite, recently described by Meixner<sup>2</sup> from Hüttenberg, Carinthia, is chemically the arsenate analogue of bassetite. It is tetragonal in morphology, with biaxial optical anomalies.

Optically, the material received from Hallimond and five additional specimens later identified in the Harvard collection gave concordant measurements on air-dried samples, but with indices of refraction and extinction angles considerably higher than those originally reported by him (table II). The differences, however, are found to be due to variation in the content of zeolitic water in the mineral, a feature already well known in the minerals of the torbernite and metatorbernite groups.<sup>3</sup> When the samples were dried for two years at room-temperature over CaCl<sub>2</sub> the indices of refraction increased markedly. On the other hand,

<sup>1</sup> Kindly made by C. Annel and K. Valentine of the Trace Elements Laboratory, U.S. Geological Survey, Washington, D.C.

<sup>2</sup> H. Meixner, *Der Karinthin*, 1953, no. 23, p. 277; *Chemie der Erde*, 1940, vol. 12, p. 433.

<sup>3</sup> J. Beintema, *Rec. Trav. Chim. Pays-Bas*, 1938, vol. 57, p. 155 [M.A. 7-237]; A. F. Hallimond, *Min. Mag.*, 1916, vol. 17, p. 326, and 1920, vol. 19, p. 43; E. W. Nuffield and I. H. Milne, *Amer. Min.* 1953, vol. 38, p. 476 [M.A. 12-281]; C. Frondel, *Amer. Min.*, 1951, vol. 36, p. 671 [M.A. 11-412].

the indices and the extinction angle decreased virtually to the values of Hallimond when the air-dried samples were kept for two years at room-temperature over  $H_2O$ . The samples kept over water became surficially turbid and brown due to oxidation of the ferrous iron. Hallimond's original material probably was near the fully hydrated condition, and

TABLE I. X-ray powder spacing data for bassetite.  
(Copper radiation, nickel filter, in Ångströms.)

<i>d.</i>	<i>Int.</i>	<i>d.</i>	<i>Int.</i>	<i>d.</i>	<i>Int.</i>	<i>d.</i>	<i>Int.</i>
8.59	6	2.96	3	2.13	1	1.557	1
4.89	10	2.85	2	2.07	$\frac{1}{2}$	1.429	$\frac{1}{2}$
4.66	$\frac{1}{2}$	2.72	$\frac{1}{2}$	1.921	$\frac{1}{2}$	1.374	$\frac{1}{2}$
4.24	3	2.55	$\frac{1}{2}$	1.830	2	1.316	$\frac{1}{2}$
4.05	3	2.46	2	1.783	$\frac{1}{2}$	1.191	1
3.46	10	2.34	$\frac{1}{2}$	1.741	2	1.162	$\frac{1}{2}$
3.32	$\frac{1}{2}$	2.26	$\frac{1}{2}$	1.708	$\frac{1}{2}$	1.128	1
3.10	1	2.20	6	1.627	1	1.106	1

TABLE II. Optical data for bassetite.  
(All measurements in Na-light.)

Sample.	$\alpha$ .	$\beta$ .	$\gamma$ .	Ext. angle.	2V.
Hallimond's 1915 data	...	—	1.574	1.580	-4° large
Hallimond's new sample					
air-dried ...	...	—	1.606	1.610	+19 large
2 years over $CaCl_2$ ...	...	—	1.627	1.665	— large
2 years over $H_2O$ ...	...	—	1.585	1.585	0 small
Harvard specimen, 101274					
air-dried ...	...	1.603	1.610	1.617	+18 $\frac{1}{2}$ ~ 90°
2 years over $CaCl_2$ ...	...	—	1.632	1.67	— large
2 years over $H_2O$ ...	...	—	1.583	1.583	0 small
Harvard specimen, 88119					
air-dried ...	...	—	1.604	1.611	~ 20 large
Harvard specimen, 101276					
air-dried ...	...	—	1.603	1.607	~ 9 moderate
Harvard specimen, 101277					
air-dried ...	...	—	1.610	1.610	~ 8 small
George, 1949, New Mexico (dark brown) ...	...	1.60	1.65	1.66	? 40-50°

loss of water therefrom is accompanied by an increase in the extinction angle (a fact noted by Hallimond) and by increases in the indices of refraction, the partial birefringence  $\gamma - \beta$ , and 2V. The absorption of  $\gamma$  also increases relative to that of  $\beta$ . The optical differences between Hallimond's original material and the material later sent by him doubtless reflect the climatic differences between London and Cambridge, Mass. [See note appended to this paper.] The relatively high indices reported by George on what appears to be bassetite from New Mexico,

cited in table II, may be due to dehydration and, in part, to oxidation. The samples treated over  $\text{CaCl}_2$  gave very poor X-ray patterns and their relation to the lower hydrates of the metatorbernite group could not be established; however, the phase change, if there is one, appears from the optical evidence to be reversible.

Bassetite from Cornwall is of two types. One consists of tabular crystals of pseudo-tetragonal appearance, with a yellow, brownish-yellow or, more commonly, bronze-yellow colour. The matrix usually is a black, rather porous gossan. The crystals vary from distinct single-crystals, of the sort measured by Hallimond, to aggregates of rectangular laths criss-crossing at right angles to give a lattice-like or chess-board appearance. The specimens described by Meixner are of the latter nature, and similar specimens are kept in various European and American collections. A specimen possibly of bassetite or autunite was figured in colour in 1806 by Sowerby.<sup>1</sup> Three specimens of the chess-board habit were found in the Harvard collection. One was unlabelled, another carried the notice 'Uranium Mineral? Cornwall. Talling, 1874', and the third specimen, although unlabelled, was entered in the Museum accession records as from Wheal Basset, Cornwall. Richard Talling (1820-83) of Lostwithiel was an English mineral collector and dealer, who supplied material to many collections. These specimens were identified as bassetite by optical, X-ray, and qualitative chemical study.

The second type of bassetite, comprising distinctly monoclinic single-crystals, was observed on only two specimens, both in the Harvard collection. These specimens are deeply oxidized pieces of pyritic vein matter, impregnated with clayey material of a greenish-grey colour, that contain small cavities and veinlets lined or filled with lamellar aggregates of yellow bassetite of the first type, together with tiny monoclinic crystals of an olive-green to olive-brown mineral. One of the specimens, no. 101274, carried a handwritten label 'Uranium? From Mr. Brooke. A. K. Barnett (Penzance) called on me a few weeks ago and said that he knew this mineral well as lime uranite. J. P. Jan. 31, 1886.' This specimen was acquired from the Calvert collection by Harvard in 1938, and it had earlier belonged, as appears from the label, to the English metallurgist and chemist John Percy (1817-89). The Mr. Brooke mentioned is the English crystallographer and mineralogist H. J. Brooke (1771-1857), from whose mineral collection, now preserved in Cambridge, England, came the bassetite twin crystal measured by Hallimond. The second specimen, no. 101275, carried a faded, handwritten label reading

<sup>1</sup> J. Sowerby, *British mineralogy*. London, 1806, vol. 2, p. 48, plate 126.

Yellow uranite. Huel Basset'. The two Harvard specimens correspond exactly, and there is little doubt that they were found in immediate association in Wheal Basset.

A chemical analysis by Mr. F. A. Gonyer, cited in table III, established the composition of the monoclinic olive-green crystals (and therefore of bassetite in general) as  $\text{Fe}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot n\text{H}_2\text{O}$ . In the analysed sample  $n$  is about 8, and this value can be taken as representative of material kept in a warm, dry atmosphere. The small amount of Cu

TABLE III. Chemical analyses of bassetite and uranospathite.

	$\text{P}_2\text{O}_5$ .	$\text{As}_2\text{O}_5$ .	FeO.	CuO.	$\text{UO}_3$ .	$\text{H}_2\text{O}$ .	insol.	Total.
1.	15.26	—	7.73	—	61.51	15.50	—	100.00
2.	15.21	—	7.60	0.28	61.99	14.49	0.63	100.20
3.	4.50	14.59	—	7.57	54.47	18.87	—	100.00
4.	4.35	13.76	0.72	6.65	56.16	17.94	—	99.58

1. Theoretical weight percentages,  $\text{Fe}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$ .
2. Bassetite, Wheal Basset, Cornwall. Olive-green monoclinic crystals. Harvard specimen 101274. F. A. Gonyer, analyst, 1949.
3. Theoretical weight percentages,  $\text{Cu}(\text{UO}_2)_2(\text{As}_2\text{P}_2\text{O}_7)_2 \cdot 11\text{H}_2\text{O}$ , with As:P = 2:1.
4. Uranospathite (?), Wheal Basset, Cornwall. Harvard specimen 98068. F. A. Gonyer, analyst, 1949.

reported doubtless is in substitution for Fe. A few crystals were observed that showed an indistinct colour zoning, with an accompanying variation in extinction angle from about  $18^\circ$  on the periphery to about  $6^\circ$  in the core, due to compositional variation of an unknown nature.

Morphological and X-ray single-crystal study indicates that bassetite is monoclinic in crystallization, although with very marked tetragonal pseudo-symmetry. The olive-green crystals are lozenge-shaped plates flattened on (010) and recall gypsum in habit (fig. 1). The interfacial angles could be measured only approximately due to the poor surface quality of the crystals. They are consistent within the limits of error with a tetragonal interpretation in which the plane of flattening is taken as (001) and alternate faces of forms other than (001) are undeveloped. The monoclinic axes  $a b c$  then are equivalent to the tetragonal axes  $a c a$  respectively. A list of the observed forms is given in both the monoclinic and tetragonal interpretations in table IV, and the relation of the two orientations is shown in fig. 1. The forms  $a n q$  are small in size and often are lacking. Hallimond also concluded from morphological study of crystals of the first type that bassetite was monoclinic. His material had an almost square outline with large faces of the negative orthodome ( $10\bar{1}$ ) and other forms not observed here. His elements, cited below, are

in fair agreement, but they differ from those for the present analysed crystals.

<i>a.</i>	<i>b.</i>	<i>c.</i>	$\beta$ .	
0.3615	1:0	0.3662	90° 30'	(Hallimond, specimen 1)
0.3473	1:0	0.3456	90° 43'	(Hallimond, specimen 3)
0.409	1:0	0.411	90° 32'	(present study, X-ray)

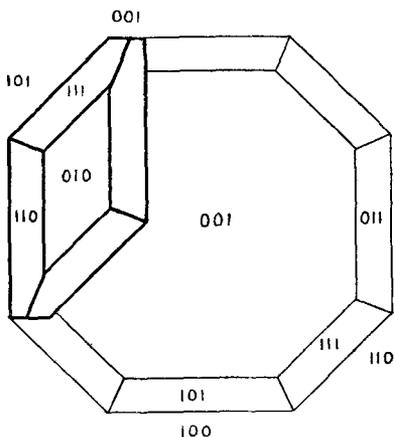


FIG. 1.

FIG. 1. Bassetite crystal projected on (010) (heavy lines), showing relation of the monoclinic and tetragonal interpretations.

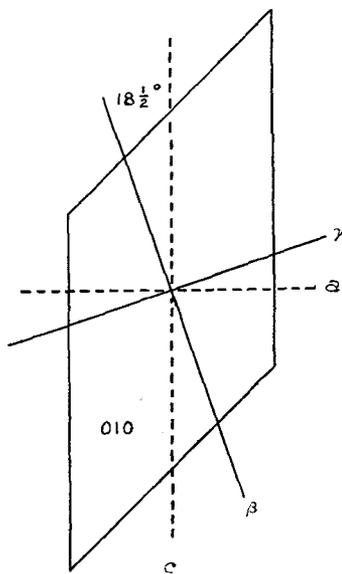


FIG. 2.

FIG. 2. Optical orientation of bassetite. Olive-green crystals from Wheal Basset, Cornwall.

An X-ray single-crystal study by the Weissenberg method in both Cu and Fe radiation on crystals from the analyzed sample gave cell dimensions, cited below, consistent within the limits of error with tetragonal

<i>a</i> 6.98 ± 0.04 Å.	<i>a</i> : <i>b</i> : <i>c</i> = 0.409:1:0.411
<i>b</i> 17.07 ± 0.04	$\beta$ = 90° 32' ± 5' (Laue)
<i>c</i> 7.01 ± 0.07	Cell contents [Fe(UO <sub>2</sub> ) <sub>2</sub> (PO <sub>4</sub> ) <sub>2</sub> ·8H <sub>2</sub> O]

symmetry. The cell dimensions in a tetragonal interpretation (*a* 7.0, *c* 17.07 Å.) approach those of the members of the torbernite group. The Weissenberg films were of poor quality, and the film symmetry was ambiguous due to slight smearing out of the spots which obscured intensity relations. All of the spots could be indexed as far as their

position was concerned in terms of a tetragonal cell. Rather sharp Laue photographs were obtained in W-radiation, with the beam travelling perpendicular to the plane of flattening, and these showed slight but definite departure from tetragonal symmetry in both the intensity and position of the innermost spots. Measurement of the axial directions of the Laue films established that  $\beta$  was  $90^\circ 32' \pm 5'$ .

TABLE IV. Angle table for bassetite.

(Angles calculated from the elements of the unit cell determined by X-ray measurement on olive-green crystals from Harvard specimen 101274.)

Monoclinic Interpretation.

$a:b:c = 0.409:1:0.411$ ;  $\beta 90^\circ 32'$ ;  $p_0:q_0:r_0 = 1.005:0.411:1$ ;  
 $r_2:p_2:q_2 = 2.433:2.445:1$ ;  $\mu 89^\circ 28'$ ;  $p'_0 1.005$ ;  $q'_0 0.411$ ;  $x'_0 0.009$ .

Forms.	$\phi$ .	$\rho$ .	$\phi_2$ .	$\rho_2 = B$ .	$C$ .	$A$ .
<i>c</i> 001	90° 00'	0° 32'	89° 28'	90° 00'	—	89° 28'
<i>b</i> 010	0 00	90 00	—	0 00	90° 00'	90 00
<i>a</i> 100	90 00	90 00	0 00	90 00	89 28	0 00
<i>n</i> 120	50 43	90 00	0 00	50 43	89 39½	39 17
<i>m</i> 110	67 45½	90 00	0 00	67 45½	89 46	22 14½
<i>d</i> 101	90 00	45 24	44 36	90 00	44 52	44 36
<i>p</i> 111	67 56	47 34½	44 36	73 54	47 05	46 50
<i>q</i> 121	50 58	52 32½	44 36	60 00	52 08	51 55½

Tetragonal Interpretation.

$a:c = 1:2.439$ ;  $p_0:r_0 = 2.439:1$ .

Forms.	$\phi$ .	$\rho$ .	$A$ .	$\bar{M}$ .
<i>c</i> 001	—	0° 00'	90° 00'	90° 00'
<i>a</i> 010	0° 00'	90 00	90 00	45 00
<i>m</i> 110	45 00	90 00	45 00	90 00
<i>n</i> 012	0 00	50 39	90 00	56 51½
<i>d</i> 011	0 00	67 42½	90 00	49 08
<i>q</i> 112	45 00	59 53½	52 17	90 00
<i>p</i> 111	45 00	73 50	47 13½	90 00

Monoclinic symmetry is also shown by the optical properties. The analysed crystals show parallel extinction when viewed along the plane of the (monoclinic) *a* and *c* axes and extinction angles of about  $+18^\circ$  when viewed along the *b* axis. Their optical orientation is shown in fig. 2. The lamellar and platy bassetite of the first type also shows inclined extinction (table II). The sense of the extinction angle cannot be determined on crushed grains, since these are ordinarily bounded by virtually rectangular cleavage planes ( $\beta \sim 90^\circ$ ). The optic sign is negative.

The dispersion of the optic axial angle is strong, with  $r > v$ , and is not perceptibly inclined. Grains resting on (010) show anomalous interference colours in white light. The pleochroism is distinct, with  $\alpha$  pale yellow to pale greenish-yellow and  $\beta$  and  $\gamma$  deep yellow to dark olive-brown or dark brown. The intensity of the pleochroism apparently varies somewhat with the degree of oxidation of the ferrous iron. The absorption of  $\beta$  and  $\gamma$  is about equal in relatively highly hydrated material, but both the absorption and the index of refraction of  $\gamma$  increase relative to  $\beta$  as water is lost. The lustre is bronzy inclining to metalloid on (010) and is weakly vitreous on other faces. Bassetite has a perfect cleavage (010) and two distinct additional cleavages, that appear on crushed grains under the microscope as a system of cracks on (010) that parallel the  $a$  and the  $c$  axes. The absorption and cleavages conform in the tetragonal orientation to that observed in the members of the torbernite and metatorbernite groups. The hardness is  $2\frac{1}{2}$ . The specific gravity determined by the Berman balance on a coarse powder is 3.4 (3.6 calculated for  $7\frac{1}{2}\text{H}_2\text{O}$ ). Hallimond gives the specific gravity of yellow crystals of the first type as 3.10. The agreement between these values is not satisfactory. Bassetite does not fluoresce in ultra-violet light.

The true symmetry of the members of the torbernite and metatorbernite groups has been under discussion for many years. Almost every member of these groups has been variously described as tetragonal, orthorhombic and pseudo-tetragonal, or monoclinic and pseudo-tetragonal. Lower than tetragonal symmetry has been ascribed chiefly on the basis of the optical properties, although attention also has been directed to slight departures in crystal angles from the requirements of tetragonal symmetry, to monosymmetric etching effects on the perfect cleavage, and to apparent differences in the ease of presumably equivalent cleavage planes. The X-ray structural study of Beintema (loc. cit.) on autunite showed that the basic structure of these minerals is tetragonal, and that the biaxial optical properties commonly observed are dependent on the number and symmetry of distribution of the zeolitic water molecules present. Later X-ray and dehydration studies on various members of these groups have confirmed this situation. In the present case there appears to be a definite distortion of the basic structure to give monoclinic symmetry, which is expressed in a distinctly monoclinic morphology, although there is no doubt but that the mineral is virtually isostructural with the torbernite group. This may also be the case with the ill-defined mineral trögerite, which appears to be a member of the

metatorbernite group although it is monoclinic in both crystal habit and optics.<sup>1</sup>

#### URANOSPATHITE.

The following account of uranospathite is based on a type specimen from Redruth, Cornwall, supplied by Dr. Hallimond. The remarkably low indices of refraction that characterize the mineral were verified. The rapidity with which the mineral loses water unfortunately was underestimated, and the sample dehydrated irreversibly in lack of adequate precautions before all of the measurements on it were completed. Under the microscope, the fresh laths were biaxial negative with  $\alpha$  perpendicular to the flattening and  $\gamma$  parallel to the elongation. There are distinct cleavages parallel and perpendicular to the elongation of the rectangular laths, and there is a perfect cleavage parallel to the flattening. The pleochroism is distinct with  $\alpha$  colourless to pale yellow,  $\beta$  and  $\gamma$  deep yellow to greenish-yellow. The indices of refraction were rather variable, with the centres of the thicker crystals having the lower values. The measured values of  $\alpha$  and  $\gamma$  are not quite as low as those of Hallimond, but this doubtless is due to partial dehydration. A sample exposed in the open air for a few hours increased considerably in indices, and when checked again overnight a larger increase was found with accompanying decrease in  $2V$ . A sample kept for two years over  $\text{CaCl}_2$  at room-temperature showed a further increase in indices, with  $2V 0^\circ$ , and the material was quite uniform in its optics. The decrease in  $2V$  on dehydration also was noted by Hallimond. Another sample that had been air-dried for four weeks, and then had  $\gamma \sim 1.59$ , was kept for two years over  $\text{H}_2\text{O}$  at room-temperature. This sample decreased in indices, but not to the original low values. The optical measurements are summarized in table V.

An X-ray powder pattern of the fresh material with low indices proved to be virtually identical with that of fully-hydrated synthetic zeunerite,<sup>2</sup> but with two additional lines at  $d$  14.6 and  $d$  7.56. Material that had been dehydrated by exposure to air or  $\text{CaCl}_2$ , on the other hand, was found to give the X-ray pattern of metazeunerite. A metazeunerite pattern also was afforded by material that had been air-dried and then kept over  $\text{H}_2\text{O}$  for two years, indicating that the phase change on

<sup>1</sup> A. Schrauf, *Min. Mitth.*, 1872, p. 185; V. Goldschmidt, *Zeits. Kryst. Min.*, 1899, vol. 31, p. 468.

<sup>2</sup> The synthetic material described by J. W. Frondel, *Amer. Min.*, 1951, vol. 36, p. 249, was used for comparison. [M.A. 11-323.]

dehydration is not reversible. The same behaviour has been found in metazeunerite itself. A semi-quantitative spectrographic analysis of the sample showed it to be an arsenate-phosphate of copper and uranium, with As > P.

With the aid of the above information, a specimen in the Harvard collection labelled 'Autunite? Wheal Basset' was found to be probably identical with dehydrated uranospathite. This specimen, originally from the Calvert collection earlier mentioned, showed fan-like groups of

TABLE V. Optical data on uranospathite.

Sample.	$\alpha$ .	$\beta$ .	$\gamma$ .	2V.
Hallimond's original data,				
1915	[ $\sim$ 1.49]	1.510	1.521	69°
Hallimond's new sample,				
freshly opened vial	1.485-1.495	1.522-1.527	1.527-1.532	55-60°
after 4 weeks in open air	1.558	1.591-1.593	1.593-1.595	20-30
after 2 years over CaCl <sub>2</sub>	—	1.612	1.612	0
after 2 years over H <sub>2</sub> O	—	1.54-1.57	1.54-1.57	0-10
Harvard specimen, air-dried	1.56	1.594-1.604	1.594-1.604	0-5
after 2 years over CaCl <sub>2</sub>	—	1.614	1.614	0
after 2 years over H <sub>2</sub> O	—	1.565-1.575	1.565-1.575	0-5

rectangular laths on a black porous gossan. The indices of refraction of the air-dried Museum specimen were relatively high, and corresponded not with the values of fresh uranospathite but with the values obtained after the latter mineral had been air-dried for four weeks. The refractive indices of material held for two years over H<sub>2</sub>O and over CaCl<sub>2</sub> also were virtually identical with those of Hallimond's material when similarly treated (table V). A chemical analysis by Mr. F. A. Gonyer of the Harvard specimen, cited in table III, established the formula as Cu(UO<sub>2</sub>)<sub>2</sub>{(As,P)O<sub>4</sub>}<sub>2</sub>·11H<sub>2</sub>O, with As:P = 2:1. This composition accords with the semi-quantitative spectrographic analysis made on the type uranospathite. The Harvard specimen gave the X-ray pattern of metazeunerite, and the analysis establishes it as an arsenic-rich member of a series between metazeunerite and metatorbernite.

The dehydration product of Hallimond's uranospathite thus appears to be identical with metazeunerite. This view might imply that the fully-hydrated material could be identical with zeunerite. The indices of refraction found for the fully-hydrated material, however, are considerably lower than those reported for zeunerite or torbernite. Unless zeunerite and torbernite may contain much more zeolitic water in the fully-hydrated state than has been recognized, uranospathite may represent a still higher hydrate in this group of minerals. The writer also has

been informed by Dr. C. Guillemin of the Laboratory of Mineralogy of the Sorbonne that a specimen of uranospathite supplied to him by Dr. Hallimond was found by qualitative chemical tests not to contain copper. It seems desirable to retain the name uranospathite in a provisional status until these matters are clarified.

NOTE BY A. F. HALLIMOND (February 1954).

I am grateful to Professor Frondel for the opportunity of commenting on this paper. It is indeed satisfactory to have the present measurements and analyses on carefully studied material.

*Bassetite.* The author remarks on the substantial differences in density and axial ratios between my original measurements and those on his partially dehydrated material. I do not think they are accidental.

The values may be compared as follows (tetragonal representation).

	<i>c:a</i>	Sp. gr.		<i>c:a</i>	Sp. gr.
Torbernite (H.)	2.974	3.219	Metatorbernite (H.)	2.28	3.67
Bassetite (H.)	2.89	3.10	Bassetite, Harvard (F.)	2.44	3.4

My original bassetite is isomorphous with torbernite (both fully hydrated). The new bassetite (with only 8H<sub>2</sub>O) approaches the values for metatorbernite. I should regard this as due to morphotropic contraction of the *c*-axis on dehydration, analogous with that which I proved for torbernite (1920). This may well be the case even if the present altered mineral has not assumed complete 'meta-' structure.

*Uranospathite.* I would agree that the density and optical data exclude the possibility of this mineral being either zeunerite or metazeunerite. It is almost certainly a higher hydrate than 12H<sub>2</sub>O. The yellow colour of my original mineral is unlike that of a copper compound. It seems quite possible that uranospathite is one of a series of higher hydrates of the same uranyl compounds as are present in bassetite, &c.

*Dehydration.* Work now in progress on these and other uranium minerals in the Museum of Practical Geology (South Kensington), by S. H. U. Bowie and R. Harrison, indicates that considerable alteration has taken place in some species. This is no doubt connected with the transfer (about 1933) of the collection from the old Jermyn Street building. It was there stored in a basement where the atmospheric conditions were not so far removed from those of their original situation in the mine, while the present storage is in a top floor of the Museum, which is centrally heated.