HURLBUTITE, $CaBe_2(PO_4)_2$, A NEW MINERAL

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ABSTRACT

Hurlbutite, $CaBe_2(PO_4)_2$, is a new mineral from the Smith mine, Chandler's Mill, Newport, New Hampshire. Crystals are orthorhombic and stout prismatic [001] in habit with {001}, {010}, {110}, {101}, {201}, and {311} doubtful. Faces often delicately etched with striations on {110}. Unit cell dimensions: $a_0=8.29$ Å, $b_0=8.80$, $c_0=7.81$ ($a_0:b_0:c_0=0.9420:1:0.8875$), with the space group D_{2h}^1-Pmmm. Colorless to greenish white. Hardness 6. Specific gravity 2.877 (meas.), 2.88 (calc. for four formula-units per cell). Cleavage not observed. Optically biaxial negative (−) with $n\text{X}=1.595$, $n\text{Y}=1.601$, $n\text{Z}=1.604$; $2\text{V}=70°$; $r>v$, weak; $\text{X}=b$, $\text{Y}=c$. Analysis gave: CaO 21.84, BeO 21.30, P_2O_5 56.19, insol. 0.76; total 100.09. The strongest x-ray powder lines are 3.67 Å (10), 3.03 (9), 2.78 (9), and 2.21 (9). The name *hurlbutite* is proposed for the mineral in honor of Cornelius S. Hurlbut, Jr., Professor of Mineralogy, Harvard University.

INTRODUCTION

The mineral here described as hurlbutite was first found as a large broken crystal on the dump at the pegmatite known as the Smith mine, Chandler's Mill, Newport, New Hampshire by Dr. Judith Weiss-Frondel in August, 1949. Within five minutes of the original find the writer picked up a matrix specimen containing two crystals of hurlbutite embedded in light-smoky quartz in the same general section of the dump. It is very probable that these original specimens would have been overlooked had it not been for the yellow stain on the surface of the crystals. Successive visits to the same locality were not fruitful until the spring and summer of 1951 when nineteen additional crystals were collected by various members of the mineralogy department at Harvard. Other than the aforementioned crystals the only other specimens of hurlbutite known to have been found were by Gunnar Bjareby of Boston and Curt G. Segeler of Brooklyn, New York.

OCCURRENCE AND PARAGENESIS

The pegmatite at which hurlbutite was found is located at Chandler's Mill, Sullivan County, in the township of Newport, New Hampshire (43°21′27″ North and 72°15′00″ West). It was originally opened for the production of mica and is known locally as the Smith mine, being on the land owned by George and Agnes Smith. The mine is easily reached by a dirt road on the south side of Sugar River, about 4½ miles west of the center of Newport. It lies at the boundary of the Claremont and Sunapee,

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N. H. quadrangles. The pegmatite is an easterly dipping, tabular body with a maximum exposed thickness of approximately 20 feet and a length of at least 300 feet parallel to the strike.

The pegmatite is of the complex type with distinct lithium and phosphate phases. Quartz and albite constitute most of the mass; potash feldspar is noticeably absent. Muscovite and black tourmaline are present in smaller quantities and with albite form a zone extending a few inches from the contact of the pegmatite into the surrounding schist. Large magnesia-rich triphylite crystals for which this locality is noted (Chapman, 1943) occur most characteristically in euhedral crystals up to four inches in length. The triphylite crystals have been found to occur only locally. The pegmatite appears to have been locally traversed by late-stage relatively low-temperature hydrothermal solutions, resulting in the formation of secondary minerals which occur as drusy crystals in small solution cavities—beryllonite, albite, brazilianite in composite growths as well as single crystals, twinned amblygonite crystals, tiny colorless and purple hexagonal prisms of apatite, and siderite.

Observations and conclusions concerning the paragenetic sequence of hurlbutite are made with reservations since no specimens of the mineral have as yet been found *in situ* in the pegmatite. Hurlbutite appears to belong to the early stage hydrothermal period of formation since no crystals have been found in cavities or in such relationship to other minerals in the hand specimens to suggest otherwise. The relationships observed in those specimens collected to date suggest that hurlbutite is later than triphylite but earlier than quartz. The minerals with which hurlbutite has been found directly associated include muscovite, albite, triphylite, massive, light-smoky quartz, and siderite. The sequence of formation appears to have been muscovite-albite-triphylite-hurlbutite-quartz. The best crystals of hurlbutite are those found embedded in the smoky quartz, and when not stained could easily be mistaken for feldspar crystals. Several interesting pseudomorphs of siderite after hurlbutite have been found.

CRYSTALLOGRAPHY

Hurlbutite crystals occur embedded for the most part in a matrix of massive, light-smoky quartz and feldspar. Hurlbutite is orthorhombic. The crystals are stout prismatic [001] in habit, with relatively large development of $c\{001\}$ and $m\{110\}$. They range in size from 4 to 25 millimeters along [110]. The faces are delicately etched and exhibit striations or what may actually be fibration on $\{110\}$. The crystals appear to have grown attached to the matrix by one end of the [100] axis. Two doubly terminated crystals were freed from the embedding material.

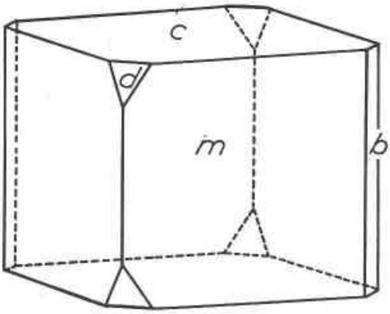

FIG. 1. Hurlbutite crystal of typical habit.

The crystals are rather simple in habit. The forms *c*{001} and *m*{110} are dominant and are truncated by *d*{201} and *b*{010}. On one crystal the form *e*{101} occurred, but only as a very small face. The form to which the symbol *r*(311) has been assigned is uncertain since measurements were possible only on the Goldschmidt two-circle contact goniometer. Because the faces of this form were rounded, the ϕ and ρ angle measurements were found to spread over as much as from 2° to 4° and therefore were not considered reliable enough for angle table calculations. It is without question an {*hkl*} form and its presence is indicative of holohedral symmetry.

Two of the larger crystals were measured on the Goldschmidt two-circle contact goniometer; one small doubly terminated crystal was measured on the reflecting goniometer. An average of the measured angles tabulated below gives the ratio $a:b:c = 0.9420:1:0.9017$ which is in fairly good agreement with that derived from *x*-ray study ($a_0:b_0:c_0 = 0.9420:1:0.8875$).

Forms	*Measured*		*Calculated* (*x*-ray cell)	
	ϕ	ρ	ϕ	ρ
c 001	— —	0°00′	— —	0°00′
b 010	0°00′	90 00	0°00′	90 00
m 110	46 35	90 00	46 42½	90 00
e 101	90 00	43 15	90 00	43 17½
d 201	90 00	61 59	90 00	62 02½
(?)*r* 311	72 40	71 43	72 34	71 21

An angle table based on the elements derived from *x*-ray study for forms observed on hurlbutite crystals is given in Table 1.

PHYSICAL AND OPTICAL PROPERTIES

Crystals of hurlbutite are colorless to greenish white; when stained, yellow. Transparent to translucent. Cleavage not observed. Fracture conchoidal. Brittle. Hardness 6. Specific gravity 2.877±0.005 (an

TABLE 1. HURLBUTITE: ANGLE TABLE

Orthorhombic; dipyramidal—$2/m\ 2/m\ 2/m$

$a:b:c=0.9420:1:0.8875$ $p_0:q_0:r_0=0.9421:0.8875:1$

$q_1:r_1:p_1=0.9420:1.0615:1$ $r_2:p_2:q_2=1.1268:1.0616:1$

Forms	ϕ	ρ	ϕ_1	$\rho_1=A$	ϕ_2	$\rho_2=B$
c 001	— —	0°00′	0°00′	90°00′	90°00′	90°00′
b 010	0°00′	90 00	90 00	90 00	— —	0 00
m 110	46 42½	90 00	90 00	42 17½	0 00	46 42½
e 101	90 00	43 17½	0 00	46 42½	46 42½	90 00
d 201	90 00	62 02½	0 00	27 57½	27 57½	90 00
(?)*r* 311	72 34	71 21	41 35½	25 19	19 29	73 30½

average of measurements on 8 different fragments on the Berman microbalance); 2.88 (calculated). Luster vitreous to greasy. Streak white. Difficult to fuse. Very slowly soluble in acids. Not fluorescent in either short-wave or long-wave ultraviolet radiation.

The optical properties of hurlbutite are cited in Table 2 in comparison with those of beryllonite and herderite.

CHEMICAL COMPOSITION

A chemical analysis of one of the original matrix crystals, cited in column 2 of Table 3, proves the mineral to be $CaBe_2(PO_4)_2$. A comparison with the reported analyses of beryllonite and herderite shows that hurlbutite has a higher BeO and P_2O_5 content than either of these beryllium phosphates. *X*-ray studies discussed later in this paper indicate that hurlbutite is not a possible end-member of a series with beryllonite or herderite.

A spectrographic analysis on the same material in the spectral range between 2200 Å and 4300 Å showed that the minor constituents and traces included Si, Al, Na, and Sr.

The cell volume 570 Å and the measured specific gravity, 2.877, give the molecular weight of the cell contents, $M_0=994$. Multiplying this value by the atomic quotients, the experimental cell contents are derived. Assuming the integers given under the theoretical cell contents in Table 3 as correct, the unit cell contents are $Ca_4Be_8(PO_4)_8$ or $4[CaBe_2(PO_4)_2]$.

X-RAY STUDY DATA

Single-crystal work on hurlbutite was done using a fragment of known orientation drilled out from the original crystal found by Dr. Judith Weiss-Frondel. This fragment contained what was assumed to be (001)

TABLE 2. COMPARISON OF SOME PHYSICAL AND OPTICAL PROPERTIES OF HURLBUTITE, BERYLLONITE, AND HERDERITE

		Beryllonite				Herderite		
	Hurlbutite (Mrose, 1951)	(Dana and Wells 1889)			(Palache and Shannon, 1928)	Hydroxyl-herderite (Penfield, 1894)	Herderite (?) (Yatsevitch, 1935)	Herderite (?) (Bertrand in Des Cloizeaux, 1886)
Locality:	Newport, N. H.	Stoneham, Maine			Newry, Maine	Paris, Maine	Topsham, Maine	Stoneham, Maine
Color:	colorless to greenish white	colorless to snow white or pale yellowish				colorless to pale yellowish or greenish white		
Opt. sign:	(−)	(−)			(−)	(−)	(−)	(−)
Indices:								
nX	1.595 ± 0.003	$1.5492_{(Li)}$	$1.5520_{(Na)}$	$1.5544_{(Tl)}$			1.591 ± 0.003	$1.592_{(Na)}$
nY	1.601 ± 0.003	1.5550	1.5579	1.5604	1.558	$1.632_{(Na)}$	1.611 ± 0.003	1.612
nZ	1.604 ± 0.003	1.5604	1.5608	1.5636	1.562		1.619 ± 0.003	1.621
Opt. orient.:	$X=b$, $Y=c$	$X=b$, $Y=a$, $Z=c$					$X\wedge c\sim+87°$, $Y=b$, $Z\wedge c\sim-3°$	
Dispersion:	$r>v$, weak	$r<v$, weak					$r>v$, inclined	
2V (meas.):	70°				medium	72°	75°±5°	66°59′34″
2V (calc.):	70°18′	67°51′	67°56′	67°57′				
Cleavage:	not observed	{010} perfect, {100} good but interrupted, {101} distinct, {001} in traces					{110} interrupted	
Hardness	6	5½–6					5–5½	
G. (meas.)	2.877		2.845		2.806 (Berman)	2.952; 2.95 (hydroxyl-herderite) to 3.01 (hydroxyl-herderite with OH:F=1.5:1)		
G. (calc.)	2.88				2.81	2.94 (hydroxyl-herderite)		
Composition	$CaBe_2(PO_4)_2$	$NaBe(PO_4)$				$CaBe(PO_4)(OH, F)$		$CaBePO_4(F, OH)$

TABLE 3. CHEMICAL ANALYSIS AND UNIT CELL CONTENTS OF HURLBUTITE

	Weight per cent		Molecular quotients	Atomic quotients	Experimental cell contents (×994/100)	Theoretical cell contents
	1	2				
CaO	21.84	21.99	0.3921	(Ca) 0.392	3.90	4
BeO	21.30	21.44	0.8569	(Be) 0.857	8.52	8
P_2O_5	56.19	56.57	0.3983	(P) 0.797	7.92	8
Insol.	0.76			(O) 3.210	31.92	32
Total	100.09	100.00				

1. Gonyer analysis, 1951.
2. Recalculated to 100% after deducting insoluble.

because of the importance of the form development. Rotation and Weissenberg photographs were taken using copper radiation and nickel filter, and rotating about the *c*, *b*, and *a* axes of the fragment. The axes were located by the oscillating technique on the Weissenberg unit. The Laue symmetry D_{2h} was clearly observed for the 0- and *n*-level Weissenberg photographs and the orthorhombic character of the mineral hence confirmed. No space group extinctions were found on any of the Weissenberg photographs. If the crystal class is taken to be dipyramidal as is indicated by the form development and absence of piezoelectricity, the space group is definitely established by the diffraction effects as $D_{2h}^1 - Pmmm$.

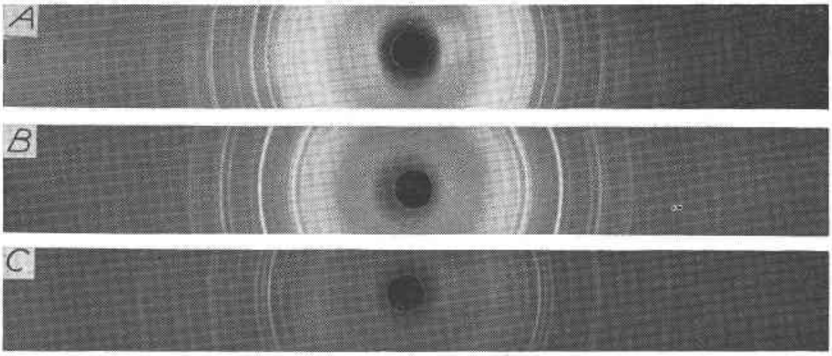

FIG. 2. *X*-ray powder photographs taken with Cu/Ni radiation. A. Hurlbutite. Smith mine, Newport, New Hampshire. B. Beryllonite. Stoneham, Maine. C. Herderite. Palermo mine, North Groton, New Hampshire.

The powder photograph taken with copper radiation was indexed in terms of the dimensions of the cell found by single-crystal study. Because of the large number of solutions possible for the lines of high sin θ, the *hkl*'s for lines with *d*-spacings less than 1.969 Å were not determined. The indices thus obtained are listed in Table 4 and are consistent with the space group $D_{2h}^1 - Pmmm$.

Table 4. Possible Indices for Reflections Occurring on Powder Photograph of Hurlbutite—$CaBe_2(PO_4)_2$

Copper radiation ($\lambda = 1.5418$ Å), nickel filter
(Indices for *d* values below 1.969 have been omitted.)

Line	*d* (meas.)	*hkl*	*d* (calc.)	Line	*d* (meas.)	*hkl*	*d* (calc.)
1	5.83	011	5.84	12	2.50	311	2.498
2	3.91	002	3.906			013	2.496
		120	3.887			103	2.484
3	3.67	201	3.662	13	2.40	230	2.395
4	3.50	102	3.510			113	2.390
		121	3.480			222	2.388
5	3.39	211	3.381	14	2.29	231	2.291
6	3.28	112	3.279	15	2.21	203	2.205
7	3.03	220	3.018			040	2.200
8	2.93	030	2.933	16	2.17	312	2.185
		022	2.921			123	2.163
9	2.86	202	2.848	17	2.10	140	2.127
10	2.78	221	2.815			041	2.117
		130	2.766	18	2.06	400	2.072
		300	2.765	19	2.02	410	2.018
11	2.64	310	2.636			330	2.011
		131	2.607			401	2.003
		003	2.604	20	1.969	223	1.970

In Table 5 are listed the *x*-ray powder spacing data for hurlbutite, beryllonite, and herderite; the powder photographs of these minerals are shown in Fig. 2. The *d*-spacings and intensities of hurlbutite are distinct from those of beryllonite and herderite. The unit cell dimensions of hurlbutite, beryllonite, and herderite are cited in Table 6. The *x*-ray, chemical, and optical data all confirm hurlbutite as a new and distinctive mineral species.

A structural resemblance may exist between hurlbutite and beryllonite. It may be noted that the unit cell volumes are nearly in the ratio of 2 to 3, and that in equal volumes in arbitrary units the numbers of Be, O, and P atoms are identical with $Ca^{+2} = 2\ Na^{+1}$.

Table 5. *X*-ray Powder Spacing Data for Hurlbutite, Beryllonite, and Herderite

Copper radiation ($\lambda = 1.5418$ Å), nickel filter

Hurlbutite $CaBe_2(PO_4)_2$		Beryllonite $NaBe(PO_4)$		Herderite $CaBe(PO_4)(OH,F)$	
Intensity	*d* (meas.)	Intensity	*d* (meas.)	Intensity	*d* (meas.)
2	5.83	4	4.44	2	5.99
5	3.91	2	4.11	2	4.77
10	3.67	6	3.92	3	3.79
7	3.50	9	3.65	1	3.65
2	3.39	2	3.52	5	3.43
6	3.28	$\frac{1}{2}$	3.40	$\frac{1}{2}$	3.33
9	3.03	1	3.25	10	3.14
1	2.93	1	3.04	6	3.00
1	2.86	$\frac{1}{2}$	2.91	8	2.86
9	2.78	10	2.84	$\frac{1}{2}$	2.75
1	2.64	3	2.70	6	2.55
7	2.50	1	2.64	2	2.46
6	2.40	$\frac{1}{2}$	2.56	1	2.40
1	2.29	2	2.44	3	2.34
9	2.21	6	2.37	5	2.26
6	2.17	7	2.28	7	2.20
$\frac{1}{2}$	2.10	1	2.22	1	2.11
5	2.06	1	2.19	1	2.05
5	2.02	3	2.11	4	2.00
5	1.969	2	2.05	$\frac{1}{2}$	1.957
1	1.951	4	1.965	$\frac{1}{2}$	1.922
1	1.833	4	1.910	4	1.881
1	1.792	2	1.821	4	1.781
5 broad	1.729	2	1.755	1	1.749
4	1.691	$\frac{1}{2}$	1.719	3	1.722
3	1.635	1	1.675	1	1.684
2	1.596	2 diffuse	1.593	5	1.650
$\frac{1}{2}$	1.572	3	1.526	$\frac{1}{2}$	1.573
3	1.523	2	1.508	$\frac{1}{2}$	1.547
1	1.496	4 diffuse	1.443	$\frac{1}{2}$	1.506
6	1.462	1	1.328	$\frac{1}{2}$	1.465
4	1.428	2	1.218	$\frac{1}{2}$	1.443
6	1.387			$\frac{1}{2}$	1.419

(16 additional lines with *d* values below 1.387 have been omitted.)

TABLE 6. UNIT CELL DIMENSIONS OF HURLBUTITE, BERYLLONITE, AND HERDERITE

	Hurlbutite (Newport, N. H.) (Mrose, 1951)	Beryllonite (Locality unknown) (Gossner and Besslein, 1934)	Herderite (Topsham, Me.) (Strunz, 1936)
Cryst.	Orthorhombic; dipyramidal $(2/m\ 2/m\ 2/m)$	Monoclinic; prismatic $(2/m)$ (marked ortho. pseudo-symmetry)	Monoclinic; prismatic $(2/m)$
a_0	8.29 Å	8.15 Å	4.81 Å
b_0	8.80	7.78	7.70
c_0	7.81	14.28	9.82
$a_0:b_0:c_0$	0.9420:1:0.8875	1.0477:1:1.8260	0.625:1:1.276
β		90°00′	90°06′
Cell volume	570 Å	894 Å	361 Å
Cell contents	$Ca_4Be_8(PO_4)_8$	$Na_{12}Be_{12}(PO_4)_{12}$	$Ca_4Be_4(PO_4)_4(OH, F)_4$
Space group	D_{2h}^1-Pmmm	$C_{2h}^5-P2_1/c$	$C_{2h}^5-P2_1/c$

NAME

This mineral is named *hurlbutite* after Professor Cornelius S. Hurlbut, Jr., of the Department of Mineralogy and Petrography, Harvard University. The name is particularly appropriate in view of Prof. Hurlbut's interest and studies in the beryllium-bearing minerals. The name hurlbutite has already appeared in the literature, having been given gratuitously by Gagarin and Cuomo (1949) to the species wurtzite-4H described by Frondel and Palache (1948, 1950). The prior usage is unnecessary and unjustifiable and is not here recognized. Fleischer (1951) in commenting on the mineral names proposed by Gagarin and Cuomo in their paper, and also in private communication (1951) with the writer on the proposed naming of this new mineral states: "It seems to me that mineralogists should not feel bound by any names proposed in this paper." Professor Frondel concurs in this opinion.

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