

CRYSTALLOGRAPHY OF HUREAULITE

JOSEPH MURDOCH, *University of California, Los Angeles.*

The rare mineral hureaulite was first discovered about 1825 by Allaud¹ on a few small specimens from Hureaux in the Department of Haute Vienne, France. The material was described by Dufrénoy² and analyzed by him^{2a} and by Vauquelin,³ the former making also a rough determination of the prism angle. Des Cloizeux⁴ found more material in a specimen of heterosite from La Vilate, near Chanteloube, in the same district, with crystals well enough developed to measure some of the forms with fair accuracy, and others by approximation. Hureaulite is also reported as probably occurring in Silesia. In the United States, hureaulite has been found at three localities only: Branchville⁵ and Portland, Conn.,⁶ and Pala, Calif.⁷ The Branchville material was fairly well crystallized, and measurements on it were much better than those of Des Cloizeux, although according to the authors, not very accurate because of the multiple habit of the crystals. From these crystals the ordinarily accepted elements of crystallization were calculated.

OCCURRENCE

The writer, in collecting recently at the Stewart mine, Pala, California, found a specimen of dark colored phosphates showing crystalline hureaulite on one of the fractured surfaces. The mineral in this crust is colorless to pale or deep amber, with none of the violet-rose or deep orange-red shown at other localities. The crystals are practically iron free, as shown by a microchemical test for iron, and confirmed by spectroscopic analysis (0.1% Fe). The limited amount of material did not permit a complete analysis, but qualitative tests showed Mn, P, and H₂O. Hardness, as de-

¹ Allaud, Notices sur l'Hétérosite, l'Hureaulite (fer et manganèse phosphaté) et sur quelques autres minéraux du Department de la Haute Vienne: *Ann. de Sci. Nat.*, **8**, 334-354 (1826).

² Dufrénoy, *Annales des Mines*, 2d ser., **7**, p. 137.

^{2a} Dufrénoy, Sur deux nouveaux phosphates de manganèse et de fer: *Ann. de Chimie et de Physique*, 2d ser. **41**, 338 (1829).

³ Vauquelin, Analyse de l'Hureaulite, mineral trouvé dans la commune d'Hureaux: *Ann. de Chimie et de Physique*, 2d ser., **30**, 302 (1825).

⁴ Des Cloizeux, Determination des formes cristallines et des propriétés optiques de l'Hureaulite: *Ann. de Chem. et de Physique*, ser. 3, **53**, 293 (1858).

⁵ Brush, G. J., and Dana, E. S., On the mineral locality of Branchville Conn. 5th Paper: *Am. Jour. Sci.*, 3d ser., **39**, 207 (1890).

⁶ Shairer, J. F., Lithiophilite and other rare phosphates from Portland Conn.: *Am. Mineral.*, **11**, 101-104 (1926).

⁷ Schaller, W. T., New manganese phosphates from the gem tourmaline field of southern California: *Jour. Wash. Acad. Sci.*, **2**, 143-145 (1912).

terminated carefully on crystals, was between 3 and 4, a value in agreement with that of Alluaud, but not with that of Des Cloizeaux, whose value of 5 has been accepted by Dana and Hintze. Hureaulite occurs as one of the near-end members of a series of alterations from some earlier mineral, perhaps lithiophilite, although none of this was observed on the hureaulite specimen. The minerals of this series are intimately intergrown, in general, so closely as to be indeterminable, although palaite was noted in veins of colorless cross fibers cutting the specimen, and blue manganiferous strengite (vilateite?) and yellow stewartite appear on the surface of cavities. Sicklerite also was tentatively identified among the earlier minerals of the series. The strengite was observed in some places overlying hureaulite, but stewartite was nowhere seen where its relative age could be determined. The palaite is clearly different in habit and appearance from the hureaulite, although it has been recently suggested⁸ that the two may be identical, and it is true that most of the optical properties of the two minerals are quite similar.

CRYSTALLOGRAPHY

The crust of hureaulite was in part made up of excellent crystals, so that it has been possible to make rather accurate measurements on them. Calculations from these measurements has led to a slight modification of the lengths of the a - and c -axes, and of the value of β , with a doubling of the length of the c -axis.

The crystals are small, none of them much over one mm. in longest dimension, and appear in two general habits, both somewhat elongated parallel to c . One habit is tabular parallel to $\{100\}$, the other stout prismatic, with nearly equal development of $\{100\}$ and $\{110\}$. A typical crystal is shown in Fig. 1. In general, the faces are smooth and of good quality so that the reflections are good to fair. None are strongly striated as described by Des Cloizeaux,⁹ but occasionally vicinal faces are present so that the signals are multiple. Seventeen crystals in all were measured and Table 1 shows the average readings for faces used in calculating the crystallographic elements.

These values have been heavily weighted in favor of one particularly good crystal, especially for the forms m , c , and α . It will be noted that the average of all measured values for ϵ is not in very good agreement with the calculated value, although the selected better signals are very close. This lack of agreement is due to the fact that the pyramid face is very

⁸ Mason, Brian, Minerals of the Varuträsk pegmatite, XXIII: Some iron manganese phosphate minerals: *Geol. För. Förh.*, **63**, 117-175 (1941). (Abstr. *Am. Mineral.*, **26**, 682, 1941).

⁹ *Loc. cit.*, p. 296.

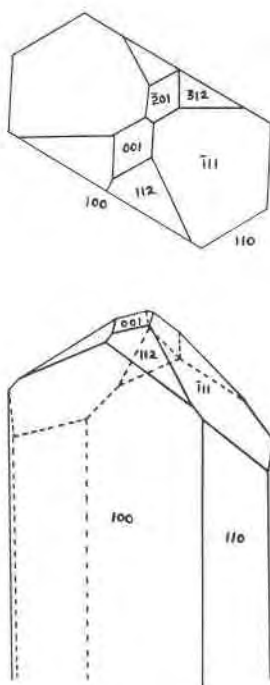


FIG. 1

TABLE 1. FORMS USED IN CALCULATION OF AXES

Form	No. readings	Qual.	Weighted average		Calculated	
			ϕ	ρ	ϕ	ρ
<i>c</i> 001	3	A	90°00'	6°40'	90°00'	6°40'
<i>m</i> 110	30	B	27 35	90 00	27 32½	90 00
α 201	6	A	-90 00	44 17	-90 00	44 17
δ 112	10	B	36 35	33 09	36 40½	33 08
ϵ 111	7	B	-22 17	48 23	-22 17	48 32
	(15)	C	-22 42	48 18—average of all good signals)		

frequently represented by a vicinal face of a quality about equal to the true one, sometimes alone, sometimes occurring with the latter, so that it is not always possible to distinguish one from the other. Accordingly, the calculations have been weighted in favor of the other forms. The lengths of the axes derived from these calculations agree fairly well with those of Brush and Dana,¹⁰ if their length of *c* is doubled, and also with those of

¹⁰ *Loc. cit.*, p. 208.

De Schulten¹¹ on pure synthetic crystals. In both these cases, however, the available material was not particularly good, although better than Des Cloizeaux's, and it has seemed justifiable to the writer to offer his own values as more nearly the correct ones for this mineral. The comparative values are shown below:

TABLE 2. AXIAL RATIOS

	<i>a</i>	<i>b</i>	<i>c</i>	β
Brush and Dana	1.9192	1	$\frac{1}{2}(1.0490)$	95°59'
De Schulten	1.9048	1	$\frac{1}{2}(1.0378)$	96 28
Murdoch	1.9307	1	1.0470	96 40

Dana's choice of axial lengths results in rather complex indices, and accordingly Goldschmidt, in the *Winkeltabellen*, chose a reversed orientation, a doubling of *c*, and a higher value for β giving fairly simple indices, but a rather steeply inclined base. If, however, we keep Dana's orientation, but double the length of his *c*-axis, the indices become essentially as simple as Goldschmidt's with the added advantage that {001} is more nearly horizontal, as it should be according to convention. The transformation formulae for the different settings are as follows:

$$\begin{array}{ll} \text{Dana to Murdoch} & 100/010/002 \\ \text{Goldschmidt to Murdoch} & 10\bar{1}/010/001 \end{array}$$

X-ray oscillation photographs, taken about the vertical axis, confirm this choice of axial lengths. The measurements give the following cell size: a_0 17.42 Å, b_0 9.12 Å, c_0 9.50 Å. This corresponds to $a:b:c = 1.908:1:1.040$, which is in reasonably close agreement with the crystallographic values.

The space group, from rotation photographs, is probably C_{2h}^4 , the unit cell carries four molecules, and the calculated specific gravity is 3.23. This value checks very closely with the determined values which range from 3.198 to 3.149. The small amount of material available did not allow direct determination of specific gravity for the Pala crystals.

NEW FORMS

On the measured crystals the following recognized forms were observed: *a*, *m*, ϵ , *k*, α , δ , *c*, *g*, and in addition a number of new forms. These are listed in Table 3, which shows the number of times each was observed, the quality and position of each. Some occurring only once are in such good position as to be considered acceptable, likewise, one appearing six times, although with poorer signals. These have been given letters, while others, occurring only once, with poor signals, are listed, but as doubtful forms.

¹¹ De Schulten, A., Production artificielle de hureaulite et de la hureaulite de cadmium: *Min. soc. franc., Bull.*, 27, 123 (1904).

TABLE 3. NEW FORMS

Form	No. times	Quality	Measured		Calculated	
			ϕ	ρ	ϕ	ρ
<i>n</i> 580	1	B	18°20'	90°00'	18°03'	90°00'
<i>h</i> 760	1	B	31 18	90 00	31 19	90 00
<i>g</i> 111	3	D	32 13	50 01	32 20	51 06
			38 35	51 40		
<i>s</i> 311	1	C	56 55	63 44	59 11	63 55½
<i>l</i> 511	1	A	67 49	72 14	69 48½	71 45
? 611	1	D	69 50	75 00	72 51	74 16
? 12.1.1	1	D	79 21	81 30	81 05	81 34½
? 232	1	D	23 28	57 25	22 53	59 36
? 513	1	E	-70 14	48 15	-70 29½	46 16

The full angle table for hureaulite, with the revised values, is given in Table 4.

TABLE 4

$a:b:c=1.9307:1:1.0470$				$\beta=96^{\circ}40'$		
$p_0=0.5423$		$q_0=1.0400$		$r_0=1$	$\mu=83^{\circ}20'$	
$r_2=0.9615$		$p_2=0.5215$		$q_2=1$		
$p_0'=0.5460$		$q_0'=1.0470$		$x_0'=0.1169$		
Form	ϕ	ρ	ϕ_2	$\rho_2=B$	C	A
<i>c</i> 001	90°00'	6°40'	83°20'	90°00'	0°00'	83°20'
<i>a</i> 100	90 00	90 00	0 00	90 00	83 20	0 00
<i>b</i> 010	0 00	90 00	0 00	0 00	90 00	90 00
<i>n</i> 580	18 03	90 00	0 00	18 03	87 55	71 57
<i>m</i> 110	27 32½	90 00	0 00	27 32½	86 55	62 27½
<i>h</i> 760	31 19	90 00	0 00	31 19	86 31½	58 41
α 201	-90 00	44 17	134 17	90 00	50 57	134 17
β 502	-90 00	51 18	141 18	90 00	57 58	141 18
<i>g</i> 111	32 20	51 06	56 31½	48 53	47 46½	65 24
ϵ 111	-22 17	48 32	113 13½	46 06	51 20	106 30
δ 112	36 40½	33 08	68 42	64 00	29 36	70 57
<i>p</i> 113	40 34½	24 40½	73 21½	71 31	20 56	74 14½
<i>s</i> 311	59 11	63 55½	29 40½	62 36	58 15	39 31
<i>z</i> 311	-55 27½	61 33½	146 40½	60 05½	67 10	136 25
<i>l</i> 511	69 48½	71 45	19 21	70 52	65 30½	26 57½
<i>k</i> 512	-67 14½	53 32	141 18	71 52	59 43	137 52
<i>q</i> 534	-35 46	44 03½	119 29½	55 39	48 12	113 59
<i>l</i> 421	-44 45½	71 16	154 17	47 44½	76 01	131 49½

The writer wishes to thank Dr. J. D. McCullough, of the department of Chemistry, University of California, Los Angeles, for taking the x-ray photographs and assisting in the calculations. Dr. W. T. Schaller, of the U. S. Geological Survey, has been kind enough to waive his prior rights on the description of hureualite from Pala, which he was the first to find, and to permit the publication of this note. The spectroscopic analysis was made possible by a grant from the Research Fund of the University of California.