CRYSTALLOGRAPHY OF MEYERHOFFERITE

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The calcium borate meyerhofferite was first described by W. T. Schaller (1916) and nothing has since been published concerning its crystal form. Numerous specimens of this and other borates were collected at the original locality by W. F. Foshag and F. A. Gonyer in 1930. A series of these was presented to the Harvard Mineralogical Museum, and examination of this material has revealed new crystallographic data which seem to merit publication, especially as they seem to justify a modification of Schaller's original crystal elements.

His description of meyerhofferite was based on crystals formed on or within fibrous pseudomorphs after inyoite. Similar pseudomorphs of great perfection are included in the new collections. There are also masses of interlaced glassy crystals of meyerhofferite embedded in a hard yellow clay, their interstices filled by snow-white fibrous aggregates of a later generation of meyerhofferite. It was from these masses that the newly studied crystals were obtained. Most of the hundreds of crystals examined were of the simple form described as typical by Schaller: prismatic crystals terminated by three forms in the macrodome zone and a single pyramid. A small number of the crystals, however, presented other terminal faces including a number of pyramids.

Meyerhofferite is triclinic and Schaller so orientated the crystal that the single observed pyramid should be {111}. This position unfortunately made the basal pinacoid {001} slope to the rear. With the finding of pyramids in other quadrants of the crystal there seemed no good reason for maintaining this unusual position, so that the crystals of meyerhofferite are described in this paper as rotated 180° about the vertical axis from the position of Schaller.

It was observed that many of the more highly modified crystals showed a more or less curved solution surface in a quadrant diagonally opposed to that containing the common pyramid. This rounded surface sometimes developed into two facets, still rather imperfect in quality; but crystals were finally found in which these faces were measurable on the goniometer. It would appear that the general direction of what has been here adopted as the pyramid {111} is peculiarly sensitive to solution attack.

Fourteen crystals were measured completely. The perfect cleavage parallel to {010} was rarely absent and served as a means of establishing the v_0 of each crystal. The prism zone was generally of good quality and

in no case was any prism form observed besides {110} and {1$\bar{1}$0}. The position angles of the forms present on the 14 crystals were collected and their mean values taken. These average angles were very similar to the average angles recorded in Schaller's paper. It was therefore regarded as best to combine the two sets of measurements in an average, weighted for the number of observations of each form. In Table 1 these figures are shown, Schaller's values for ϕ being adjusted to the new position above mentioned. Table 2 contains the observations of new pyramids of which one, $u\{\bar{1}11\}$ was found frequently and in excellent position.

TABLE 1. MEASURED ANGLES OF MEYERHOFFERITE

Form		No. of measurements	*Schaller* ϕ	*Schaller* ρ	*Palache* No.	*Palache* ϕ	*Palache* ρ	Weighted mean No.	Weighted mean ϕ	Weighted mean ρ
c	001	6	90°13′	11°48′	5	89°27′	11°56′	11	89°52′	11°51½′
a	100	26	93 12	90 00	14	93 05	90 00	40	93 09½	90 00
m	110	19	54 15	90 00	11	54 19	90 00	30	54 16½	90 00
M	1$\bar{1}$0	13	129 49	90 00	18	129 39	90 00	31	129 43	90 00
y	101	9	93 00	50 22	12	92 29	50 26	20	92 41½	50 24½
t	$\bar{1}$01	9	− 85 59	38 35	12	− 85 49½	38 22	21	− 85 53½	38 27½
p	$\bar{1}\bar{1}$1	9	−132 26	46 54	15	−132 30	46 53	24	−132 28½	46 53

TABLE 2. MEASURED ANGLES OF NEW FORMS ON MEYERHOFFERITE

Form		No. of faces	Quality	ϕ	ρ	Range ϕ	Range ρ
u	$\bar{1}$11	5	excellent	− 43°20′	48°53′	43°27′–43°08′	48°42′–49°07′
o	111	2	poor	57 58	54 05	Many other observations in this general vicinity—faces rounded.	
E	212	1	poor	76 32	51 13		
D	2$\bar{1}$2	1	good	−112 55	40 22		

On the basis of these combined data, elements were calculated with results which are presented in the heading of Table 3. The new elements correspond very nearly to those of Schaller as was to be expected. The same is true of the position angles of the forms which appear in the same table. Those forms described by Schaller, which he found but once have been omitted from this table. The table also contains the angles made

by each form to the three pinacoids, B, C and A, a negative sign before B or A indicating that the face is nearest to the negative end of the normal to (010) or (100), respectively.

TABLE 3. MEYERHOFFERITE—$Ca_2B_6O_{11} \cdot 7H_2O$

Triclinic; pinacoidal—$\bar{1}$

$a:b:c = 0.7904:1:0.7763$; $\alpha = 90°41'$, $\beta = 101°51'$, $\gamma = 86°44'$

$p_0:q_0:r_0 = 0.9837:0.7610:1$; $\lambda = 89°49'$, $\mu = 78°10\frac{1}{2}'$, $\nu = 93°11\frac{1}{2}'$

$p_0' = 1.0051$ $q_0' = 0.7775$ $x_0' = 0.2098$ $y_0' = 0.0003$

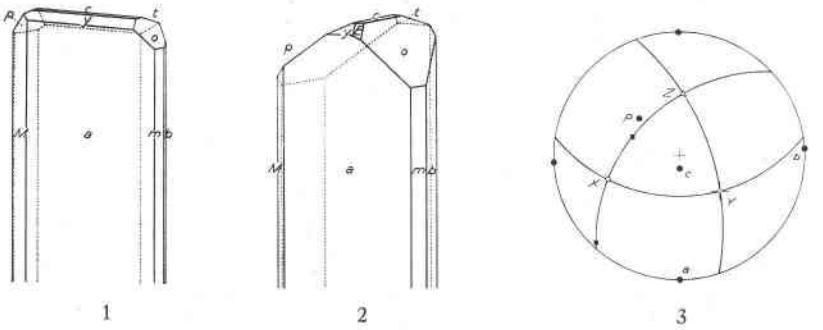
Form		ϕ	ρ	A	B	C
c	001	89°55½′	11°51′	78°10½′	89°59′	0°00′
b	010	0 00	90 00	93 11½	0 00	89 59
a	100	93 11½	90 00	0 00	93 11½	78 10½
k	370	29 43	90 00	63 28½	29 43	84 08½
A	350	38 59	90 00	54 12½	38 59	82 34
m	110	54 17	90 00	38 54½	54 17	80 23½
n	520	75 44½	90 00	17 27	75 44½	78 31
s	310	78 33½	90 00	14 38½	78 33½	78 23½
r	810	87 39	90 00	5 32½	87 39	78 09½
h	$3\bar{1}0$	107 26	90 00	14 14½	107 26	78 42½
w	$4\bar{3}0$	122 29½	90 00	29 18	122 29½	80 02
M	$1\bar{1}0$	129 43	90 00	36 31	129 43	80 55½
v	$3\bar{5}0$	143 25	90 00	50 13	143 25	82 59
y	101	92 38	50 32	39 28	92 02	38 42
t	$\bar{1}01$	− 85 56½	38 30½	128 30½	92 31½	50 20
f	$\bar{6}05$	− 86 07	44 54½	133 54	92 44	56 44
g	$\bar{5}04$	− 86 09	46 19	136 18½	92 47	58 08½
o	111	59 15	54 41½	47 23½	65 20½	44 47
E	212	74 39	51 31½	42 05	78 02½	49 49
u	$\bar{1}11$	− 43 35½	49 01½	123 23	56 51	57 39
p	$\bar{1}\bar{1}1$	−132 15½	47 00½	120 52	119 28	56 12½
D	$\bar{2}\bar{1}2$	−112 43½	40 43	125 55½	104 24	51 49

The orientation of the indicatrix, determined by Dr. F. H. Pough from a single crystal mounted on a universal stage, is as follows:

	ϕ	ρ	
X	165°00′	62°00′	2V = 78°
Y	45 30	47 00	
Z	− 83 00	55 00	

A stereographic projection of the indicatrix is given in figure 3.

The structural lattice constants have been determined by Mr. George Switzer upon these newly studied crystals. Because of the quality of the material it was possible to determine all of the unit cell dimensions by x-ray methods with considerable accuracy. Rotation, zero-layer and first-layer Weissenberg photographs were taken with $c[001]$ as the axis



1 2 3

FIG. 1. Meyerhofferite: typical crystal in new position.
FIG. 2. Meyerhofferite: more complex crystal, showing two new forms $o\{111\}$ and $E\{212\}$.
FIG. 3. Meyerhofferite: stereogram of the optical indicatrix. (After F. H. Pough.)

of rotation, and rotation and zero-layer photographs about the $a[100]$ and $b[010]$ axes. From the zero layer photographs about each of the three crystallographic axes, two values for each of the unit spacings betwen the pinacoidal planes were obtained, and also the planar spacings of (110), $(10\bar{1})$, and (011). From the average values of these spacings were then calculated the reciprocal lattice constants a^*, b^*, c^*, α^*, β^*, γ^*, which in turn yielded the following unit cell dimensions:

$$a_0 = 6.60\ (\pm 0.02)\text{Å} \qquad \alpha = 91°00'\ (\pm 0°05')$$
$$b_0 = 8.33\ (\pm 0.02) \qquad \beta = 101°31'\ (\pm 0°05')$$
$$c_0 = 6.48\ (\pm 0.02) \qquad \gamma = 86°55'\ (\pm 0°05')$$
$$a_0 : b_0 : c_0 = 0.792 : 1 : 0.778$$

The unit cell volume then becomes 348.83 cubic Å, and with the density 2.12 given by Schaller (1916), the molecular weight of the unit cell $M = 448.18$.

Table 4 gives the atomic content of the unit cell, using the average of two analyses by Schaller.

TABLE 4. ANALYSIS OF MEYERHOFFERITE AND CONTENT OF UNIT CELL

	1	2	3		4	5
CaO	26.45	25.30	0.4512	2×.226	2.17	2
B_2O_3	46.40	46.09	0.6618	3×.221	2.97	3
H_2O	28.76	28.61	1.5895	7×.227	7.12	7

1. Analysis by W. T. Schaller (1916).
2. Analysis calculated to 100%.
3. Molecular ratios.
4. Atomic content of the unit cell, from $M=448.18$.
5. Theoretical unit cell content, expressed by the formula $(Ca_2B_6O_{11}\cdot 7H_2O)$.

REFERENCE

Schaller, W. T. (1916): *Mineralogical Notes, Series 3. U.S. Geol. Survey, Bull.* **610**, pp. 41–55.