CRYSTALLOGRAPHY AND *X*-RAY MEASUREMENTS OF HOWLITE FROM CALIFORNIA

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ABSTRACT

Macroscopic crystals of howlite, $H_5Ca_2SiB_5O_{14}$, have been found encrusting massive material at the old Sterling Borax mine, Tick Canyon, California. These have been measured on the reflecting goniometer and studied by *x*-ray methods. The crystals are tabular in habit, up to one millimeter across, and are usually attached by one end of the symmetry axis. They are monoclinic, with {100} dominant, {001} and {011} well developed on all crystals. Occasional faces in the orthodome zone, such as {104} or {102}, are present but narrow and often in poor position.

X-ray examination confirms the monoclinic symmetry and yields crystallographic elements which are entirely satisfactory. Weissenberg rotation and layer line photographs about *c* and *b* give the following cell dimensions and beta angle.

$$a_0=12.93\ \text{Å},\quad b_0=9.34\ \text{Å},\quad c_0=8.60\ \text{Å},\quad \beta=104°50'$$

Systematic extinctions place the crystal in space group $P2_1/c(C_{2h}^5)$. Powder photograph lines have been indexed down to 1.495 Å. Strongest lines and their intensities are as follows: 6.20, I=10; 3.90, I=8; 2.036, I=7.

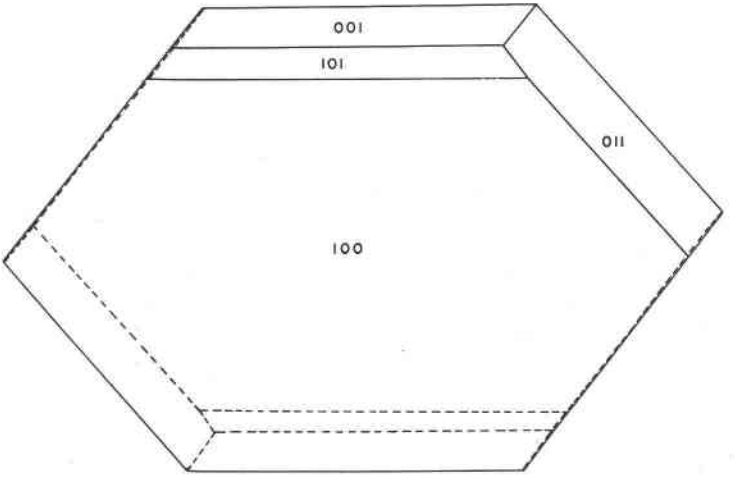

FIG. 1. Typical crystal habit of howlite.

The mineral howlite, $H_5Ca_2SiB_5O_{14}$, has been recorded from a number of localities in California and elsewhere, Palache *et al* .(1951) p. 362, and microscopic crystals have been described by Larsen (1921), p. 87, but in general the mineral is massive and very fine granular. Recently however, the writer has been fortunate enough to find crystals of reasonable size at the Sterling Borax mine in Tick Canyon, Los Angeles County, California. These crystals are tabular in habit, in some instances as much

as one millimeter in largest dimension, and well formed. They have been measured on the reflecting goniometer, and have also been studied by powder and single crystal x-ray methods. The larger crystals are always singly terminated, but some of the smaller ones are essentially complete. They occur on some of the less solidly massive cauliflower-like aggregates of howlite, often closely associated with finely crystalline bakerite, which appears to be usually somewhat earlier.

Measurements on selected crystals show that the mineral is monoclinic,

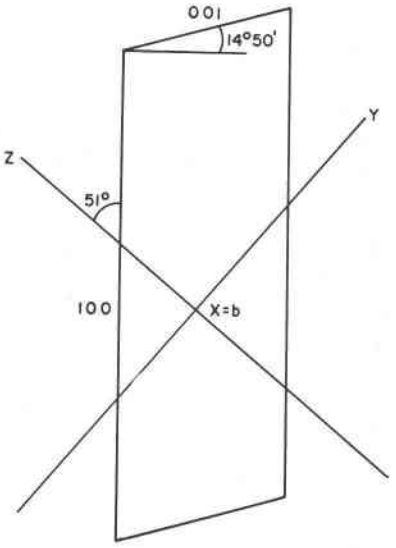

FIG. 2. Optical orientation of howlite.

and normally attached on one end of the symmetry axis. Crystals are tabular parallel to {100} and terminated by {011} which gives them a sharply pointed aspect. The basal pinacoid bevels {100}, and is comparable in size to {011}. These forms are present on all crystals, but occasionally others, such as {101} {102} or {104}, appear. These are narrow and often not in very good position. Fig. 1 shows the typical crystal habit.

No pyramid or prism faces were observed, and thus the only crystallographic element determinable is β, with an average value (calculated from numerous good quality measurements of {001} and {011}), of 105° 20′. The measurements confirm Larsen's determination of monoclinic symmetry, although the direction of elongation appears to be b rather than c.

Indices of refraction agree closely with Larsen's values. The mineral is biaxial, optically negative, and 2V as determined on the universal stage,

is close to 73°. Determination of the optical orientation shows that $X=b$, and $Z\wedge c=51°\pm$ (see fig. 2). The accompanying angle table (Table 1) has been calculated, mainly from x-ray data, for the observed forms and gives values in good agreement with the measured goniometric angles.

TABLE 1

Monoclinic, space group $P2_1/c$ a_0 12.93 Å b_0 9.34 Å c_0 8.60 Å
$a:b:c=1.3486:1:0.9207$ $\beta=104°50'$
$p_0:q_0:1=0.6651:0.8901:1$ $\mu=75°\,10'$
$r_2:p_2:1=1.123:0.7472:1$
$p_0'=0.6880$ $q_0'0.9207$ $x_0'=0.2648$

Form	ϕ	ρ	ϕ_2	ρ_2=B	C	A
001	90° 00	14° 50	75° 10	90° 00	—	75° 10
100	90° 00	90° 00	0° 00	90° 00	75° 10	—
011	16° 03	42° 38	75° 10	48° 24	40° 37	75° 10
106	90° 00	23° 35	66° 25	90° 00	8° 45	66° 25
104	90° 00	27° 37	62° 23	90° 00	12° 47	62° 23
102	90° 00	38° 02	51° 58	90° 00	23° 12	51° 58
101	90° 00	52° 25	32° 35	90° 00	37° 35	32° 35
403	90° 00	58° 38	31° 22	90° 00	43° 48	31° 22

X-RAY STUDY

X-ray powder patterns were made from the massive material of the "cauliflowers" and from the larger crystals of the crust. These show entire agreement with each other and with the pattern of Nova Scotia howlite (A.S.T.M. card No. 4-0170). Table 2 gives measured spacings, intensities and indexing.

Single crystal study included rotation photographs about the b and c axes, with equator, first- and second-layer line Weissenberg photographs about each direction. The crystals could be easily and accurately oriented, and the resulting films show them to be single individuals. Twinning was not observed on any crystal. From these photographs, taken with copper radiation ($\lambda=1.5418$ Å) and nickel filter, the following data were derived by measurement and calculation: symmetry monoclinic, with systematic extinctions ($00l$), ($h0l$), ($0k0$), with l and k odd, leading to space group $P2_1/c$ (C_{2h}^5)

$$a_0=12.93\text{ Å},\quad b_0=9.34\text{ Å},\quad c_0=8.60\text{ Å},\quad \mu=75°10'$$

The value for b_0 is the average from three layer lines of the rotation photograph, plus the calculated value from (020) on the zero level film.

The value for c_0 is the average from four layer lines of the rotation

TABLE 2. *X*-RAY PATTERN OF HOWLITE, STERLING BORAX MINE, TICK CANYON, CALIFORNIA

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

d	*I*	*hkl*	*d*	*I*	*hkl*
12.4	4	100	2.18	½	240, 511, 141
6.2	10	200, 011	2.16	½	$\bar{2}41, \bar{6}11$
5.24	½	210, 111	2.069	5	004, 600, 241
4.95	½	$\bar{2}11$	2.036	7	610, 340, $\bar{3}41$
4.65	½	020	2.010	2	$\bar{5}31, \bar{2}42$
4.35	3	120	1.975	3	$\bar{6}21$, 502
4.13	4	002, 300, 021, 211	1.927	3	$\bar{6}22$, 620
3.90	8	310, $\bar{3}11, \bar{1}12$	1.895	2	$\bar{4}41, \bar{5}12, \bar{4}33$
3.78	½	220	1.859	1	150, 440, $\bar{7}02$
3.647	½	$\bar{2}21$	1.841	½	$\bar{7}11$, 150
3.099	9	400, $\bar{3}21$, 202, $\bar{4}11$	1.794	5	700, 151, $\bar{6}31$
3.017	3	130, $\bar{2}22$	1.764	2	710, 342, 621
2.93	4	410, $\bar{1}31$, 031	1.647	1	351, 711
2.86	½	$\bar{4}02$, 122	1.530	½	061, 702, 352
2.79	1	230, 131	1.496	1	260, 641
2.74	1	321, $\bar{2}31$	1 479	½	
2.656	2	302, $\bar{4}21$	1.387	2	
2.58	1	420, 231, 222	1.344	½	
2.52	1	500, $\bar{3}31$	1.313	½	
2.45	4	$\bar{5}02, \bar{2}32$	1.213	1	
2.35	½	040, 421	1.190	1	
2.29	½	140, 402	1.022	½	
2.248	½	422, 042			

photograph, plus calculated values from (002), (004), and (006) of the zero level film.

The value for a_0 is the average of fourteen measurements of six orders of (h00) from the Weissenberg films.

The powder pattern was indexed using the above cell-dimensions.

The writer wishes to express his thanks to his colleague, Professor Cordell Durrell, for assistance in determining the optical orientation of howlite.

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