CRYSTALLOGRAPHY OF BRAUNITE FROM NAGPUR, INDIA

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INTRODUCTION

The Karabacek Collection of the Harvard Mineralogical Museum contains some excellent specimens of crystallized braunite ($3Mn_2O_3 \cdot MnSiO_3$) from Nagpur, India, which seem to merit a description both because of their quality and their unusual habit. Fermor (1909) has previously given an incomplete crystallographic description of braunite from this locality in his work on the manganese deposits of India.

MORPHOLOGY

Choice of setting. Braunite is tetragonal holohedral and has, therefore, two possible choices of the a crystallographic axes. It has been set up in both of these two possible positions by various investigators. Dana (1892) chose a pseudo-isometric setting with $c=0.9922$. Goldschmidt (1897) chose the alternative setting, with $c=1.4032$.

Aminoff (1931) made an x-ray investigation of braunite from Långban, Sweden. He took rotation photographs about the c axis and the two possible a axes, and by means of the usual criteria determined the Goldschmidt setting to be correct. Rotation, and zero- and first-layer line Weissenberg photographs of braunite from Nagpur, with c[001] as the rotation axis, were taken by the writer, whose work is in agreement with that of Aminoff. Table 1 summarizes the results obtained.

TABLE 1. STRUCTURAL LATTICE CONSTANTS OF BRAUNITE

	Aminoff	*Switzer*
a_0	13.43 Å	13.23 Å
c_0	18.93	18.77
c_0/a_0	1.404	1.415

The Goldschmidt setting for braunite is therefore correct and has been used in the following crystallographic description. The transformation from Dana to Goldschmidt is obtained by the formula $110/\bar{1}10/002$ and from Goldschmidt to Dana by $1\bar{1}0/110/001$.

Crystallography. Nagpur braunite is black and massive with occasional crystal-lined cavities which may or may not be filled with calcite. The crystals are usually small (less than 3 mm.), and the largest are not over 8 mm. in length. The crystals selected for measurement were from $\frac{1}{2}$ to 2 mm. in length, singly terminated, and of very good quality.

Four crystals were measured completely and several others examined and their forms identified. The morphological elements were calculated from the three best crystals. The forms $e\{011\}$ and $x\{131\}$ were best developed and most often present and were used for the calculations. Table 2 gives the range of the measured values and the morphological elements obtained from the measured mean for the forms $e\{011\}$ and $x\{131\}$ of three crystals.

TABLE 2. CALCULATION OF MORPHOLOGICAL ELEMENTS

Form	No. of readings	Measured range ϕ	Measured range ρ	Measured mean ϕ	Measured mean ρ	$p_0=c$
$e\{011\}$	11	−0°05′ to 0°08′	54°30′ to 54°41′	0°00′	54°36′	1.4071
$x\{131\}$	18	18 15 to 18 28	77 14 to 77 24	18 26	77 20	1.4069
				Average value p_0		1.4070

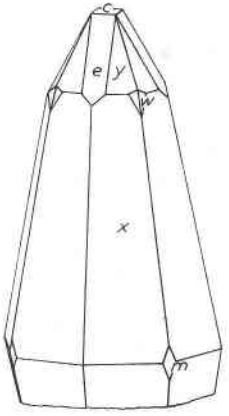
Habit. Nagpur braunite occurs in two distinct habits. The more common habit has the ditetragonal pyramid $x\{131\}$ as the dominant form, with the prism and base very small or lacking; $e\{011\}$ is always present but is smaller than $x\{131\}$. Various other forms are present as small truncating edges.

The second habit is typified by a dominance of $e\{011\}$ with $c\{001\}$ or $x\{131\}$ as the second largest form, and various other truncating forms.

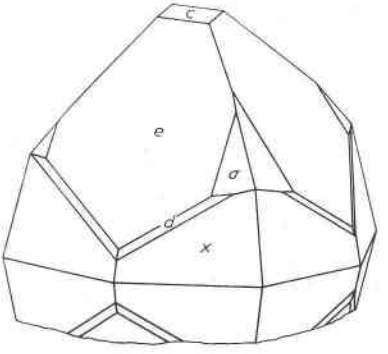
Combination of forms. Below is given the combinations of forms observed on six crystals, listed in order of decreasing dominance. The form letters used are those adopted by Koechlin (1913). (See angle table for the complete form list.)

1. *x, y, e, c, n*
2. *x, e, y, τ, n, d, ϵ, w*
3. *x, e, y, m, τ, n, d*
4. *x, n, e, y, m*
5. *x, e, y, c, n, γ, τ*
6. *e, x, c, i, g*

Figures 1 and 2 illustrate typical crystals of braunite from Nagpur.



1



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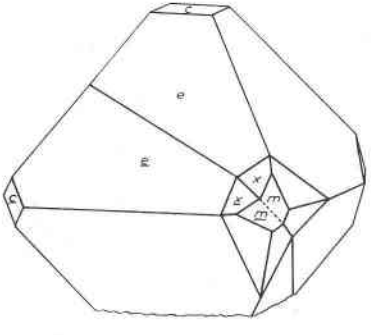

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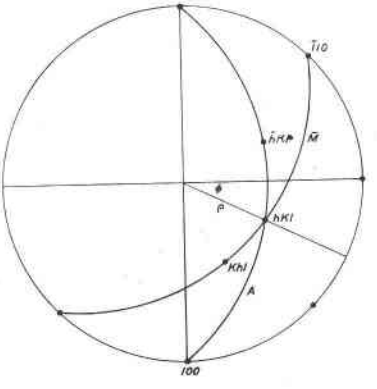

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FIG. 1. Braunite: typical crystal, showing dominance of $x\{131\}$.
FIG. 2. Braunite: less common habit, with $e\{011\}$ as the dominant form.
FIG. 3. Braunite: twin crystal. Twin plane $\{112\}$.
FIG. 4. Diagram to illustrate the usage of columns A and $\overline{M}$ of angle table.

TABLE 3. BRAUNITE—3 $Mn_2O_3 \cdot MnSiO_3$

Tetragonal; ditetragonal-dipyramidal—$4/m\ 2/m\ 2/m$

$p_0 = c = 1.4070$

Forms	ϕ	ρ	A	$\overline{M}$
c 001	—	0°00′	90°00′	90°00′
a 010	0°00′	90 00	90 00	45 00
m 110	45 00	90 00	45 00	90 00
τ 013	0 00	25 07½	90 00	72 31½
γ 012	0 00	35 07½	90 00	65 59½
e 011	0 00	54 36	90 00	54 48
s 021	0 00	70 26	90 00	48 13
o 338	45 00	36 44	64 59	90 00
q 5.5.12	45 00	39 39½	63 10½	90 00
n 112	45 00	44 51	60 05	90 00
p 111	45 00	63 19	50 49	90 00
l 221	45 00	75 53½	46 22	90 00
r 331	45 00	80 29½	45 44	90 00
b 441	45 00	82 50½	45 33½	90 00
D 177	8 08	54 52	83 21½	60 37
g 135	18 26	41 40	77 52	72 42
σ 155	11 18½	55 07½	80 44½	62 55½
i 134	18 26	48 02½	76 24	70 34½
y 133	18 26	56 00½	74 48	68 14
u 153	11 18½	67 18½	79 34½	59 13
t 378	23 12	53 15½	72 41	72 39
λ 5.11.13	24 26	52 27½	70 49	73 47½
v 122	26 34	57 33½	67 49½	74 31½
d 142	14 02	70 58½	76 45	60 53½
f 344	36 52	60 22½	52 04½	82 56
ϵ 353	30 58	69 55	61 06	72 10
w 121	26 34	72 22	64 46½	72 27½
x 131	18 26	77 20	72 02	64 07½
η 151	11 18½	82 04	78 48	56 40½
j 241	26 34	80 58	63 47½	71 48

Rare and doubtful:

ρ 175	8.14.3	571
μ 343	δ 351	11.13.1

Twinning. One specimen of the material examined exhibited numerous small twinned crystals of braunite, the twin plane being {112}. Since the plane {112} has $\rho = 44°51'$, the faces of the form $e\{011\}$ of the two individuals of a twin are almost coplanar. The calculated angular difference between them is 0°18′. The measured angle on one crystal of fair quality was 0°33′. Figure 3 illustrates a typical twin.

Angle table. The elements accepted by Goldschmidt and Dana are based on measurements by Flink (1891). Flink gives little of the quality of his measurements, and all are zonal, and without statement of the number of observations. Therefore, it seems safe to conclude that the elements obtained from the Nagpur crystals are based on superior data, and they have been used as the basis of a new angle table. The form list is that of Koechlin (1913) with the modification that forms seen only once, or forms seen twice but in poor position are considered "rare and doubtful." The columns A and $\overline{M}$ give the interfacial angles to the faces (100) and $(\bar{1}10)$ respectively, which is a new usage. These two angles, as shown in the diagram, figure 4, give angles comparable to the pinacoidal angles of the orthorhombic system (Peacock 1934), and also by a simple calculation the important interfacial angles.

$$A = (100) : (hkl)$$
$$90\text{-}A = \tfrac{1}{2}(hkl : \bar{h}kl)$$
$$\overline{M} = (\bar{1}10) : (hkl)$$
$$90\text{-}\overline{M} = \tfrac{1}{2}(hkl : khl)$$

The order of listing the forms is established as follows: (1) pinacoids, (2) prisms, (3) 2nd order pyramids, (4) 1st order pyramids, (5) ditetragonal pyramids according to increasing values of the ratio h/l (x coordinate) of the face (hkl) in gnomonic projection.

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