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Brewsterite: re-investigation of morphology and elongation

H. J. BROOKE (1822) discovered brewsterite, Sr_2 $(Al_4Si_{12}O_{32}).10H_2O$, from Strontian, Scotland. He gave a set of interfacial angles for an orientation with the crystal's cleavage plane horizontal. Subsequent workers (Brooke and Miller, 1852; Greg and Lettsom, 1858; Mallet, 1859; Michel-Lévy and Lacroix, 1888; Dana, 1892) depict brewsterite with vertical elongation and one can deduce from their measurements that the elongated vertical axis, *c*, is longer than the horizontal *a*-axis.

Single crystal X-ray diffraction studies (Strunz and Tennyson, 1956; Perrotta and Smith, 1964; Khomyakov *et al.*, 1970) show it desirable to label the elongated axis as the *a*-axis to retain the standard space group setting for $P2_1/m$. From these studies and the present work it is now certain that the X-ray orientation is $c>a$, elongation *a*, and it conflicts with the morphological orientation $c>a$, elongation *c*, because when the *a* and *c* axes reversed, in accordance with the X-ray results, the morphological orientation becomes $c<a$, elongation *a*. This confused state of affairs is reflected in two recent publications (Gottardi and Galli, 1985; Nawaz, 1988) which expose the conflicting orientations. The present note is written to clear the ambiguity surrounding the elongation question.

Experimental

The study involved determining the morphology and optics of brewsterite and the relation of this morphology to Weissenberg X-ray results. The crystal used for this work was taken from the Ulster Museum specimen BELUM: I1574. A second crystal from the same specimen was used for the determination of accurate cell dimensions on a PV/3 single crystal diffractometer.

Results

The first crystal measured 0.9×1.2×2.0 mm. It had octagonal outline around the longer dimension which was made to rotate for an oscillation and Weissenberg zero and first-level photographs. The photographs showed elongated axis to be 6.8 Å, and the 1.2 mm and 0.9 mm directions to correspond to 17.7 and 7.7Å respectively. These are clearly the *a*, *b* and *c* dimensions of the X-ray unit cell (loc. cit.). The angle β could not be measured as the crystal was mounted along the *a*-axis.

The crystal morphology was deduced by transferring the goniometer head to a spindle stage mounted on the stage of a polarizing stereomicroscope. The crystal clearly contained the three pinacoids (100), (010) and (001) and a dominant, striated clinodome (011), flattened on (001) and tabular on (010), somewhat similar to that in Fig. 1. The measured angles between (001) and (100) and between (001) and (011) were 85.8° and 23.6° respectively.

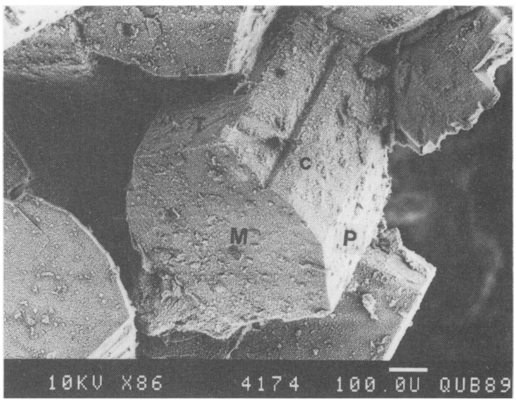

FIG. 1. An *a*-elongated crystal of brewsterite from Strontian showing faces (Brooke's lettering) P(010), T(001), c(011) striated and M(100) (SEM, ×86).

Optically the crystal had a sharp, straight extinction on (001) but an undulose oblique extinction on (010), with a: α variable between 23.0 to 32.3° in the obtuse angle β. The cleavages were (010) perfect and (001) weak. This study confirmed the previous findings of $c>a$ for an elongation.

Precise cell dimensions, measured on a second,

Table 1. Morphological data for brewsterite in chronological order

(1)		(2)		(3)		(4)		(5)		(6)		(7)		(8)	
form	Angle (obs)	form	Angle (obs)	form	Angle (obs)	form	Angle (obs)	form	Angle (obs)	form	Angle (rep)	form	Angle (obs)	form	Angle ǂ (calc)
a	3 30	e		e	3 20*	1/6-i'	4 8*	-		e	4 0	f	3 45	(610)+	3 41
b	29 30	-		-		-		-		-		-		(054)	28 46
c	24 30	m	22 0	M	22 0	I	22 14*	m	22 0	m	22 0	k	23 58#	(011)	23 43
d	22 0	-		-		-		-		-		-		(078	21 2
e	2 0	-		-		-		-		-		-		(0113)	1 56
-		-		-		-		-		-		l	47 47#	(052)	47 41
M		c		P		0		p		c		a		(100)	85 51
P		b		b		i-i'		-		b		b		(010)	90 00
-		-		-		-		-		s (Heddle)		-		(032)	33 23
T		a		a		-		h'		a		c		(001)	0 00
-		t	38 56	t	38 56	-		-		t	39 0	-		(021)	41 18
-		-		-		1-i'(?)	22 40*	-		110⊖	22 45.5	-		(110?)+	21 6.4
-		-		-		-		-		101⊖	44 39.7	-		(101?)+	43 41.5
β	93 40		93 40		93 40		-		93 4		93 40		94 18		94 9
ASB	0.3670		-		0.3495		0.4336		2x0.4409		0.4196		0.3933		0.3860
CSB	0.4557		0.4040		0.4040		0.4091		0.4040		0.4040		0.4446		0.4393
AR	c>a		unknown		c>a		c<a		c<a		c<a		c>a		c>a

Notes:

ASB=a Sin β, CSB=c Sin β respectively calculated from the observed angles for forms (610) and (011) given in columns 1 to 7.
AR = Axial ratio, obs = observed, rep = repeated, calc.= calculated.

* Averaged values, angles in degrees and minutes.
\# Calculated from the observed phi and rho angles.
ǂ Calculated from cell dimensions of this study, Ulster Museum specimen I1574. a=6.806(9), b=17.585(15), c=7.745(8)Å, β = 94.15(10)°, PV/3 diffractometer.
\+ Angles for these forms are between the form and (100), all the others are between the form and (001).
⊖ Dana's a and c axes reversed here.

(1) Brooke (1822).
(2) Phillips's Mineralogy by Brooke and Miller (1852).
(3) Greg and Lettsom (1858).
(4) Mallet (1859).
(5) Michel Levy (1888).
(6) Dana's System of Mineralogy (1892).
(7) Khomyakov et al (1970).
(8) Present study.

smaller crystal, *a* 6.806(9), *b* 17.585(18), *c* 7.745(8)Å, *β* 94.15(10)° compare favourably with those Schlenker *et al.* (1977) obtained from a structure refinement.

Discussion

Since brewsterite is *a*-elongated and has *c*>*a* it remains to deduce when and how the discrepancy crept in. An examination of morphological data of Table 1, which is a compilation of literature work and theoretical calculations, reveals this discrepancy clearly to have arisen after Brooke's publication (1822), for forms *c* (011) and *a* (610) (Table 1, column 1) clearly demonstrate *c*>*a* for *a*-elongation. The subsequent five studies labelled the dominant form *c* (011) of Brooke as a unit prism *m*, *M* or *I* (110). All the five studies give a much lower angle than Brooke's, giving a constant but consistently lower *c* Sin *β*. Similarly they labelled the form *a* (610) of Brooke as the dome *e* or 1/6—*i* (016). Their given or implied angle for this form is variable, being in some cases lower and in others higher than Brooke's. Consequently their *a* Sin B is either higher or lower than that of Brooke (1822) and hence in most cases *c*<*a*, and where it is not, the reason is quite clear (Table 1, columns 2, 3).

It is fair to infer then that the mix-up in the subsequent studies occurred due to inaccurate measurement of interaxial angles for the two crucial forms *a* and *c* of Brooke (1822). The work of Khomyakov *et al.*, 1970 (Table 1, column 7), should have led to a similar conclusion had they compared their morphological data with the literature data.

The main reasons for inaccurate measurements are sectoring and striations. Sectoring occurs on the (010) sections due to differential growth rates of (001) and (100) faces. Horizontal striations occur on (011) and (001) due to alternating growth of the forms (011) and $(0\bar{1}1)$. Vertical striations occur on (100) due to alternating growth of the forms (610) and $(6\bar{1}0)$ (Akizuki, 1987, and pers. comm., 1989).

Some of the forms listed in Table 1, column 8, such as (054), (078) and $(01\underline{13})$, may be vicinal, similar to Akizuki's (1987) form $(0\underline{17}1)$, as they are not parallel to important lattice planes. They rarely accompany the major forms of brewsterite *a*(610), *c*(011), *P*(010), *M*(100) and *T*(001). Forms *l*(052), *s*(032) and *t*(021) are very rare and forms (110) and (101) are doubtful.

Conclusion

In conclusion, Brooke's data are remarkably accurate for their time, although he did not specify the orientation. Subsequent workers assumed *c*-elongation and difficulties and errors in measuring angles on striated faces, some of them vicinal, led them to erroneously conclude $c>a$ for *c*-elongation. When the X-ray results, with $c>a$, elongation *a*, became known a period of uncertainty ensued which hopefully will end with this study.

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References

Akizuki, M. (1987) *Amer. Mineral.* **72**, 645–8.
Brooke,. H. J. (1822) *Edin. Phil. J.* **6**, 112–5.
—— and Miller, W. H. (1852) *Phillips's Mineralogy*. London, p. 442.
Dana, E. S. (1892) *The System Mineralogy*, 6th edn. Kegan Paul, Trench, Truber and Co. Ltd., London, p. 577.
Gottardi, G. and Galli, E. (1985) *Natural Zeolites*. Springer-*Verley*, Berlin, p. 302.
Greg, R. P. and Lettsom, W. G. (1858) *Manual of the Mineralogy of Great Britain and Ireland*, John van Voorst, p. 185.
Khomyakov, A. P., Latayeva, Z. T., Kurova, T. A., Rudnitskaya, E. S. and Smol'yaninova, N. N. (1970) *Dokl. Akad. Nauk. SSSR*, **190**, 1192–5. (in Russian).
Mallet, J. W. (1859) *Phil. Mag.* ser. 4, **18**, 218–20.
Michel-Lévy, A. and Lacroix, A. (1888) *Les Mineraux des Roches*, Paris, p. 301.
Nawaz, R. (1988) *Mineral. Mag.* **52**, 416–7.
Perrotta, A. J. and Smith, J. V. (1964) *Acta Crystallogr.* **17**, 857–62.
Schlenker, J. L., Pluth, J. J. and Smith, J. V. (1977) Ibid. **33**, 2907–10.
Strunz, H. and Tennyson, C. L. (1956) *Neues Jahrb. Mineral., Mh.*, p.1.

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