

3. PHASE TRANSITIONS, TWINNING AND DOMAIN STRUCTURES

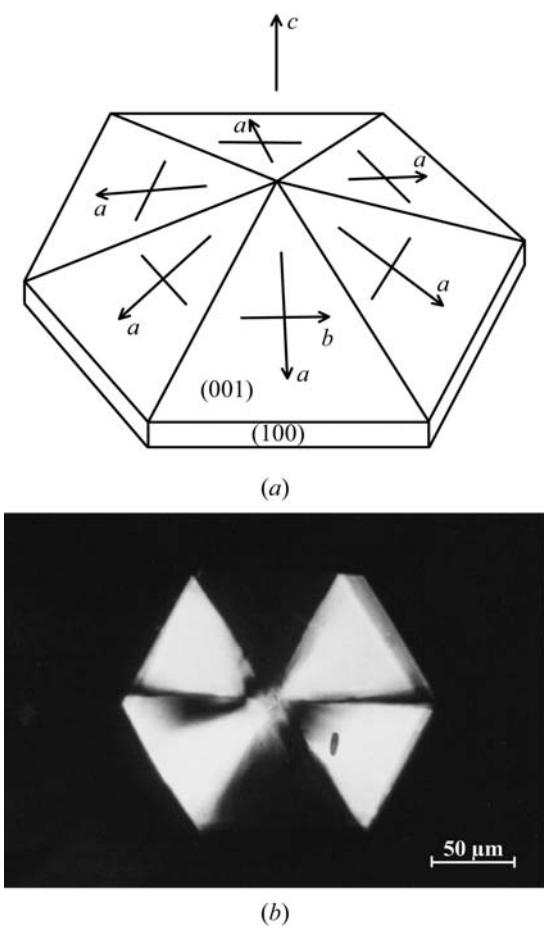


Fig. 3.3.6.10. Sixfold reflection twin of gibbsite, $\text{Al}(\text{OH})_3$, with equivalent (110) and $\bar{(110)}$, both as twin mirror and composition planes. (a) Perspective view of a tabular sixfold sector twin with pseudo-hexagonal twin axis c . In each sector the monoclinic b axis is normal to the twin axis c , whereas the a axis slopes slightly down by about 4.5° ($\beta = 94.5^\circ$), leading to an umbrella-like shape of the twin. (b) Polarization micrograph of a sixfold twinned hexagon (six orientation states) of the shape shown in (a). Pairs of opposite twin components have the same optical extinction position. Courtesy of Ch. Sweegers, PhD thesis, University of Nijmegen, 2001.

(iv) ‘Median law’: According to Brögger (1890), this twin law implies exact parallelism of non-equivalent edges $[110]_I$ and $[010]_{II}$, and *vice versa*, of partners I and II. The twin element is an irrational two-fold axis parallel to (001), bisecting *exactly* the angle between [110] and [010], or alternatively, an irrational twin reflection plane normal to this axis. This interesting orientation relation, which has been observed so far only for gibbsite, does not obey the minimum condition for twinning as set out in Section 3.3.2.2. An alternative interpretation, treating these twins as *rational* [130] rotation twins, is given by Johnsen (1907), cf. Tertsch (1936), pp. 483–484. Interestingly, this strange ‘twin law’ is the most abundant one among natural gibbsite twins.

3.3.6.11. Plagioclase twins

From the point of view of the relationship between pseudosymmetry and twinning, triclinic crystals are of particular interest. Classical mineralogical examples are the plagioclase feldspars with the ‘albite’ and ‘pericline’ twin laws of triclinic (crystal class 1) albite $\text{NaAlSi}_3\text{O}_8$ and anorthite $\text{CaAl}_2\text{Si}_2\text{O}_8$ (also microcline, triclinic KAlSi_3O_8), which all exhibit strong pseudosymmetries to the monoclinic feldspar structure of sanidine. Microcline undergoes a very sluggish monoclinic–triclinic phase transformation involving Si/Al ordering from sanidine to microcline, whereas albite experiences a quick, displacive transformation from monoclinic monalbite to triclinic albite.

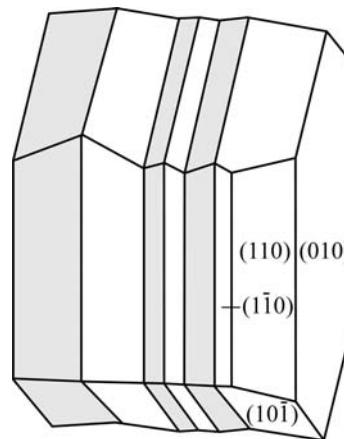


Fig. 3.3.6.11. Polysynthetic albite twin aggregate of triclinic feldspar, twin reflection and composition plane (010).

The composite symmetries of these twins can be formulated as follows:

Albite law: reflection twin on (010); composition plane (010) rational (Fig. 3.3.6.11, Table 3.3.6.5). $\mathcal{K}_A = 2'/m'(1)$ with rational $m' \parallel (010)$.

Pericline law: twofold rotation twin along [010]; composition plane irrational $\parallel [010]$: ‘rhombic section’ (Fig. 3.3.6.12, Table 3.3.6.5). $\mathcal{K}_P = 2'/m'(\bar{1})$ with rational $2' \parallel [010]$.

Both twin laws resemble closely the monoclinic pseudosymmetry $2/m$ in two slightly different but distinct fashions: each twin law \mathcal{K} uses one rational twin element from $2/m$, the other one is irrational. The two frameworks of twin symmetry $2'/m'$ are inclined with respect to each other by about 4° , corresponding to the angle between b (direct lattice) and b^* (reciprocal lattice).

Both twins occur as growth and transformation twins: they appear together in the characteristic lamellar ‘transformation microclines’.

3.3.6.12. Staurolite

The mineral staurolite, approximate formula $\text{Fe}_2\text{Al}_9[\text{O}_6(\text{O},\text{OH})_2](\text{SiO}_4)_4$, has ‘remained an enigma’ (Smith, 1968) to date with respect to the subtle details of symmetry, twinning, structure and chemical composition. A lively account of these problems is provided by Donnay & Donnay (1983). Staurolite is strongly pseudo-orthorhombic, $Ccmm$, and only detailed optical, morphological and X-ray experiments reveal monoclinic symmetry, $C12/m1$, with $a = 7.87$, $b = 16.62$, $c = 5.65 \text{ \AA}$ and $\beta = 90^\circ$ within experimental errors (Hurst *et al.*, 1956; Smith, 1968).

Staurolite exhibits two quite different kinds of twins:

(i) *Twinning by high-order merohedry* (after Friedel, 1926, p. 56) was predicted by Hurst *et al.* (1956) in their detailed study of staurolite twinning. Staurolite crystals are supposed to consist of very fine scale monoclinic ($\mathcal{H} = 12/m1$) microtwins on $m(001)$, which yield a twin aggregate of orthorhombic composite symmetry $\mathcal{K} = 2'/m' 2/m' 2'/m'$. The coset consists of $m'(001)$, $m'(100)$, $2' \parallel [100]$ and $2' \parallel [001]$. Even though this twinning appears highly probable due to the pronounced structural pseudosymmetry (‘high-order merohedry’) of staurolite and has been mentioned by several authors (*e.g.* Smith, 1968), so far it has never been unambiguously proven. In particular, electron-microscopy investigations by Fitzpatrick (1976, quoted in

Table 3.3.6.5. Plagioclase: albite and pericline twins

\mathcal{H}	$k \times \mathcal{H}$ (albite)	$k \times \mathcal{H}$ (pericline)
1	$m \parallel (010)$ rational	$2 \parallel [010]$ rational
$\bar{1}$	$2 \perp (010)$ irrational	$m \perp [010]$ irrational