

graphic analyses. The analyses from Tyndrum show that Cd replaces Zn and Fe in the tetrahedrite structure. There are usually two atoms of divalent elements in the formula; as up to 1.92 atoms of Cd were detected (TY 9XJ, Table II), this suggests the existence of a new variety of tetrahedrite, $\text{Cu}_{10}\text{Cd}_2\text{Sb}_4\text{S}_{13}$. Although the Cd-rich sample contains the inclusions with the highest values of Cd, Ag, and Fe, there is no simple relationship between the Cd content of the inclusions and the other substituting elements.

The Cd-rich inclusions are often very irregular in shape and sometimes resemble tennantite in appearing greenish in colour. The inclusions were rather small for reflectance or cell-size measurements, but this will be undertaken on synthetic equivalents.

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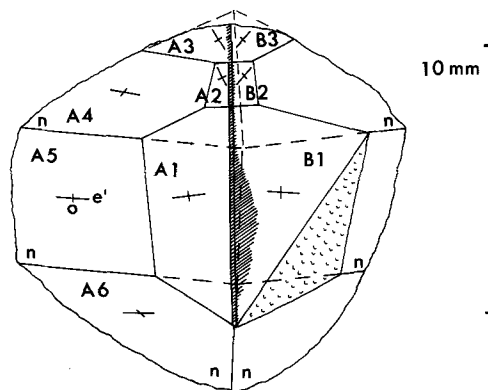
Post-growth readjustment of a cassiterite twin-boundary revealed by cathodoluminescence

A SIMPLE planar contact marking the change in crystallographic orientation of the two members of a cassiterite 'knee twin' (fig. 1) can be seen using reflected-light microscopy (fig. 2, I). However, cathodoluminescence by scanning electron microscopy (fig. 2, II, III, and IV) reveals details of growth

history and provides evidence that the present twin contact must have replaced an original growth-twin contact. The observations leading to this conclusion are outlined below.

Cassiterite, SnO_2 is tetragonal ($a = 4.73 \text{ \AA}$ and $c = 3.18 \text{ \AA}$), has principal refractive indices

FIG. 1. The prepared cassiterite 'knee twin'. Only natural faces (labelled 'n') belonging to the forms $\{100\}$ and $\{110\}$ were represented on the specimen. The two members of the twin have been termed A and B. Three of the natural faces were diamond polished (A4, A5, and A6) and three new faces normal to the (011) twin plane were manufactured by grinding and diamond polishing (A1/B1, A2/B2, and A3/B3). The mottled surface has been ground but not polished. The cross-hatched region represents the palimpsest, which appears dark in simple oblique-incident illumination. The vibration directions of all polished areas are shown. These directions represent extinction positions in reflected-light microscopy. The extraordinary-ray vibration direction is also the trace of the c -axis. This direction is that of the higher refractive index and the higher reflectance. In fact the orientation of polished sections of cassiterite, with respect to the c -axis, can be determined on small areas ($50 \mu\text{m}$) using micro-reflectance measurements and this was undertaken in order to confirm the nature of the twin using the technique outlined by K. von Gehlen (1960).



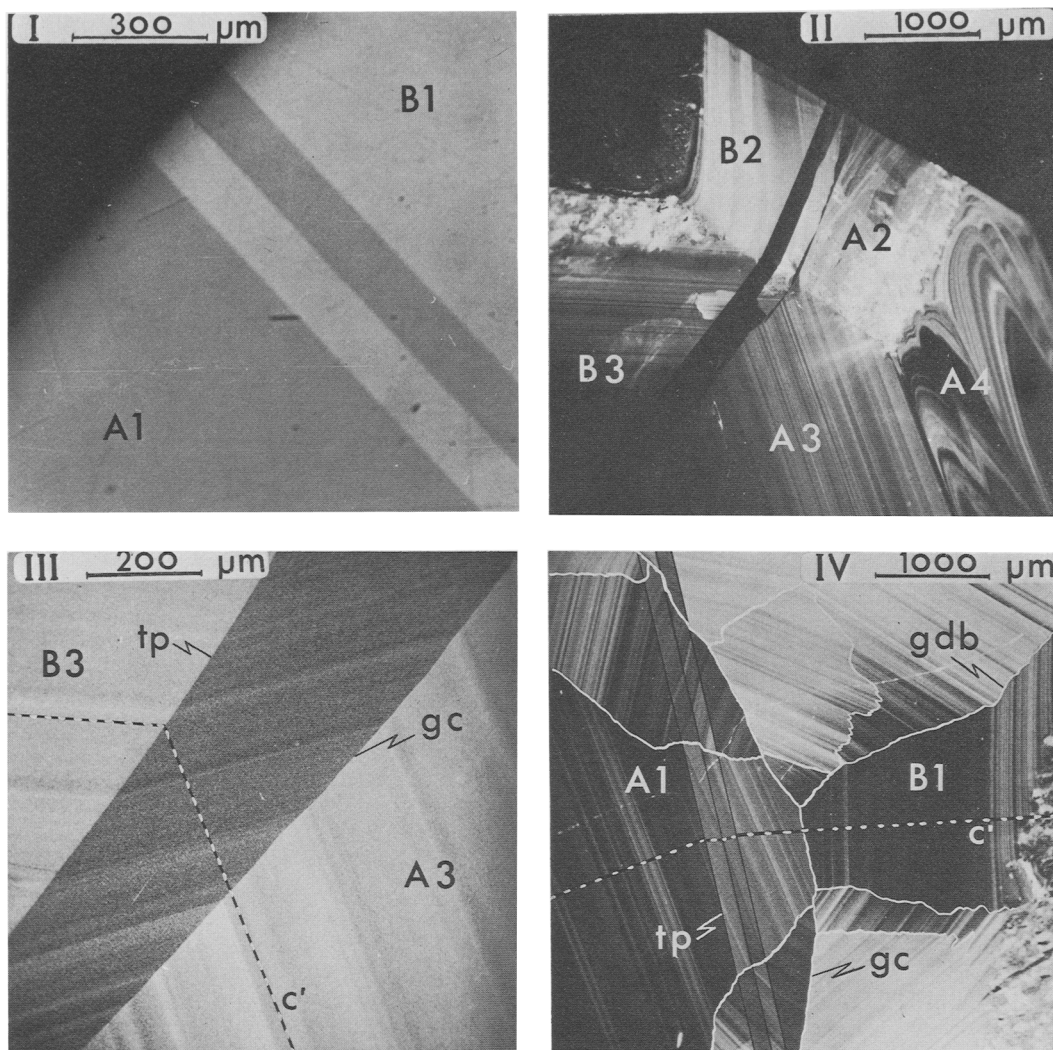


FIG. 2. I. View of the manufactured face A1/B1 in reflected light (crossed polars). The crystallographic boundary consists of three close planes indicating repeated twinning. Note that no growth features are visible. II. View of the specimen using SEM (cathodoluminescence image) showing two manufactured faces (A2/B2 and A3/B3), a polished natural face A4, and an unpolished natural face. The planar growth zones parallel to natural face A4 are seen to have been contoured by polishing and they have been cut by the two manufactured faces resulting in fine banding on areas A2 and A3. The *c*-axis traces of the two members of the twin are parallel to the banding in areas A3 and B3. The palimpsest is marked by a dark band 200 μm wide shown in detail in III. III. View of manufactured face A3/B3 using SEM (cathodoluminescence image). The original growth contact (invisible in reflected light microscopy) appears as an irregular line (gc). Kinking of banding marks the present twin plane (tp). The *c*-axis trace (*c'*) of each member of the twin is shown. Within the palimpsest the *c*-axis trace of twin member A continues at an angle across the banding which originally had the crystallographic orientation of B. IV. View of manufactured face A1/B1 using SEM (cathodoluminescence image). The growth zones of many natural faces have been intersected resulting in 'growth domains'. The growth domains are identified as being areas containing parallel banding. The irregular growth domain boundaries (gdb) have been enhanced for clarity. The change in width of bands across domain boundaries is due to the different growth rate of faces and the different angle of intersection of the zones with the polished surface. The original growth contact (gc) of the 'knee twin' is an irregular line convex towards B1. The present twin boundary consisting of three twin-planes (tp) is marked by three lines of kinking of banding (enhanced for clarity) running across several growth domains and across the growth-twin contact at the top of IV. The *c*-axis traces (*c'*) of each member of the twin run normal to the growth zones of their (100) faces. Within the palimpsest the *c*-axis trace of B runs at an angle across the (100) zones which originally had the crystallographic orientation of member A.

$\omega \approx 1.995$ and $\varepsilon \approx 2.095$, and commonly twins on $\{011\}$ to produce 'knee twins' (Deer *et al.*, 1963).

Cathodoluminescence is known to reveal a wealth of detail invisible in ordinary microscopy (e.g. Smith and Stenstrom, 1965). Fine banding seen in cassiterite is due to zonation of crystal defects or trace element impurities, or both (Rémond *et al.*, 1970).

The following sequence of events in the growth history of a cassiterite 'knee twin' has been established in the present study:

Nucleation of the cassiterite crystal.

Early nucleation of the 'knee twin'.

Growth of the twin into a macroscopic specimen. The two twin members grew at a similar rate. They had a definite crystallographic relationship to each other expressed by the $\{101\}$ twin law along an irregular non-planar contact.

The irregular growth contact of the 'knee twin' was an unstable crystallographic contact, and a planar crystallographic contact formed close to the growth contact. The switching of crystallographic orientation produced a palimpsest in the part of the crystal between the growth contact and the new planar crystallographic contact. This involved kinking of growth zones along the new planar

crystallographic contact. Kinking took place along one plane through part of the specimen and along three parallel planes through the rest of the specimen. Thus polished manufactured faces show either simple or repeated twinning.

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Occurrence of thaumasite in weathered furnace slag, Merthyr Tydfil

THAUMASITE, a hydrated calcium silicate with the general formula $[\text{Ca}_3\text{Si}(\text{OH})_6(\text{H}_2\text{O})_{12}] (\text{SO}_4)(\text{CO}_3)$, has a structure consisting of columns of empirical composition $[\text{CaSi}(\text{OH})_6(\text{H}_2\text{O})_{12}]^{4+}$ aligned parallel to c with CO_3^{2-} and SO_4^{2-} groups located between them (Edge and Taylor, 1971). The most interesting structural feature is the six-fold coordination of silicon—an arrangement usually associated with formation at high temperatures and pressures, as in the SiO_2 polymorph stishovite. However, it seems certain that this is not the case with thaumasite. Most findings of the mineral are in altered basic igneous rocks (e.g. Medici, 1972; Brown, 1973; Paulitsch, 1973) or altered limestones (Carpenter, 1963; Stephens and Bray, 1973). To the writer's know-

ledge, the only reported occurrences of thaumasite in Britain are from a borehole in Co. Down, Northern Ireland, where it occurs coating fracture surfaces in a dolerite sill (Knill, 1960), and in a vein transecting a quartz-dolerite sill exposed in a quarry near Cockermonth, Cumberland (Embrey—see Knill, 1960).

The present note records the occurrence of thaumasite in abundant quantity in weathered furnace slag heaps derived from the now disused Dowlais and Cyfartha Iron Works in the vicinity of Merthyr Tydfil, South Wales. The Dowlais slag heap forms a conspicuous feature, locally known as the 'White Tip', and the thaumasitic slag was collected on the north side of the A4060 road between Pentrebach and Dowlais Top, about 600 m