SHORT COMMUNICATIONS

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Hornblende twinning on (ī01) in an amphibolite from Barra, Outer Hebrides, Scotland

THIN sections of a well-exposed late Lewisian intrusion on the shore of the Isle of Barra, east of Lochan nam Faoileann, have been examined. The rock has a high-temperature amphibolite facies assemblage of andesine ($An_{47\pm3}$), tschermakitic hornblende, diopsidic pyroxene (sahlite), and quartz. Several hornblende crystals of sample 18.2, with their *b* axes oriented almost perpendicular to the plane of the thin section, exhibit very fine lamellae, recognizable by their slightly different extinction position, making an angle of about 75° with the {110} cleavages of the host crystals. Examination of the amphiboles at higher magnification (500 ×) reveals that the cleavages do not cut through the crystals entirely in straight planes but are deflected at the host-lamellae boundary by 30–2° (fig. 1), which suggests that the lamellae are parallel to (001) (*I*2/*m* space group) and were mechanically twinned. Tröger (1969) mentioned a rare twinning on (001) in hornblende caused by shear.

Buck and Paulitsch (1969), Rooney *et al.* (1970), Buck (1970), and Rooney *et al.* (1975) carried out deformation experiments on hornblende single crystals. According to Rooney *et al.* (1970, 1975), (ī01) twinning (*C*2/*m* space group) occurs at confining pressures from 5 kb to 20 kb at temperatures below 800 °C and [001] as the only possible compression direction. Buck (1970) observed twinning at pressures from 10 kb to 20 kb at room temperature and compression directions parallel to (*oko*).

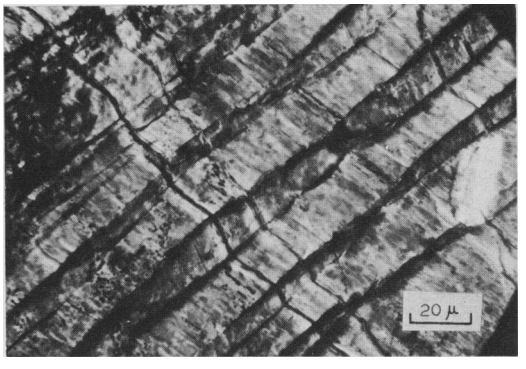


FIG. 1. Strongly magnified amphibole with twin lamellae on (ī01) showing the deflection of cleavages at the host-lamellae boundary.

Temperatures and pressures exceeding 800 °C and 20 kb respectively effect dehydration and break-up of the SiO_4 ribbons parallel to [001] and twinning does not appear beyond these conditions.

The (ī01) deformation-twinning mechanism obeys the laws of simple shear (Johnsen, 1913), and the twin elements for hornblende in the *C*2/*m* space group are $K_1 = (\bar{1}01)$ (glide plane), $\eta_1 = [\bar{1}0\bar{1}]$ (glide direction), and S = (010) (shear plane). The shear strain *s* and 2φ, the angle between the two undistorted sections K_1 and K_2 of the strain ellipsoid, can be calculated from the known cell parameters. The mathematical relations are stated below, and fig. 2 shows a projection of the host and twin cell and strain ellipsoid on to the (010) plane.

$\vec{r}_c = (\sin\varphi, \cos\varphi)\,|\vec{r}_c| = c = 1$ is the radius vector of the undistorted circle section

$\cos\alpha = (a + c\cos\beta)/(c^2 + a^2 + 2ac\cos\beta)$.

$s(\alpha,\beta) = \sin(180° - 2\beta + 2\alpha)/\sin(\beta - \alpha)$ is the shear strain.

$\vec{s} = (-s\cos\varepsilon, -s\sin\varepsilon)$ is the maximum displacement vector at unit distance from the composition plane (ī01).

$z(\varphi) = \cos\varphi + tan\,\varepsilon\sin\varphi$ is the proportionality factor relating the net displacement and the distance from the composition plane.

$\vec{d} = \vec{s}.z(\varphi)$ is the displacement vector parallel to $[\bar{1}0\bar{1}]$.

$\vec{r}_e(\varphi) = \vec{r}_c(\varphi) + \vec{s}.z(\varphi)$ is the ellipse vector of the projection of the strain ellipsoid on to (010).

The principal axes of the strain ellipsoid can be derived from solving the equation $d\vec{r}_e(\varphi)/d\varphi = 0$.

In the present study it was not possible to give direct optical evidence for a twinning on (ī01) from universal stage measurements, apart from the conspicuous deflection of {110} cleavages across the

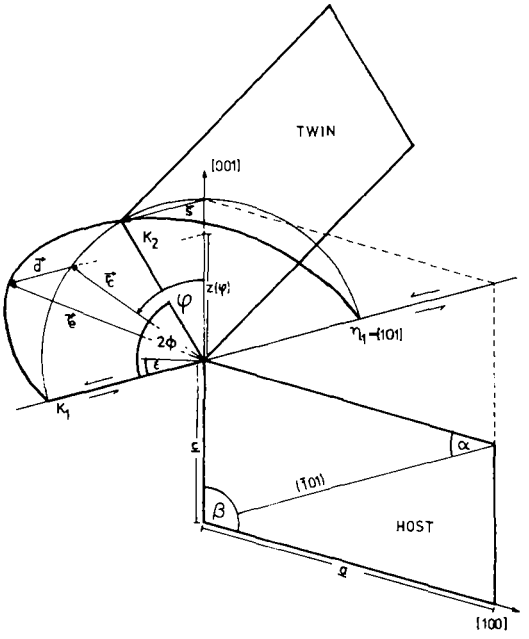
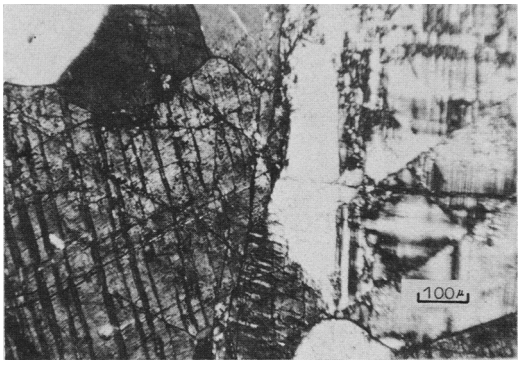


FIG. 2. Projection of the host and twin cell and strain ellipsoid on to (010).

twin lamellae. The extinction angle γ:[001] for the hornblende is almost 16° and in this particular case γ (host) and γ' (twin) coincide. However, a tectonically cracked plagioclase, next to a twinned amphibole (fig. 3), furnished an indirect but nevertheless conclusive way to ascertain ($\bar{1}$01) twinning. From its conjugate pair of rupture planes, assumed to be parallel to the undistorted sections of a strain ellipsoid, the direction of maximum stress was constructed, which should be parallel to the *c* axis direction of the amphibole or, at least, lie within the (0*k*0) plane, according to the experimental results. For brittle substances the direction of maximum stress bisects the acute angle at which the non-distortion planes of a stress ellipsoid intersect (Hills, 1953). The stereographic projection in fig. 3 shows that, after making reasonable allowances for uncertainties in measuring the angular coordinates, the *c* axis and the direction of σ_1 actually coincide.

The sample came from fairly near the Hebridean Thrust. Obviously these tectonic movements caused the formation of pseudotachylite, which can also be observed in the thin section, and the deformation of plagioclase and hornblende. With due consideration to the experimental data, the deformation features, especially the twinning, may be useful for the reconstruction of the *PT* conditions and the stress field prevailing at the time of thrusting.



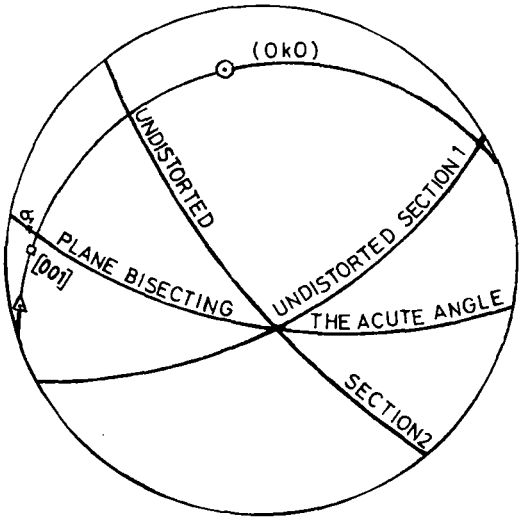


FIG. 3. Tectonically deformed plagioclase and amphibole (above), stereographic projection showing α and γ for the amphibole, and the traces of the conjugate rupture planes of the plagioclase with derived elements [001] and σ_1 (below).

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