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Oblique girdle orientation patterns of quartz C-axes from a shear zone in the basement core of the Maggia Nappe Ticino, Switzerland

CAROL SIMPSON

Geologisches Institut, ETH Zentrum, CH8092, Zürich, Switzerland

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Abstract—In the granitic basement of the Maggia Nappe, a pre-existing quartz *C*-axis fabric has been modified by later shearing. The progressive changes in the preferred orientation patterns of quartz across one boundary of a shear zone are described. A single girdle fabric is developed and a reference framework to specify the 'obliquity' of such fabrics with respect to the major axes of the finite strain ellipsoid, is introduced.

INTRODUCTION

THE HERCYNIAN basement core of the Maggia Nappe (Ticino, Switzerland) comprises granitic and dioritic rocks, augen gneisses and compositionally banded gneisses. A strong linear fabric is pervasive throughout the granitic rocks and is deformed by shear zones, thought to be of Alpine age, which vary in width from 5 cm to 1 km. The petrography of the area has been described by Günthert (1954, 1976) and some of the shear zones have been described by Ramsay & Graham (1970) and Allison (1974). Results of a study of the progressive changes in the preferred orientation patterns of quartz *C*-axes are presented for a series of specimens taken across one boundary of a 10 m-wide sinistral shear zone in the granitic gneiss. The shear zone selected here has remained unaffected by the later folding and crenulation events in the Maggia region. However, the rocks have suffered some post-tectonic recrystallization during the lower amphibolite facies Lepontine metamorphism (approx. Eocene – Oligocene boundary), so that in this particular shear zone almost no optical strain features are visible in the quartz grains.

ANALYTICAL PROCEDURES

Carefully orientated thin sections from each sample were cut perpendicular to both the lineation and to the foliation where present. Each thin section was stained for potassium and plagioclase feldspars using the method of Ruperto *et al.* (1964), modified by Starkey & Cutforth (1978), in order to ensure that no quartz grains were overlooked. The orientation of quartz *C*-axes was measured optically using a universal stage and plotted onto lower hemisphere equal area projections. Contouring of the data was carried out using a computer programme which uses a small circle counter with an area of $100/n\%$ of the area of the projection (where $n =$ the number of data points) to produce diagrams in which the areas occupied by different concentrations are independent of sample size (Starkey 1977).

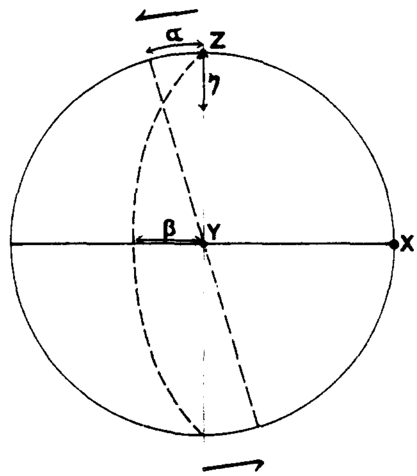

Fig. 1. The three angles α, β and η, required to exactly define single girdle fabric diagrams with respect to the *XYZ* reference framework of the finite strain ellipsoid. See text for details.

The 'obliquity' of girdle fabric diagrams

A complete description of the observed girdle patterns requires three angles to define the orientation of the great circle drawn through the girdle, with respect to the *XYZ* axes of the finite strain ellipsoid (Fig. 1).

(i) The angle α is measured between the foliation normal (Z) and the intersection of the great circle with the XZ plane. The sense of α must be specified relative to the sense of shear in the sample. This is the angle used by some workers, for example Laurent & Etchecopar (1976) and Burg & Laurent (1978), to describe the 'obliquity' of their fabric diagrams.

(ii) The angle β, between the Y axis of the finite strain ellipsoid and the great circle, is measured in the XY plane. When the great circle coincides with the ZY plane, then both α and β are zero.

(iii) The angle η, between maxima contained in the great circle and the foliation normal (Z), is measured in the ZY plane. η is zero when a point maximum lies on the XY plane.

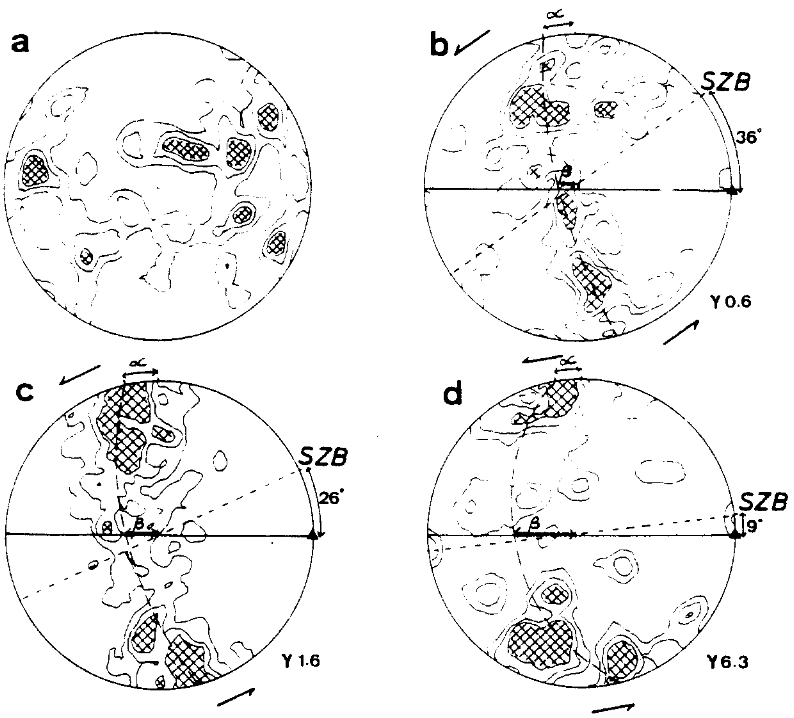

Fig. 4. Lower hemisphere equal area projections of quartz *C*-axes. Foliation E–W vertical, lineation E–W horizontal (solid triangle). SZB = shear zone boundary plane. (a) Outside shear zone deformation, 151 data, contours 1, 2, 3 points per 0.7% area, (b) at shear zone boundary, 137 data, contours at 1, 2, 3 points per 0.7% area, (c) from 5 cm inside shear zone, 675 data, contours 1, 2, 3 points per 0.1% area, (d) centre of shear zone, 122 data, contours 1, 2, 3 points per 0.8% area.

OPTICAL MICROSTRUCTURES

Outside the shear zone the granitic gneiss has a linear fabric, defined by elongated polycrystalline aggregates of quartz, oligoclase/K-feldspar, biotite and occasional muscovite; very rarely, deformation bands are visible in the quartz grains (Fig. 2). Foliation is generally absent or at best extremely weakly developed. At the shear zone boundary, i.e. the position in the rock where an obvious foliation is first visible, the previously elongated aggregates become more platy in appearance and a new foliation is defined by these platy aggregates together with the alignment of biotite flakes. Within the central part of the shear zone the rock is very finely banded with foliation planes defined by biotite flakes. Over 98% of the quartz occurs in very elongated lenses and ribbons, set in a matrix of fine grained oligoclase, K-feldspar, epidote and muscovite, with larger grains of biotite (Fig. 3). Small quartz grains around the margins of larger ones display only very slight variations in crystallographic orientation with respect to their host, which suggests that the small grains were formed syntectonically by progressive disorientation of subgrains (Poirier & Nicolas 1975). Unfortunately, post-tectonic recrystallization has removed almost all optical strain features from these rocks; deformation lamellae have not been found and quartz grains only very occasionally show the presence of deformation bands.

THE QUARTZ PETROFABRIC DIAGRAMS

In specimen A, from well outside the shear zone, the pre-shearing quartz *C*-axis fabric comprises a number of point maxima which tend towards a small circle distribution about the lineation (Fig. 4a). This fabric pattern has been reproduced from a number of unsheared specimens of granitic gneiss in the area. In specimen B, taken at the shear zone boundary, the quartz *C*-axes fall on a poorly defined great circle which is oblique to the foliation normal by an angle $\alpha = 10°$ in a sinistral sense, which is the same as the sense of shear for the zone (Fig. 4b). The angle $\beta = 10°$ (approx.) and within the great circle the two strongest maxima lie at about $\eta = 45°$.

The quartz *C*-axes in specimen C, from 5 cm within the shear zone, form a strong great circle pattern which is oblique to Z by $\alpha = 15°$, also in a sinistral sense (Fig. 4c). The angle β is approximately 20° and the maximum concentration of *C*-axes spreads up to 45° on either side of the foliation normal.

Within the central part of the shear zone, the quartz *C*-axes show a very weak girdle distribution so that angular relationships are difficult to measure exactly (Fig. 4d). However, the angle α does not differ significantly from that found in specimens B and C whereas the angle β has increased considerably to approximately 40° and there is a tendency for the *C*-axes to form a broad maximum at $\eta = 25°$. Similar fabric patterns have been found for the central parts of several shear zones in the area; with increasing shear strain both a decrease in the angle η and a more diffuse distribution pattern occur.

CONCLUDING REMARKS

In the granitic basement rock of the Maggia Nappe core, the pre-shearing quartz *C*-axis fabric tends towards a small circle distribution about the lineation.

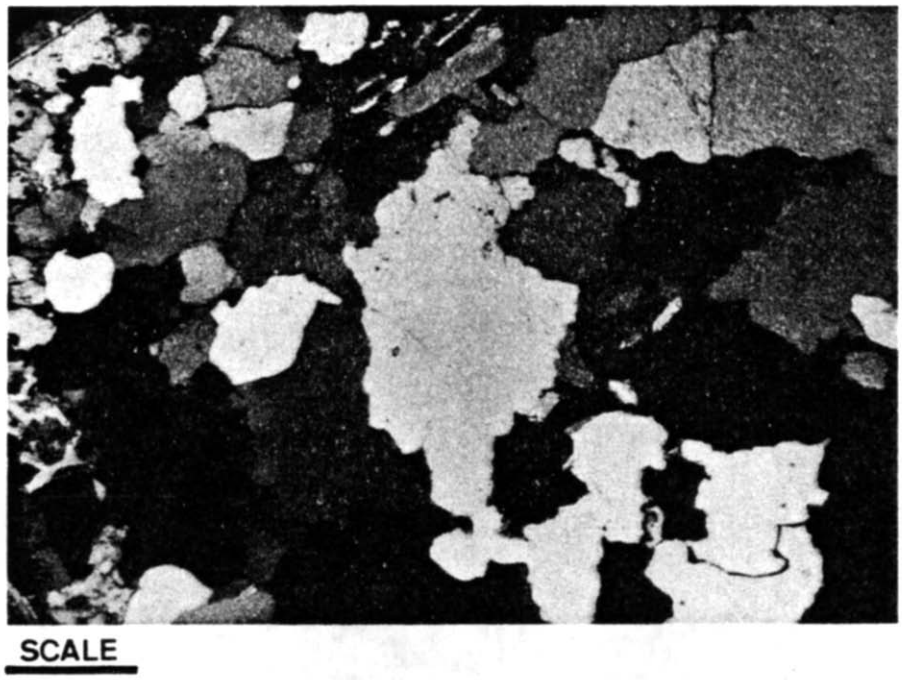

Fig. 2. Photomicrograph of part of an aggregate of quartz grains, taken from the unsheared gneiss (specimen A). The majority of the grains are strain free but very occasionally, deformation bands are visible (bottom left). Scale bar 0.5 mm.

Fig. 3. Photomicrograph of specimen D, taken from the central part of the shear zone; a portion of an elongated lens of quartz grains (strain-free, due to post-tectonic recrystallization), set in a matrix of biotite and oligoclase. Q = quartz, B = biotite. Scale bar 0.5 mm.

Within the shear zone this fabric is modified into a great circle distribution, which is asymmetric to both the stretching lineation and the foliation in the shear zone. Despite the removal of optical strain features from the quartz grains during post-tectonic recrystallization, the *C*-axis preferred orientation patterns have been preserved. This is in agreement with the findings of Phillips (1945), who comments on "... the readiness with which quartz suffers *recrystallization* and the reluctance which it shows to undergo *reorientation*".

A great circle pattern first develops in the shear zone boundary region, at a shear strain of 0.65. The girdle distribution lies at $\alpha = 10°$ to the ZY plane of the finite strain ellipsoid, with maxima at approximately 45° to Z. With increasing shear strain, i.e. with increasing development and rotation of the new foliation to approach the orientation of the shear zone boundary plane, α remains essentially constant at 10°–15°. At the same time, β increases from 10° in the shear zone boundary region, to 40° in the central part of the shear zone, the girdle pattern becomes less well defined and the angle η is reduced, i.e. the maxima move towards Z. This final quartz *C*-axis pattern developed in the central part of the shear zone comprises a very weak great circle distribution, in which the position of a broad maximum close to Z may be the most important feature. The observed increase in β and decrease in η into the shear zone, together with the spreading or weakening of the girdle distribution, is possibly related to the increase in shear strain.

A single great circle distribution of quartz *C*-axes within a shear zone has also been described by Laurent & Etchecopar (1976) and Burg & Laurent (1978). The results presented here support their findings that the rotation of the girdle is sympathetic to the sense of shear, but there is no direct relationship between the value of α and the angle between the foliation and the shear boundary plane in the Maggia shear zone. Hence it appears that α is only of importance in defining the sense of shear and cannot be used to estimate the shear strain.

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