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Quartz CPO in a polymineralic ultramylonite

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Polymineralic ultramylonites often show microstructures indicative of diffusion creep. Disintegration of monomineralic aggregates and phase mixing inhibits dislocation creep of single phases. Grain boundary sliding can lead to rigid body rotation of individual grains and low differential stresses prevent dislocation glide to occur at a significant rate. Thus, grain boundary sliding and low differential stresses usually preclude the presence of a strong crystallographic preferred orientation (CPO).

The Truzzo granite in the Central Alps (Italy) hosts ultramylonitic shear zones which formed under amphibolite facies conditions. At high strain quartz aggregates with a preexisting CPO disintegrate and form a grain-scale phase mixture together with oligoclase, biotite and K-feldspar.

Within the ultramylonite quartz CPOs are very weak but distinct from random. Shape and size dependent CPOs and CPO-dependent shapes have been analyzed by means of computer integrated polarization microscopy, EBSD and image analysis techniques. In partially mixed layers, larger grains (> 50 μm), which are more elongated (axial ratio > 0.5) and have a small angle between the grain long axis and the lineation, show a preferred c-axis orientation close to the lineation. This is usually interpreted to result from prism [c] slip.
Smaller grains (< 50 μm) with more equant shapes show a peripheral c-axis orientation at a high angle to the lineation, inclined against the sense of shear. At the highest degree of phase mixing, only a peripheral c-axis maximum is observed, which is inclined against the sense of shear. This CPO type is different from what would typically occur in monomineralic quartz aggregates, which are deformed by dominant simple shear.
Larger grains (> 50 μm) contain abundant low angle boundaries. Analysis of the intragranular crystallographic misorientation indicates that at least some low angle boundaries can be attributed to subgrain boundaries related to the basal <a> or prism [c] slip system with edge dislocations forming tilt walls.

The presented data indicates that certain phases can still undergo dislocation glide during diffusion creep of a polymineralic rock within a grain-scale phase mixture. The data is incompatible with dissolution-precipitation creep of quartz as suggested in the literature for low grade conditions (e.g. Hippert 1994). The activity of prism [c] slip is probably related to the earliest high temperature initiation of shear zones. However, the metamorphic assemblage does not record a temperature drop or earlier high temperature relics.

We propose that the development of the dominant but weak CPO type forms by a combination of basal <a> slip and grain-scale strain partitioning. Quartz grains behave as higher viscous particles and therefore some grains experience internal back-rotation of the c-axis into the shortening field as expected for pure shear flow.

References:

Hippertt, J., 1994. Microstructures and c-axis fabrics indicative of quartz dissolution in sheared quartzites and phyllonites. Tectonophysics 229 (3-4), 141-163.