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Quartz deformation mechanism during the transition from polyphase to monophase rheology

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We have studied the microstructural and textural transition of a shear zone in metagranodiorite deformed under lower amphibolite facies conditions in the Gran Paradiso nappe (Western Alps).

Three microstructurally different parts are defined: a polyphase mylonitic outer part, a transition zone and a homogeneous mylonitic center (ultramylonite). The average quartz content (30%) remains constant in all parts. In the coarse aggregates, quartz textures are measured using the CIP method (Panozzo Heilbronner & Pauli, 1993). EBSD is used for the analysis of the fine grained phase mixtures.

In the mylonitic outer part of the shear zone, layers of recrystallized quartz behave as the mechanically stronger phase in a fine grained matrix (approx. 5-20 μm) of biotite and decomposed plagioclase grains. Quartz deforms by dislocation creep. Recovery is dominated by grain boundary migration recrystallization and minor subgrain rotation. Quartz c-axis crystallographic preferred orientations (CPO) typically show synthetically rotated peripheral maxima and - occasionally - weak single girdles suggesting basal <a> and only minor prism <a> slip. The texture is consistent with a moderate asymmetric shape preferred orientation (SPO).

We have calculated strain rates for the quartz aggregates and the bulk sample using recrystallized grain size piezometry and quartz flow laws. For 70% matrix content strain rates are 2 to 5 times lower in the quartz aggregates than in the matrix.

The ultramylonitic center of the shear zone consists of a homogeneous phase distribution. Here quartz occurs as isolated grains dispersed in the matrix and is of the same size as the other phases. Minor compositional layering is defined by K-feldspar, biotite and plagioclase content. The quartz texture is very weak and largely below the bias of the EBSD. The SPO of single dispersed grains is symmetric and shows a slight stretching in the foliation plane.

In the transition zone between the mylonite and the ultramylonite the phases are increasingly mixed. Quartz aggregates are boudinaged at the grain scale with primarily K-feldspar precipitating between separated quartz grains. No fractures are observed within quartz grains. Subgrain structures of the grain size in the ultramylonite are almost absent.
Average quartz grain size decreases from 60-80 μm in mylonite to smaller than 40 μm in the ultramylonite. Texture intensity decreases and a relict CPO of the mylonite is formed by larger grains that are not sufficiently separated to rotate independently.

The initial disruption process is interpreted to be a consequence of the inability of the increasingly thinned quartz layers to accommodate strain. As grains separate along (sub-)grain boundaries (cavitation) grain size decreases although there is no evidence for fracturing. We suggest that therefore this process is accompanied by quartz dissolution along grain boundaries and precipitation of K-feldspar.

Further phase distribution, randomization of the CPO and grain size reduction in the ultramylonite is a result of dissolution-precipitation accommodated granular flow.

Extrapolating from the matrix strain rate determined in the mylonite (mechanical biphase) a lower bound for the strain rate in the ultramylonite (mechanical monophase) can be estimated even though no proper flow law is available.

References:
Panozzo Heilbronner, R. and Pauli, C., 1993. Integrated spatial and orientation analysis of quartz c-axes by computer-aided microscopy. J. Struct. Geol., 15 (3-5): 369-382.