Geophysical Research Abstracts
Vol. 17, EGU2015-5512, 2015
EGU General Assembly 2015

Brittle-viscous deformation of vein quartz under fluid-rich low greenschist facies conditions

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A coarse grained, statically crystallized quartz vein with a random CPO, embedded in a phyllonitic matrix, was studied by optical microscopy, SEM imaging and EBSD to gain insights into the processes of strain localization in quartz deformed under low greenschist facies conditions at the frictional-viscous transition. The vein is located in a high strain zone at the front of an imbricate stack of Caledonian age along the northwesternmost edge of the Repparfjord Tectonic Window in northern Norway. The vein was deformed within the Nussirjavrri Fault Zone (NFZ), an out-of-sequence thrust with a phyllonitic core characterized by a ramp-flat-ramp geometry, NNW plunging stretching lineations and top-to-the SSE thrusting kinematics. Deformation conditions are typical of the frictional-viscous transition. The phyllonitic core formed at the expense of metabasalt wherein feldspar broke down to form interconnected layers of fine, synkinematic phyllosilicates. In the mechanically weak framework of the phyllonite, the studied quartz vein acted as a relatively rigid body deforming mainly by coaxial strain.

Viscous deformation, related to the development of a mesoscopic pervasive extensional crenulation cleavage, was accommodated within the vein initially by basal <a> slip of suitably oriented quartz crystals, which produced e.g. undulose extinction, extinction bands and bulging grain boundaries. In the case of misoriented quartz crystals, however, glide-accommodated dislocation creep resulted soon inefficient and led to localized dislocation tangling and strain hardening. In response to 1) hardening, 2) progressive increase of fluid pressure within the actively deforming vein and 3) increasing competence contrast between the vein and the surrounding weak, foliated phyllonitic fault core, quartz crystals began to deform frictionally along specific lattice planes oriented optimally with respect to the imposed stress field. Microfaulting generated small volumes of gouge along intracrystalline microfractures. These fractures were rapidly sealed by nucleation of new grains as transiently over-pressured fluids flushed the deforming system. The new nucleated grains grew initially by solution-precipitation and later by grain boundary migration. They are relatively strain free and show a scattered CPO in resemblance with the host grain, although there is a slight synthetic rotation of the crystallographic axes.

Due to the random initial orientation of the vein crystals, strain was thus accommodated differently in the individual crystals, leading to the development of remarkably different microstructures. Crystals oriented optimally for basal slip accommodated strain mainly in a viscous fashion and experienced only minor to no fracturing. Instead, crystals misoriented for basal slip hardened and deformed by pervasive fracturing promoted by the fluid over-pressure and controlled by the orientation of crystallographic planes. Viscous deformation continued after the microfractures sealed, again increasing the fluid pressure. This study indicates the importance of considering shear zones as dynamic systems wherein the activated deformation mechanisms vary transiently in response to the complex temporal and spatial evolution of the shear zone, often in a cyclic fashion.