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Coesite as stress indicator in experimentally deformed quartz gouge

Bettina Richter (1), Holger Stünitz (2), and Reneé Heilbronner (1)

(1) Basel University, Geological Institute, Department of Environmental Sciences, Basel, Switzerland (bettina.richter@unibas.ch), (2) Tromsø University, Department of Geology, Tromsø, Norway

In shearing experiments conducted to study the behaviour of quartz gouge at the brittle - viscous transition, coesite was found in samples that were deformed at confining pressures of 1.0 GPa or 1.5 GPa, at temperatures between 600°C and 800°C, and at constant displacement rates of $\sim$1.3 x 10^{-5} mms^{-1} or $\sim$1.3 x 10^{-4} mms^{-1}. The experiments were performed in a Griggs type deformation apparatus and the starting material was obtained from a hydrothermally grown single crystal. The crystal was crushed and sieved to a grain size < 100 μm. 0.1 g of the powder, with 0.2 wt% water added, was introduced in a 45° pre-cut between alumina forcing blocks forming a $\sim$1 mm thick shear zone.

In all experiments, the confining pressures $(\sigma_3)$and the peak mean stresses (1/3 $(\sigma_1 + \sigma_2 + \sigma_3)$ for the general case or 1/2 $(\sigma_1 + \sigma_3)$ for $\sigma_3 = \sigma_2)$ remained below the quartz - coesite transition. Only the highest principal stresses (σ_1) reach the coesite stability field. With the exception of low-temperature experiments, the occurrence of coesite coincides with whether or not σ_1 reached the coesite stability field. In samples deformed at 600^{o}C coesite did not form despite the fact that σ_1 reached the coesite field, indicating some temperature effect for the transformation kinetics.

In two samples, σ_1 crosses the quartz-coesite phase transition and stays in the coesite field at the beginning of the shearing deformation and - with ongoing weakening - crosses back into the quartz stability field at higher strains. As expected, the reverse phase transformation, from coesite to quartz, can be observed in these samples.

Coesite forms as soon as σ_1 comes very close to or enters the coesite stability field. Clusters of small idiomorphic tabular coesite crystals are distributed throughout the sample and are commonly aligned with the [010] direction parallel to the σ_1 direction. With increasing deformation in the coesite stability field, coesite grains grow (forming up to 2 vol %) and the [010] directions rotate into parallelism with the foliation (rigid particle behaviour).

Once σ_1 drops below the phase transition, the coesite grains are corroded, indicating a back-transformation to quartz. A preferred growth direction of the new quartz grains with respect to the old coesite grains is not obvious but the replacing quartz grains show a constant crystallographic orientation (single crystal orientation).

In conclusion, in deformation experiments, the coesite formation seems to only depend on the maximum compressive stress σ_1 rather than on the confining pressure or the mean stress. σ_1 controls the quartz-to-coesite transformation as well as the reverse transformation except where low temperatures slow down the transformation kinetics. Furthermore, the accuracy of σ_1 values measured with solid medium deformation apparatus lies within the same error range as that of the quartz-coesite phase transitions determined with the piston cylinder apparatus.