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Microstructural development of quartz gouge at the brittle-to-viscous-transition in shear experiments

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We conducted a series of shear experiments on quartz gouge in a Griggs-type solid medium deformation apparatus to investigate the brittle-viscous transition. The starting material is obtained by crushing quartz single crystals (sieved grain size <100 μm) with 0.2 wt% water added. The powder is introduced in a 45° pre-cut in Al forcing blocks forming a ~1 mm thick zone. Samples were deformed at confining pressures of 0.5 GPa, 1.0 GPa or 1.5 GPa, at temperatures between 500°C and 1000°C, and at constant shear strain rates of $\sim$2.5 x 10^{-5} s^{-1}.

At high confining pressures, the strength of the samples decreases with increasing temperature while at high temperatures, it decreases with increasing confining pressure. At high pressure and temperature, continued deformation occurs at a constant flow stress whereas at lower temperature, experiments show strain hardening. The stress-strain curves of two experiments performed at lower confining pressures and high temperature display a peak strength followed by minor weakening.

At intermediate shear strain the c-axis pole figures show a random distribution at low temperatures and/or low confining pressures, an incomplete girdle at intermediate temperatures and a single y-maximum at high temperatures.

At low temperatures or low confining pressures, cataclastic flow is the dominant deformation mechanism. Deformation can be localised in R1-riedel shear orientated slip zones independent of the shear strain. An S-C' fabric is developed at 700°C/1.5 GPa and intermediate shear strain. At high shear strain most of the sample is recrystallised but several large clasts still exist. With increasing temperature the number of remaining clasts is reduced and recrystallisation is nearly complete.

A sample (500°C/1.5 GPa) was loaded to ~2.6 GPa differential stress, i.e., peak strength was not reached, the sample was still hardening, no significant shear deformation had occurred. Several 5-10 μm wide slip zones with small displacement cut the sample. They are filled with cataclastic material. At one interface between these fragments and the un-fragmented region next to these zones a highly localised band with bubble-like structures can be observed. This band is marked by slightly lower backscatter contrast and some of the bubbles are elongated in the shear direction. Similar structures have been identified in experimental studies on granitoid gouge as (partly) amorphous material (Pec et al. 2012a, 2012b). In some places the band is reworked by the ongoing comminution in the slip zones.

The transition from brittle to viscous dominated deformation processes is illustrated by the inverse pressure dependence at higher temperature. At higher confining pressures crystal plastic deformation processes become more important with increasing temperature. Furthermore, a presumably amorphous material develops at high differential stresses without large amounts of displacement in the brittle field. This material has to be analysed in more detail to reveal its development.

References:

Pec, M., Stünitz, H., Heilbronner, R., 2012a. Semi-brittle deformation of granitoid gouges in shear experiments at elevated pressures and temperatures. JSG, 13, 200-221.

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