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Transition from frictional to viscous deformation in granitoid fault rocks

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Fracturing of rocks in natural fault zones increases the permeability and produces extremely small grain sizes (< 0.1 µm). This fine grain size is a potential precursor to viscous deformation by diffusion creep, even at low temperatures if fluids are present. The aim of this study is to test the potential transition from frictional to viscous deformation in very fine-grained gouge material. We have performed a series of simple shear deformation experiments on fault gouge in a Griggs deformation apparatus. Crushed Verzasca gneiss powder (< 200 µm) with 0.2 wt% water added was placed between Verzasca Gneiss forcing blocks cut at 45 degrees and weld-sealed in a gold jackets.

Before deformation, the gouge material needs to be compacted. This is achieved by a set 1 of frictional deformation experiments at different temperatures (T = 24 °C, 300 °C, 500 °C, Pc = 500 MPa, strain rate = 10ˆ-4) to shear strains of approximately gamma = 2.5. In the subsequent experiments (set 2), potential viscous deformation processes are tested in the pre-deformed gouge. After initial frictional deformation (set 1) the samples are left at peak differential stress conditions for one week. Finally, in a third type of experiments (set 3), the peak differential stress was lowered after frictional deformation to a level similar to the confining pressure and held constant for one week.

In set 1, the peak shear stresses are temperature independent (given the limited stress resolution of the Griggs apparatus; 300° C = 780 – 870 MPa, 500° C = 760 – 820 MPa).

In set 2, the stress relaxation after frictional deformation is clearly temperature dependent (after one week at 300° C, the shear stress is approx. 370 MPa; at 500° C, approx. 230 MPa).

In set 3, no creep was observed. Further investigation of this phenomenon is required but probably the differential stress was too low.

Microstructural observations show a striking difference between samples of set 1 and set 2. The samples deformed by initial friction only (set 1) show angular clasts and many small grains. The grain size distribution is similar to that observed in natural gouge material from seismic faults and to experimentally cracked granitoid material (Keulen et al. 2007, Heilbronner and Keulen 2006). In the creep-deformed samples (set 2), we observe the disappearance of the grains of < 0.1 µm size, cementation of individual grains into larger ones, and lobate grain boundaries in rounded clasts. Thus, solution – precipitation processes have taken place in creep experiments of experimentally produced gouge. The exact nature of the creep deformation is difficult to assess at this stage, because the stress levels necessary to achieve creep in the experiments so far are above the Goetze criterion.

References:

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