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Rupture and gouge formation in fault zones - a two-stage process?

H. Stünitz, N. Keulen, R. Heilbronner
Dept. of Geosciences, Basel University, Switzerland (holger.stuenitz@unibas.ch)

Coaxial deformation experiments were carried out on isotropic Verzasca gneiss using a Grigg's deformation apparatus at 300 to 500 ˚C, 500 MPa, 1000 MPa, strain rates of 10-4 to 10-6 s-1, dry, and 0.2 %wt H2O added. Samples were deformed and quenched immediately after fracturing and gouge formation. Digital images at different magnifications were used for the analysis of the microstructures and the grain size distribution (GSD; defined by its D-value = slope in a log frequency/log size - diagram).

In all samples two endmember types of microstructures are distinguished: (1) cracked grains, with anguler outlines where the geometric relationship of the fragments with respect to each other is maintained, and (2) gouge, where the fragments are rounded and moved with respect to each other due to the fault displacement. The GSD of quartz and feldspar shows the same characteristics for all samples, regardless of H2O content, confining pressure, temperature and strain rate in gouge and cracked grains: (1) On log(N) -log(R) plots two distinct linear regions appear with a change in D-value around 2 to 4 microns. The D-values below 2 to 4 microns range between 0.7 and 1.1, those above 2 to 4 microns between 1.4 and 2.3. (2) For every sample, gouge invariably shows a higher D-value (1.9 to 2.3) than cracked grains (1.4 to 1.7) in the coarser grain size range (>2-4 micron). (3) The largest grain size range analysed (10 - 150 micron) is present in the cracked grains only and not in the gouge, while the gouge contains grains 30 - 80 nm not present in the cracked grains. (4) Mature gouge is formed after a very short slip distance (<1mm, corresponding to a gamma across the fault zone of 1-5) and an increase in displacement above that value does not increase the D-value. (5) Feldspar shows smaller D-values (1.8-2.1) in gouge than quartz (1.9-2.3) in the larger grain size range (>2-4 microns) indicating more efficient grain size reduction in quartz.

The results demonstrate that the rupture event in fault rocks produces very fine grain sizes by initial cracking of grains as concluded by Wilson et al. (2005). However, displacement in the fault zone produces a post-rupture-processing of the gouge decreasing the grain size further as documented by the higher D-values and smaller grain sizes of the gouge compared to the cracked grains. The further grain size comminution in the gouge during post-rupture processing yields higher values for the surface area of gouge than created during rupture alone and thus will lead to an overestimation the energy release during rupture when GSD’s in fault zones are used for deriving energy release values. The post-cracking grain size refinement takes place during initial displacement of the fault because a strain increase beyond a gamma of about 1-5 does not change the D-value. Thus, the grain size comminution takes place during the initial small amounts of shear displacement so that the D-values of the grain size distribution cannot be related to magnitudes of fault displacement as proposed by Sammis et al. (1987).

Wilson et al. (2005): Nature 434, p. 749-752

Sammis et al. (1987): Pageoph 125, p. 777-812