Geophysical Research Abstracts
Vol. 17, EGU2015-4698, 2015
EGU General Assembly 2015

The viscous and frictional strength of faults in experiment and nature

Renee Heilbronner (1), Matej Pec (2), and Holger Stunitz (3)

(1) Geological Institute, Basel University, Basel, Switzerland (renee.heilbronner@unibas.ch), (2) Matej Pec, University of Minnesota (mpec@umn.edu), (3) Department of Geology, Tromsø University, Tromsø, Norway (holger.stunitz@uit.no)

In an extended study of one of the authors (PhD thesis of Matej Pec), the deformational behaviour of granitoid fault rocks was explored using a Griggs solid medium deformation apparatus and a range of temperatures (T = 300˚C to 600˚C), confining pressures (Pc = 0.5 to 1.5 GPa) and strain rates (dγ/dt$\approx 10^{-3}$ to 10^{-5} s^{-1}). Layers of crushed and sieved material (1 mm thick) were deformed between alumina forcing blocks (on a 45˚ pre-cut) to finite shear strains of up to γ = 5.

The deformation within the fault rock layers is one of plane shear accompanied by considerable thinning. To a certain extent, extrusion occurs parallel to the displacement direction but not transverse to it. The fault rock material does not deform homogeneously, rather the microstructure develops from an initial Riedel fracture set into an SC' fabric at higher strains. Progressive comminution leads to strain partitioning with a microstructure that is characterized by a few survivor grains surrounded by a fine grained mantle (of the same mineral composition as the survivor grains) and an evolving network of slip zones consisting - at first - of nano-crystalline, partially amorphous and - at higher strains - of completely amorphous material.

The slip zones are approx. 10 μm thick - they are the site of highly localized shear strain. They form a percolating network from one end of the shear zone to the other and must be considerably weaker than the surrounding material as evidenced by turbulent flow structures and the occasional formation of apophyses. Yet, the fault rock layers as a whole support high shear stresses (τ $\sim$ 570 – 1600 MPa) and even in the presence of a fully connected network of slip zones (forming up to 20 vol% of the total fault rock material), they continue to deform at more or less steady state stress levels.

Within the range of experimental conditions, the flow stress sustained by the fault rock depends clearly on confining pressure (indicating a frictional components of flow) and temperature (indicating a viscous components) but only weakly on strain rate. Whether the fault rocks are comparatively strong or weak depends on which criterion is use to describe strength. For example, our experiments show that the flow stresses increase for increasing confining pressure. At the same time, the friction coefficient (τ / σ_n) decreases. In other words: with respect to the sustained flow stress, faults are 'Pc-strengthening' with respect to the friction coefficient, they are 'Pc-weakening'.

To extrapolate our experimental data to nature and to compare them to friction experiments, we present our results in terms of equivalent viscosity describing the deformation of a thin volume of material, and in terms of the friction coefficient describing the displacement along a 'thick' fault surface. We present a simple conceptual model for the temporal and spatial evolution of the geometry or topology of the weak slip zones, and the interplay between viscous and brittle behavior of faults at all scales.