Geophysical Research Abstracts,
Vol. 11, EGU2009-8996, 2009
EGU General Assembly 2009

Mechanical amorphization during experimental shearing of synthetic granite gouge

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Frictional sliding experiments performed in a rotary shear machine at 25 MPa normal stress on 2-mm thick layers of simulated Westerly granite gouge (initial particle size 1-85 μm) have produced heterogeneous microstructures comprising comminuted material with internal layering. In SEM/BSE individual layers comprise grains of rounded and sub-rounded quartz and feldspar particles that vary in size from 20nm on one side to about 300nm on the other. Characterization of the gouge ultrastructure has been undertaken by analytical scanning transmission electron microscopy (STEM). Areas were selected from high-magnification SEM images and thinned in a focused ion beam instrument (FIB). This sampling procedure produces material of even electron transparency with perfect spatial registration to the optical and SEM microstructures. The sub-micrometre-scale laminar variation of grain size and porosity is confirmed by STEM. Shards of both feldspar and quartz are progressively comminuted to form the texture in which larger grains are surrounded by finer-comminuted matrix material. Grains of both of the latter primary mineral constituents are routinely less than 100 nm in size. Most significantly, the finest grained, least porous zones comprise small grain fragments embedded within an amorphous silicate matrix. By extension, one can infer that observation of these zones throughout the gouge is consistent with extensive amorphization during the shearing. The internal layering of the brecciated fragments, with asymmetric particle size and porosity grading, indicates that Y-slip surfaces localize displacement until particles that line the slip surface are reduced to a critical size that enables mechanically induced amorphization. Fluctuations in friction recorded during formation of this microstructure can be reasonably related to cyclic softening-hardening related to porosity loss and amorphization, with subsequent brecciation of the gouge during slip on multiple Y-slip surfaces.