Experimental analysis of dilatancy in simulated fault gouges
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Pore fluid pressure plays an important role in the frictional strength and stability of tectonic faults. We report on laboratory measurements of porosity changes associated with transient stressing during frictional sliding within simulated granular fault gouge. We use our measurements to model transient pore fluid depressurization and associated frictional hardening in response to dilation resulting from step changes in shearing velocity.

Experiments were conducted in a novel true-triaxial pressure vessel using the double-direct shear geometry, as well as in a more standard biaxial load frame. Shearing velocity step tests were used to measure a dilatancy coefficient ($\varepsilon = \Delta\phi/\Delta\ln(\nu)$, where $\phi$ is porosity and $\nu$ is shear velocity) under a range of conditions: 3, 10, 30, and 100 fold increases in sliding velocity with background velocities of 1 or 3 $\mu$m/s, at effective normal stresses from 0.8 to 30 MPa. We predict dilation-induced depressurization in fault gouge based on factors including magnitude of velocity increase, dilatancy coefficient, and layer permeability.

Although experimental conditions indicate negligible depressurization, due to relatively high system permeability, model results indicate that under feasible, but end-member, conditions shear-induced dilation of fault zones could reduce pore pressures, or correspondingly increase effective stresses, by several 10’s of MPa. Our results show that transient increases in shearing rate cause fault zone dilation. Such dilation, and associated pore fluid depressurization would tend to arrest nucleation of unstable slip, and could be a significant factor in generation of slow earthquakes, non volcanic tremor, and related phenomena.