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Frictional properties and hydro-mechanical processes in clay-rich fault gouge

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Frictional properties and hydro-mechanical processes play a central role in the spatiotemporal character of faulting. In many settings, the nature of seismic and aseismic faulting are determined in part by the rheology of clay rich fault gouge. Recent results suggest that fault zone dilation may limit dynamic rupture speed of slow and low frequency earthquakes. We summarize results from laboratory experiments designed to investigate the frictional behavior of clay-quartz mixtures. Results are presented from double-direct shear friction experiments using the traditional, unconfined thin-layer geometry and tests conducted in a true triaxial system under saturated conditions. Materials include kaolinite, smectite, illite, chlorite, and quartz. We report porosity and strength changes associated with perturbations in strain rate during steady state frictional sliding. Layers dilate upon a step increase in strain rate and, consistent with previous work, we find that the magnitude of the induced porosity change scales with the log of the slip velocity jump ratio. We monitor potential transients in pore fluid pressure in response to dilation resulting from step changes in shearing velocity. Montmorillonite, chlorite, and illite gouges are consistently velocity strengthening, and the friction rate parameter (a-b) tends to increase with increasing sliding velocity. We discuss results for sliding velocities from 1 to 300 μm/s and normal stresses from 10 to 150 MPa. At higher normal stress, the rate-state friction parameter b decreases to zero. We report results from clay fabric intensity analysis using X-ray texture goniometry. Our data suggest that true contact area between clay minerals saturates at high normal stress. This implies significant changes in the friction critical slip distance as a function of normal stress. We review laboratory friction data and constitutive laws in the

context of requirements for stable and unstable faulting.