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Controls of Stress Regime and Injection Rate on Slip Events

Wen-lu Zhu (1) and Melodie French (2)
(1) University of Maryland, United States (wzhu@umd.edu), (2) Rice University, United States (mef8@rice.edu)

The practice of injecting fluids into the crust is linked to regional increases in seismicity. The standard explanation is that increasing pore pressure lowers the effective normal stress, and thus reduces the critical shear stress required for the fault to slip. Under this threshold model, the injection induced seismicity is expected to be similar regardless of the style of faulting (i.e. normal vs. reverse). We conducted friction experiments to investigate the fluid injection induced slip behaviors under stress paths typical of normal and reverse faulting regimes. We found that although fault slip is well-predicted to occur at a critical shear stress, the style of slip (i.e. slow vs. dynamic) cannot be determined by a threshold criterion. We show that effective stress decreases associated with mechanical loading are more effective than pore fluid pressure increases at initiating accelerated slip events. Fluid pressurization enhances the total slip, velocity, and stress drop of events caused by changes in normal stress, and these parameters are correlated with pressurization rate, but not the magnitude of fluid pressure. We propose that mechanical loading alters contact-scale stresses along the fault surface in a manner that is both more rapid and uniform than occurs by changes in pore fluid pressure, which occurs by diffusion. This result is consistent with field-scale observations, and indicates that induced seismicity is governed by processes active at the scale of the pore network.