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Mechanical and Acoustic Signature of Slow Earthquakes on Laboratory Faults

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Recent seismic and geodetic observations show that fault slip occurs via a spectrum of behaviors that range from seismic (fast dynamic) to aseismic (creep). Indeed faults can slip via a variety of quasi-dynamic processes such as Slow-Slip, Low Frequency Earthquakes (LFE), and Tremor. These transient modes of slip represent slow, but self-propagating acceleration of slip along fault zones. These phenomena have been observed worldwide in a variety of active tectonic environments, however the physics of quasi-dynamic rupture and the underlying fault zone processes are still poorly understood. Rate- and State- frictional constitutive equations predict that fast dynamic slip will occur when the stiffness of the loading system (k) is less than a critical stiffness (kc) characterizing the fault gouge. In order to investigate quasi-dynamic transients, we performed laboratory experiments on simulated fault gouge (silica powders) in the double direct shear configuration with a compliant central block allowing boundary conditions where k≈kc. In addition, PZTs were used to measure acoustical properties of the gouge layers during shear.

We document an evolution of the fault mechanical properties as the σn is increased. For σn < 10 MPa we observe a steady state frictional type of shear. When $\sigma n \geq 15$ MPa we observe emergent slow-slip events from steady state shear with accumulated shear displacement of about 10 mm. The typical values of stress drop ($\Delta\tau$) vary between 0.2 and 0.8 MPa, and have typical duration from 0.5 up to 3 seconds giving the characteristics of slow stick-slip. As σn is varied we observe different characteristics of slow slip. For σn = 15MPa a repetitive double period oscillation is observed with slow slip growing until a maximum stress drop and then self attenuating. When σn is increased to 20 and 25 MPa slow slip are characterized by larger $\Delta\tau$ with constant τmax and τmin, however still showing a co-seismic duration of $\sim$2 seconds.

Our results suggest that strain accumulation within the experimental fault and the increase of critical stiffness, kc, via increasing normal stress produce an evolution from frictional stable sliding to different transients of slow-slip. At the moment we have been coupling microstructural work with the characterization of the acoustic properties during the pre- and co- seismic stage in order to shed light into the physical mechanism(s) for slow-slip.