AGU Fall Meeting 2015

Laboratory observations of the full spectrum of fault slip modes: implications for the mechanics of slow earthquakes

Faults fail in a spectrum of slip behavior as demonstrated by slow slip events, slow and low-frequency earthquakes, episodic tremor and slip, and non-volcanic tremor. The underlying causes of this spectrum of behavior and the processes that control the failure mode of a particular fault are poorly understood, and constitute one of the most pressing conundrums of the field. Field observations provide documentation of slow-slip events at many different locations, but provide little insight into their mechanism. We present a systematic experimental study of slow slip and provide a mechanical explanation for the spectrum of fault slip modes from slow, aseismic slip to fast earthquake-like stick-slip.

Utilizing a double-direct shear configuration in a bi-axial apparatus, we conducted constant loading velocity shearing tests. The effective system stiffness was altered by changing the effective normal stress and via the material used for the loading blocks. In experiments that exhibited stable sliding, we conducted velocity step tests to estimate the rate-and-state parameters of the material. From the rate-and-state parameters, we calculate the predicted critical stiffness value (k_c) at which frictional failure should transition from stable to unstable sliding.

We find that slow slip occurs near the stability threshold, which is in turn controlled by the interplay of fault frictional properties, effective normal stress, and elastic stiffness of the surrounding rock. Moreover, both the peak slip velocity and the duration of slip vary systematically with distance from the stability threshold, expressed as a ratio of the system stiffness to the critical stiffness (k/k_c). Our results suggest a general mechanism for slow earthquakes and the spectrum of fault slip behaviors. Such a mechanism is consistent with the broad range of geologic environments in which these phenomena are observed, from subduction zones to the low-angle normal faults at the base of fast moving ice streams. This has implications for our understanding of frictional stick-slip as a range of behavior that can be parameterized by the stiffness alone.