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

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Faults fail in a spectrum of slip behavior as demonstrated by slow earthquakes, episodic tremor and slip, and non-volcanic tremor. While slow-slip is mostly commonly observed in subduction zones, it also occurs in the low-angle normal faults at the base of fast moving ice streams. What causes this spectrum of behavior and controls the failure mode of a particular fault is poorly understood. Natural observations are sparse and remotely sensed, and laboratory observations are scattered and poorly described.

Here we present a fully systematic study of how system compliance controls the failure mode of a laboratory fault. Utilizing a double-direct shear configuration in a bi-axial apparatus, we conducted shearing tests at a constant velocity of 10 μm/s. The effective system stiffness was modulated by changing the applied normal stress and by changing the composition of the central forcing block. 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 can calculate the predicted critical stiffness value (k_c) at which frictional failure should transition from stable to unstable sliding.

We find that both the peak slip velocity and the duration of slip scale with the ratio of the system stiffness to the critical stiffness (k/k_c). This has implications for our understanding of frictional behavior as a transitory range of behavior that can be parameterized by the stiffness alone.