Geophysical Research Abstracts
Vol. 18, EGU2016-10320, 2016
EGU General Assembly 2016

Laboratory Observations of the Spectrum of Fault Slip: Implications for Slow Earthquakes

John Leeman (1), Demian Saffer (1), Marco Scuderi (2), and Chris Marone (1)
(1) Penn State, University Park, USA (jleeman@psu.edu), (2) Sapienza Università di Roma, Rome, Italy

Fault zone failure spans a wide range of slip modes, including normal earthquakes, low-frequency earthquakes, episodic tremor and slip, non-volcanic tremor, slow slip events, and steady aseismic creep. Despite widespread observations in a range of tectonic and geologic environments, the physics underlying these events remain poorly understood. Here we present a systematic laboratory study of slow slip and build a mechanical explanation for the spectrum of fault slip modes. We show that complex behaviors can arise from relatively simple models using traditional rate-and-state friction (RSF) concepts.

We sheared quartz gouge at constant velocity in a double-direct shear configuration. We controlled the effective stiffness of the system by changing the normal stress and changing the material of the loading blocks from steel to acrylic. There is a critical stiffness value (kc) that represents a bifurcation point separating stable and unstable systems. For systems in which k < kc, the rate at which the fault weakens is greater than that at which the surrounding elastic material can release energy into the system, therefore generating a force imbalance and acceleration to fully dynamic and unstable stick-slip. For systems in which k > kc, the surrounding media unloads energy faster than the fault can weaken and therefore the system is stable. For experiments that exhibited stable behavior, we used velocity step tests and RSF modeling tools to independently determine constitutive frictional parameters and calculate the system critical stiffness. For experiments that exhibited unstable behavior we measured the stiffness of the layer directly from displacement and load measurements during individual stick-slip events, and compared it to the calculated value of kc.

We find that the predicted stability boundary (defined by k/kc = 1) delineates stable and unstable slip behavior in our experiments, but rather than a strict bifurcation, slow slip and quasi-dynamic failure occur at and very near k/kc = 1. We also find that the peak slip velocity and duration of stick slip events also vary systematically with this stiffness ratio. We therefore suggest that the stiffness ratio can directly diagnose the type of fault slip that will occur in a given system and requires no additional complicating physics such as multiple state variables, dilatancy hardening, or velocity dependent friction parameters. This mechanism is also broadly applicable and consistent with observations from natural faults ranging from subduction zones to low-angle normal faults at the base of fast moving ice streams.