Stress triggering and the mechanics of fault slip behavior

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Dynamic changes in the stress field during the seismic cycle of tectonic faults can control frictional stability and the mode of fault slip. Small perturbations in the stress field, like those produced by tidal stresses, can influence the evolution of frictional strength and fault stability with the potential of triggering a variety of slip behaviors. However, an open question that remains still poorly understood is how amplitude and frequency of stress changes influence the triggering of an instability and the associated slip behavior, i.e. slow or fast slip.

Here we reproduce in the laboratory the spectrum of fault slip behaviors, from slow-slip to dynamic stick-slip, by matching the critical fault rheologic stiffness ($k_c$) with the surrounding stiffness ($k$). We investigate the influence of normal stress variations on the slip style of a quartz-rich fault gouge at the stability boundary, i.e. $k/k_c$ slightly less than one, by adopting two techniques: 1) instantaneous step-like changes and 2) sinusoidal variations in normal stress. For the latter case, modulations of normal stress were chosen to have amplitudes greater, less or equal to the typical stress drop observed during unperturbed experiments. Also, the period was varied to be greater, less or equal to the typical recurrence time of laboratory slow-slip events. During the experiments, we continuously record ultrasonic wave velocity to monitor the microphysical state of the fault. We find that frictional stability is profoundly affected by variation in normal stress giving rise to a variety of slip behaviors. Furthermore, during strain accumulation and fabric development, changes in normal stress permanently influence the microphysical state of the fault gouge increasing $k_c$ and producing a switch from slow to fast stick-slip. Our results indicate that perturbations in the stress state can trigger a variety of slip behaviors along the same fault patch. These results have important implications for the formulation of constitutive laws in the framework of rate- and state-friction, highlighting the necessity to account for the microphysical state of the fault in order to improve our understanding of frictional stability.