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The role of shear fabric in controlling slip velocity function and breakdown work during laboratory slow slip events

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Despite slow slip events have been observed in a variety of tectonic environments worldwide, the underlying physical processes are still poorly understood. They are a manifestation of the complexity of the spectrum of fault slip behavior. Interpreting observations of slow slip events is crucial for understanding the causative processes and the associated slip time histories. The latter are also poorly constrained by observational evidence since the slip velocity function is usually imposed and assumed a-priori during kinematic and dynamic modeling of earthquake ruptures.
In this study, we analyze slow-slip events obtained during laboratory experiments at the stability boundary (k∼kc) by matching the critical fault stiffness (kc) with the machine stiffness (k). The experiments were performed in the double direct shear configuration equipped with LVDT (linear variable differential transducers) mounted on the sample assembly to accurately solve details of sample compaction/dilation and to measure the fault slip. To discern the role of shear localization during fault weakening we simulated fault gouges using quartz powders and a mixture of anhydrite and dolomite, which have a strong rheological contrast.
For both lithologies, slow-slip events have typical friction drop of ∼0.01 and duration between 6s and 12s. During each event we observe that peak slip velocity is attained before reaching the minimum shear stress, and most of the slip velocity evolution is associated with the dynamic weakening phase.
We document that the fault zone fabric controls the slip velocity function as well as the details of micro-mechanical deformation (i.e. dilation/compaction). For quartz gouge, shear deformation localizes along continuous and sharp shear planes (∼1μm thick) resulting in a smooth slip velocity function (similar to a Gaussian) where a clear pre-seismic slip is easily detectable. Fault gouge compaction is observed during the whole experiment, with the larger compaction rate occurring before peak slip velocity is attained, likely due to cataclasis and grain size reduction in the bulk. In the anhydrite and dolomite mixture, shear localizes along thick boundary shear planes interconnected by a P-foliation, resulting in a more distributed deformation, showing a Yoffe slip velocity having a short acceleration phase (∼1s) with no pre-seismic slip and a long deceleration. Fault dilation occurs simultaneously with slip acceleration likely due to slip partitioning within the entire the experimental fault.
The inferred breakdown work (seismological fracture energy) is very similar for both lithologies, but for quartz we observe a relevant portion of mechanical work absorbed before the main slip acceleration phase, probably due to the compaction within the bulk volume.
Our results confirm that the slip rate function contains the key dynamical information to characterize the evolution of dynamic traction. The retrieved differences in the slip velocity functions and mechanical work absorbed in dynamic weakening depend on the strain partitioning within the fault volume. Our results suggest that slip time histories depend on fault zone structure and strain partitioning in the fault core.