



Precursors to Failure Extend Across the Transition from Slow to Fast Laboratory Earthquakes

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Active tectonic faults exhibit a spectrum of failure modes that range from aseismic creep to slow tremor and devastating earthquakes. Slow earthquakes and other quasi-dynamic modes of fault failure have been observed in many tectonic environments but their relationship to dynamic rupture and the mechanics of regular earthquakes remains poorly understood. Current models can explain slow slip but require specialized conditions and do not address possible precursory changes in fault properties prior to failure. Here, we report elastic properties of laboratory faults for a wide range of stick-slip velocities. Our experiments document slip modes that mimic the full spectrum observed in nature from slow events, with peak slip velocity of $\sim 100 \mu\text{m/s}$, to earthquakes with slip velocity approaching m/s . We find systematic variations of fault zone elastic properties during the seismic cycle for the complete range of stick-slip rates. Our results suggest that the mechanics of slow slip and fast dynamic rupture share key features and that they can occur on the same fault segment, depending on fault rock frictional properties and elastic conditions. During the preparatory phase preceding stick-slip failure, we find that accelerated fault creep causes reduction of seismic wave velocity and elastic moduli for both fast and slow slip events, which illuminates similarities in the underlying physics of slow and fast slip. Our data suggest that real time monitoring of active faults may prove useful as a means to detect earthquake precursors.