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Slow Earthquakes and The Mechanics of Slow Frictional Stick-Slip

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Slow earthquakes represent one mode of the spectrum of fault slip behaviors ranging from steady aseismic slip to normal earthquakes. Like normal earthquakes, slow earthquakes can occur repetitively, such that a fault fails in a form of stick-slip failure defined by interseismic strain accumulation and slow, quasidynamic slip. The mechanics of frictional stick-slip and seismogenic faulting appear to apply to slow earthquakes, however, the mechanisms that limit dynamic slip velocity, rupture propagation speed, and the scaling between moment and duration of slow earthquakes are poorly understood.

Here, we describe laboratory experiments that explore the mechanics of repetitive, slow frictional stick-slip failure. We document the role of loading stiffness and friction constitutive behavior in dictating the properties of repetitive, frictional stick-slip. Our results show that a spectrum of dynamic and quasidynamic slip velocities can occur in stick-slip events depending on the relation between loading stiffness k and the rheologic critical stiffness kc given, in the context of rate and state friction, by the ratio of the friction rate parameter (b-a) divided by the critical friction distance Dc. Slow slip is favored by conditions for which k is $\sim$ equal to kc, whereas normal, fast stick slip occurs when $k/kc < 1$. We explore the role of elastic coupling and spatially extended slip propagation by comparing slow slip results for shear in a layer driven by forcing blocks of varying stiffness. We evaluate our data in the framework of rate and state friction laws and focus on the frictional mechanics of slow stick-slip failure with special attention paid to the connections between quasidynamic failure and mechanisms of the brittle-ductile transition in fault rocks.