The Mechanics of Slow Earthquakes and the Spectrum of Fault Slip Behaviors

Chris Marone[1], *John Leeman*[1], *Marco Scuderi*[2], *Demian M Saffer*[1] *and Cristiano Collettini*[2], *(1)Penn State Univ, University Park, PA, United States, (2)Sapienza University of Rome, Rome, Italy*

Abstract:
Slow earthquakes represent an important conundrum in earthquake science. Whereas normal earthquakes are understood as frictional stick-slip instabilities in which stored elastic energy is released suddenly, driving catastrophic failure, there is no such understanding of slow earthquakes or the related phenomena of tremor, low frequency earthquakes and slow slip events. In normal (fast) earthquakes the rupture zone expands at a rate dictated by elastic wave speeds, a few km/s, and fault slip rates reach 1-10 m/s. However, we do not have a similar understanding *slow earthquakes* with rupture durations of months or more and fault slip speeds of ~100 micron/s or less. What determines the rupture propagation velocity in slow earthquakes and in other forms of quasi-dynamic rupture? What processes limit stress drop and fault slip speed in slow earthquakes? Existing lab studies provide some help via observations of complex forms of stick-slip, creep-slip, or, in a few cases, slow slip. However, these are mainly anecdotal and rarely include examples of repetitive slow slip or systematic measurements that could be used to isolate the underlying mechanisms. Numerical studies based on rate and state friction also shed light on transiently accelerating slip, showing that slow slip can occur if: 1) fault rheology involves a change in friction rate dependence (*a-b)* with velocity or unusually large values of the frictional weakening distance *DC*, or 2) fault zone elastic stiffness equals the critical frictional weakening rate kc = (b-a)/Dc. Recent laboratory work shows that the latter can occur much more commonly that previously thought. We document the complete spectrum of stick-slip behaviors from transient slow slip to fast stick-slip for a narrow range of conditions around k/kc = 1.0. Slow slip occurs near the threshold between stable and unstable failure, controlled by the interplay of fault zone frictional properties, normal stress, and elastic stiffness of the surrounding rock. Our results provide a generic mechanism for slow earthquakes, consistent with the wide range of conditions for which slow slip has been observed.