Fault healing plays a key role in creating the spectrum of tectonic faulting styles from seismic to aseismic slip

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Tectonic faults fail in a broad spectrum of modes ranging from aseismic creep to fast, ordinary, earthquakes modulated by elastodynamic rupture processes. Laboratory friction experiments with repetitive stick-slip failure have reproduced this complete range of modes with failure durations spanning several orders of magnitude. These works show that the frictional weakening rate with slip (i.e., the rheological critical stiffness $k_c = \sigma_n(b-a)/D_c$, where $\sigma_n$ is effective fault normal stress, $D_c$ is the friction critical slip distance and $(b-a)$ represents the friction rate parameter) is the primary control on the mode of slip, but higher-order effects are also important including variation of $k_c$ with slip velocity. Far from the stability boundary, stick-slip occurs when the rate of elastic unloading with slip $k$ is small compared to the frictional weakening rate (i.e., $k \ll k_c$). Potential energy, in the form of stored elastic strain, drives rapid fault acceleration. Near the stability boundary, when $k \approx k_c$, lab experiments document slow and quasi-dynamic failure events, consistent with the observation that earthquake stress drop is negligible for slow earthquakes. Lab data show that stick-slip stress drop decreases systematically as $k/k_c$ approaches 1 from below. There are two possible scenarios for slow slip near the stability boundary, although they are degenerate in most cases. 1) Fault slip relieves elastic stresses prior to failure and thus the potential energy needed to drive fast rupture is absent. 2) Elastic strain accumulates but the fault rheology is velocity strengthening or otherwise inconsistent with rapid slip, for example because the frictional weakening rate $k_c$ is low. In Scenario 1, slip can occur early in the seismic cycle, as creep, or later in the cycle when shear stress reaches a critical value for precursory slip. In either case, slip occurs because the rate of fault healing is low compared to the stressing rate. A low rate of fault healing can also explain Scenario 2 because the friction state evolution parameter $b$ scales directly with the rate of fault healing and $k_c$. Given that the friction parameter $a$ is positive definite, the frictional healing rate $(b)$ sets the scale of $k_c$ for a given value of $D_c$. Thus, while these two scenarios for slow slip appear distinct they both derive from the rate of fault healing. Exceptions would involve faults that are strongly velocity weakening $(b-a) \gg 0$ yet have negligible healing rates $(b \sim 0)$, which is indeed rare. The rate of fault healing is expected to vary with mineralogy, effective stress, temperature and other factors. Thus, while we expect a systematic variation of seismic style with depth, associated with changes in $k_c$, we should not be surprised to find a spectrum of faulting styles throughout the lithosphere, including a range of styles at a given location. Discoveries of seismic tremor, low frequency earthquakes, and other modes of fault slip are challenging our views of tectonic faulting and they highlight the need for close connections...
between field observations, detailed laboratory work and theoretical studies of friction and faulting.