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Modeling of Transient Slip Events in The Lithosphere Over Short and Secular Time Scales

Luc Lavier and Xinyue Tong
University of Texas at Austin, Institute for Geophysics, Department of Geological Sciences, Austin, Texas.

In a given tectonic province and over thousands to millions of years, slip on faults is believed to be constant and approximately equal to the local tectonic rate in agreement with rigid plate tectonic theory. In this model the ductile lower crust flows in response to this steady plate motion. Moreover, brittle and ductile behaviors only interact at a sharp boundary defined as the brittle ductile transition (BDT). However ductile deformation or creep may control loading of shear zones between rigid plates and brittle (velocity weakening) and ductile (velocity strengthening) behavior may coexist over a large range of pressure and temperature conditions for different mineral compositions. This generates heterogeneities in the brittle and ductile crust that may control the length scales of localization as well as the time scales of slip on shear zones. Here, we hypothesize that the interaction between brittle (elastic) and ductile (viscous) behavior may cause deviations from steady-state slip and generates transient creep events on shear zones that release many meters of creep over days to years to thousands of years marked by a single period of tectonic activity followed by quiescence. Recent observations, numerical and analogue experiments now tend to support this hypothesis. Here, we present a set of numerical models constrained by observations that may support this hypothesis. We assume that creep events are triggered by a set of interconnected fractures modeled as propagating plastic damage zones or dislocations. The dispersion or delocalization of this damage as well as the amount of connectivity between fractures controls the nature and the intensity of the transient creep events. In our formulation most of the elastic energy accumulating during jamming or locking of the shear zone is spent in kinetic (slip) and strain (damage) energy. The ratio of kinetic to strain energy controls the size and durations of the events with the longer events spending most of the available energy in forming new damaged zones while earthquakes are dominantly kinetic. The time scale of the events may vary between seconds to thousands of years depending on the viscous, elastic and plastic (fractures) properties of the shear zone.