“Simulation of faulting and earthquakes in numerical models of long-term tectonic deformation”.

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We present two studies to showcase how numerical experiments can be used to constrained the factors controlling the rheological evolution of the lithosphere for both long term geological processes and transient slip events such as earthquakes.

We first present the case of slow-spreading ocean ridges using the example of the eastern Southwest Indian Ridge (SWIR). There, successive detachments that flip polarity (flip-flop detachments) have been documented in corridors of nearly amagmatic spreading. Serpentinization and more generally hydrous alteration minerals have been shown to localize strain at detachment-dominated slow-spreading ridge locations. Here we show that grain size reduction due to dynamic recrystallization also occurs in peridotites from the eastern SWIR. Our models explore the effect of implementing these weakening mechanisms separately or together in an amagmatic spreading context, of varying the threshold conditions for their activation, and the thermal conditions on-axis. We show that serpentinization alone does not produce flip-flop detachments, while grain size reduction alone does, albeit with unrealistically high associated topographic relief. Combining the two, we observe the activation of several modes of axial deformation: horst mode, spider mode, and long or short-lived flip-flop detachments that are consistent with the flip-flop mode of faulting .

We then focus on whether a fault generates earthquakes, slow slip events (SSEs) or creeps aseismically. This is believed to depend on the sign of the friction change resulting from an increase in slip velocity, . Faults that exhibit a decrease in friction are velocity-weakening and may generate earthquakes; those that exhibit an increase in friction are strengthening and predominantly creep aseismically. The sign and magnitude of are determined by laboratory experiments on fault zone rocks. Most models of slip behavior assume that varies mostly with temperature. However geological observations show that fault zone composition varies and often accommodates a mixture of brittle and ductile deformation. It has become clear that the nature of this mixture may play an important role in determining whether the fault creeps steadily, or slips in SSEs and/or fast earthquakes. Using numerical experiments, we explore how the ratio of brittle to ductile material affects slip behavior in brittle-ductile mixtures of variable composition and amplitude of . We show that: (1) mixtures can exhibit multiple slip behaviors including earthquakes and slow slip, (2) highly brittle mixtures do not tend to generate slow slip events while weakly brittle mixtures can generate slow slip over a wider range of compositions, (3) structural features formed during simulated creep, slow slip events and earthquakes share notable similarities with structures observed in natural fault zones.