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The generation of slow slip in chemically active and geometrically complex fault zones

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Active faults exhibit a spectrum of failure modes that range from aseismic creep, to slow slip with tremor, to devastating earthquakes. The physical processes that limit slip velocity in slow earthquakes and prevent fast rupture resulting in regular earthquakes are still debated. A potential mechanism to explain deep slow-slip and tremor has been proposed based on brittle-viscous deformation patterns seen in mélanges where brittle lenses are embedded in a ductile matrix in the presence overpressured fluids.

Here we argue for an alternative model in which the shear zone mechanics is controlled by weak brittle faults embedded in ductile stronger lens. We integrate observations from shear zones in serpentinites, quartz-rich metasediments and carbonates documenting the deformation in a range of conditions from seismogenic depths to the subsurface ($T < 400°C$, $P < 1$ GPa).

These shear zones, with thicknesses ranging from a few meters to hundreds of meters, consist of sigmoidal lenses enveloped by thin anastomosing faults typically covered by highly aligned phyllosilicates (serpentines, illite, chlorite, smectite). Within the lenses, which are typically mm- to m- size foliated blocks, progressive strain is characterized by bulk fluid-assisted diffusion mass transfer punctuated by episodic fracturing. These processes cause passive concentration and recrystallization of platy minerals along horizons later exploited by brittle faulting. Along the block-bounding faults, there is an interplay of cataclasis, frictional slip, folding and dissolution-recrystallization of phyllosilicates.

This evidence indicates shear zones characterized by slow deformation due to diffusive mass transfer coexisting with transients of faster deformation related to local fracturing and frictional sliding on weak faults, potentially followed by accelerated creep due to grain-size reduction. We suggest that accelerated slip nucleates along weak faults and is limited by: i) the anastomosing discontinuous geometry of the shear zone; and ii) by the availability of reaction-induced fluids. This inhibits through-going fracture propagation and earthquake nucleation, thus providing a viable physical mechanism for slow slip events.