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Strain localization driven by co-seismic pore fluid pressurization

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The absence of a thermal anomaly associated with the San Andreas fault, and low driving stress resolved on it, suggest that such mature faults weaken dramatically during seismic slip. Thermal pressurization (TP) and thermal decomposition (TD) are two mechanisms to explain this co-seismic weakening. Both rely on elevated pore pressures in a fluid-saturated gouge, with TP achieving this through thermal expansion of native pore fluid and TD by releasing additional pore fluid (e.g., H_2O or CO_2) during a reaction.

We use a one-dimensional model for a fluid-saturated gouge layer sheared between two undeforming half-spaces to study how TP (*Rice et al.*, *Platt et al.*, JGR-B, 2014) and TD (*Platt et al.*, submitted JGR-B) drive seismic strain localization. A linear stability analysis is first used to predict the localized zone thickness for each of the weakening mechanisms. Using representative parameters for fault gouge we predict localized zone thicknesses of a few tens of microns, in line with laboratory (*Kitajima et al.*, 2010) and field (*Chester and Chester*, 1998) observations. Next we use numerical simulations to study how the localized zone develops once nonlinear effects become important. These show that the final localized zone thickness is very similar to the linear stability prediction. In the simulations, the onset of localization accelerates fault weakening, making co-seismic strain localization an important consideration, apparently neglected in all current earthquake simulations.

Finally we show how a secondary instability can lead to migration of the deforming zone across the gouge layer. This instability is driven by hydrothermal diffusion for TP, and by reactant depletion for TD. Our results show that migration must be taken into account when inferring the width of the deforming zone from field observations. Even when the zone of localized straining is only a few tens of microns wide, migration can lead to a final strain profile with a zone of roughly uniform strain on the order of a millimeter wide. Migration also distributes frictional heating over a broader region, leading to a lower temperature rise when compared with a stationary shear zone. Our results rarely show temperatures above the melting temperature, providing a possible explanation for the scarcity of frictional melt products on mature faults.