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Spatial and temporal heterogeneity of exhumed seismogenic faults; implications for seismic slip

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Fault zone structure controls many of the active processes during the initiation and propagation of seismic slip events. We document heterogeneous fault zone properties at a variety of scales and show that the observed structural heterogeneity implies spatially variable slip processes. Pseudotachylyte-bearing faults in the central Sierra Nevada, California, are exhumed from 5 to 11km depth, and underwent multiple earthquake rupture events. Field and thin section observations show that the fault rock assemblage changes along strike over distances of metres to hundreds of metres. The inferred coseismic slipping zone thickness, permeability structure of the fault, and damage zone geometry are all laterally heterogeneous. Field and microstructural evidence show that no single slip weakening mechanism can account for the dynamic reduction in shear strength associated with past ruptures in the Sierra Nevada faults. This implies that active slip weakening mechanisms are spatially heterogeneous during a rupture event. Additionally, brecciated pseudotachylytes attest to slip-weakening mechanisms progressively changing through time and/or slip. This change in process may be during a single slip event, or from rupture to rupture. Extrapolating experimental data describing the slip weakening distance up to the scales of natural faults is therefore likely to be inappropriate unless a particular fault is shown to have consistent properties in three dimensions with progressive slip. We suggest that characterizing the spatial distribution of different fault zone properties would provide an extra tool for interpreting experimental results, and might allow models of rupture propagation to more accurately reproduce observed coseismic slip and velocity distributions.