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Characterizing km-scale faults exhumed from seismogenic depths, Sierra Nevada, California.

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A newly identified suite of pseudotachylyte-bearing faults has been defined in the Sierra Nevada, California. The faults have mapped trace lengths of up to 7 km and maximum observed displacements of approximately 100m. The presence of pseudotachylyte implies that displacement on the faults is likely to have been accumulated by some combination of seismic slip and aseismic creep. Empirical relations between subsurface fault length and earthquake size suggest that faults of this scale may have experienced 100s of earthquake rupture events, and that rupture events could have been as large as $M_w \sim 5.6$. These faults therefore represent a stage of fault evolution between small, single-jerk faults and larger, mature fault zones.

Fault zone architecture is dependent upon the amount of displacement on the fault, and also a variety of other factors including lithology, 3D geometry, fluid-rock interactions and the deformation conditions (i.e. pressure, temperature, strain rate). This broad range of influences gives rise to great variability in the style of fault architecture, and means that as many as possible of these geologic parameters must be quantified for a particular fault system if the data are to be usefully applied to models of rupture propagation. The deformation conditions prevalent during active faulting have been constrained for the faults in the study area. Amphibole geobarometry results show that the lithostatic pressure during pluton crystallization was 200 to 400 MPa. K-Ar and apatite (U-Th)/He dating show that ambient temperatures ranged from $\geq$350ºC to $<$100 ºC as the host pluton cooled, and that pressures decreased to $\geq$100 MPa in response to exhumation.

The faults in the study area display complex architectures characterized by heterogeneous strain within a distributed zone of fault-related structures. High-strain slip surfaces are defined by both striated fracture surfaces and by pseudotachylyte generation surfaces (the co-seismic slipping zone) in outcrop, and by narrow bands of highly comminuted cataclasite in thin section. Commonly multiple slip surfaces are present within the fault zone overprinting cataclasites, mylonites and undeformed host rock. Slip surface geometries are complex at both macro- and micro-scale, and cross-cutting relations and re-worked pseudotachylyte material indicate that new slip surfaces are continuously developed throughout the evolution of these faults. One or more fault core strands are present within the fault zones that are generally sub-parallel to the overall fault zone orientation, but which anastomose and bifurcate along strike. The strands are defined by cataclasites, ultracataclasites and mylonites which are inferred to have accommodated the majority of the deformation. Secondary structures in the form of opening mode fractures with a variety of morphologies are present both between and outside of fault core strands, defining the damage zone. These observations show that the architecture of km-scale seismogenic faults that have accumulated $\sim$100m of displacement is significantly different to published examples of the architecture of mature fault zones with 10s – 100s km displacement. The physical properties of faults are therefore likely to change with increasing displacement, and so models of the mechanisms of slip accumulation during an earthquake must be reconciled with the stage of fault zone evolution.