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Mirror fault formation and coseismic slip at surface conditions: an example of faulting in unconsolidated deposits in the Central Apennines (Italy)

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Faulting in seismically active regions commonly involves the deformation of unconsolidated to poorly lithified sediments at shallow to near-surface depths. When compared to classic crustal strength profiles that predict a velocity-strengthening behaviour for the first few km of depth, the propagation of seismic rupture to the surface appears counterintuitive. Rock deformation experiments have shown an inverse relationship between normal stress and displacement needed to the onset of dynamic weakening during seismic slip, meaning that for a seismic rupture to be able to propagate towards the surface, displacements should be large enough to counter the progressive decrease of normal and confining stresses.

In this contribution, we document the occurrence of mirror-like faults that formed within 20-30 m-thick, unconsolidated colluvium fan deposits at the hanging wall of the active Vado di Corno Fault Zone (VCFZ) in the Central Apennines, Italy. The deposits lie in direct contact with the master normal-fault surface, are Late Pleistocene to Holocene in age, and consist of angular carbonate clasts with grain size ranging ~0.1-10 mm derived from the dismantling of the adjacent VCFZ footwall. Field observations of cross cutting relationships and marker layer displacements suggest a maximum formation depth of the faults of c. 20-30 m and slip accommodated along single faults on the order of few cm. Faults are organised in three sets: subvertical, N-S and NE-SW trending faults, and WNW-ESE striking faults, synthetic and antithetic to the VCFZ master fault surface (N195/55°). Faults are commonly lineated with a dip-slip to slightly oblique kinematic.

Detailed microstructural analysis of the mirror faults shows extreme strain localization on a 2-5 μm thick principal slip zone composed of calcite nanograins ranging 10s-100s nm in size with amorphous material and phyllosilicates occurring along grain boundaries and within intragranular porosity. Locally, aggregates of nanograins coalesce and transition to μm-sized polygonal, larger grains. Calcite nanograins are mostly equant, with straight grain boundaries, 120° dihedral angles, and negligible porosity. These microstructures strongly resemble high temperature recrystallization structures documented along seismic faults exhumed from >5 km of depth, where stresses are significantly larger. In our case, field constraints show that deformation occurred in

very confining stress conditions and with limited displacement.

Collectively, our observations provide new documentation on the conditions for the formation of mirror faults and new insights into the mechanics of faulting and strain accommodation in the shallowest part of the crust (< 1 km).