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Slip localization by cataclasis and fluid-rock interaction in seismogenic crustal faults (Gole Larghe Fault, Italy)

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At nucleation depths of earthquakes in the continental crust (7-15 km), cataclastic processes and fluids interact in a complex way, affecting the mechanical properties, deformation mechanisms and fabric of fault rocks. In this study, we analyzed the effects of cumulative displacement, fault orientation and slip localization on the fabric of low-displacement cataclasite-pseudotachylyte-bearing faults in granodiorite and discuss the feedbacks between deformation mechanisms potentially controlling the transition to unstable slip.

The samples were stem from a well-exposed outcrop of the Gole Larghe Fault Zone (Southern Alps, Italy), which was active 30 Ma ago as a dextral transpressive fault at depths of earthquake nucleation (9-11 km, 250-280°C). Faults and shear fractures were digitized from an orthorectified photomosaic over an area of about 65 m^2 to quantify their spatial arrangement. Samples were stem from faults and shear fractures which accommodated increasing cumulative displacements from 0 to 4.8 m, with strikes ranging from N074 to N125. Samples were characterized by means of microstructural (field emission scanning electron microscope, optical cathodoluminescence), mineralogical (X-Ray powder diffraction), geochemical (Energy Dispersive X-Ray Spectroscopy, EMPA) and image analysis (clast size distribution and shape parameters) investigations.

Although fractures are uniformly distributed in the analyzed outcrop, 69% of the total displacement is accommodated along two main pseudotachylyte-bearing fault strands. Cataclasites consist of fragments of the wall rock (quartz, plagioclase and K-feldspar), in a matrix of K-feldspar, chlorite and epidote. With increasing displacement, the average grain size of quartz and plagioclase clasts decreases, the fractal dimension of the clast size distribution increases (from 1.6 to 2.8 in two dimensions) and the faults develop multiple domains of foliated cataclasites and non-foliated, highly comminuted ultracataclasites. If ultracataclasites or pseudotachylytes are present in the fault rocks, an increase of the displacement/thickness ratio suggests strain localization. The boundaries of quartz and plagioclase clasts in cataclasites are generally jagged, and clasts with equivalent diameters of less than 5 μm are rare, suggesting partial corrosion of the

clast’s boundaries and dissolution of the smallest fragments. Elongated clasts are often oriented at an acute angle with fault boundaries, forming foliated cataclasite domains. Their iso-orientation is more intense in faults having a higher resolved normal stress (assuming a constant far-field stress tensor), i.e., the P-shears. Foliation is associated with an incipient mineral segregation of the matrix minerals, with epidote and titanite aligned along the foliation surfaces and K-feldspar and chlorite in low-strain sites.

In agreement with experimental results, once slip localizes along highly comminuted horizons, slip appears to be further localized along it, suggesting slip weakening behavior associated with cataclastic flow. Diffusive mass transfer processes enhanced by comminution and fluid ingression allow a residual part of the displacement to be accommodated by frictional-viscous mechanisms (creep), especially at high driving stresses.