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Texture evolution in calcite gouge formed at sub-seismic slip

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Carbonate rocks are abundant in the upper crust and are notoriously seismogenic with Mw>6 earthquakes nucleating in fault zones in carbonate dominated units around the world. Field observations describe fault zones as characterised by a narrow principal slip zone at their core, containing fine, granular wear material referred to as fault gouge, produced during cumulative slip. The current literature on the link between texture and frictional properties of calcite gouges is very limited and somewhat contradictory: based on the study of a natural calcite gouge a link has been proposed between the presence of a crystallographic preferred orientation (CPO) and past seismic activity on the gouge hosting fault zone. However, similar features in terms of CPO were also identified on gouges experimentally generated at slip velocities well below the seismic ones, therefore questioning their interpretation as diagnostic of past seismic events.

We studied the evolution of friction coefficient and texture on calcite gouges experimentally produced by means of high pressure direct shear experiments on large, water saturated, intact blocks of travertine (calcite 99 % wt.). Several blocks were deformed at room temperature up to different amounts of maximum displacements (20 mm, 70 mm and 120 mm) under an imposed sub-seismic slip rate of approximately 0.1 microns/s. Microstructural characterization of the deformed blocks was subsequently carried out on samples representing the highest strained portion s of each blocks (i.e. gouge zones). Local and bulk texture of the original and deformed materials was studied by means of electron backscattered diffraction (EBSD) and neutron diffraction, respectively.

Direct shear experiments consistently indicate an evolution of the friction coefficient stabilizing at around values of 0.6 after 15 mm of slip.

Macroscopic observations on the deformed blocks indicate that deformation is localised in a narrow band of extreme grain size reduction (gouge zone): EBSD analysis show that deformation is predominantly cataclastic with little or no intracrystalline plasticity detected at the boundary between the intact and gouge zones. Cohesive wafers extracted from the gouge zones of the blocks were analysed via neutron diffraction, the results indicate that the original texture of the travertine is readily obliterated upon shearing by the development of a deformation induced texture. This is most evident in the (006) calcite pole figure developing a weak (maximum intensity of 1.7 multiples of random distributions) but distinct maximum at high angle (60-90 deg) with respect to the shear plane. This state of texture is reached after 20 mm of displacement; the intensity and orientation with respect to the shear direction seems to be little affected by the further slip during the experiments.

In conclusion, the experimentally produced gouge is constituted of an ultra fine grained matrix of nano-sized calcite that completely obliterates the initial texture of the protolith; despite the presence of nano-granular gouge the friction coefficient of travertine reaches a steady state value of 0.6; deformation texture in the gouge develops at sub-seismic slip rates as an early consequence of cataclasis and is unaffected by further deformation.