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Crystallographic control on early stages of cataclasis in carbonate fault gouges

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Carbonates are a recurring lithology in most of active seismic areas worldwide, such as the Apennines (Italy). Here, typical fault products are gouges and cataclasites made of mixtures of carbonate minerals (i.e. calcite and dolomite) that occasionally exhibit a foliation. Natural fault gouges often contain minerals with strong anisotropies, such as cleavage surfaces in phyllosilicates and carbonates. Therefore, the understanding of the role of such anisotropies during shearing is important to develop realistic microphysical models of brittle fragmentation and grain size reduction.

Here we present results of microstructural and coupled EDS-EBSD (Energy Dispersive Spectroscopy - Electron Backscattered Diffraction) analysis on mixtures (50/50wt%) of calcite-dolomite gouges deformed experimentally in a rotary shear apparatus (SHIVA, INGV-Rome) at room temperature under constant normal stress of 17.5 MPa and slip rates of 30 μm/s to 1 m/s. The EDS-EBSD analysis was focused on the gouge layer underlying the slip zone, which has been previously demonstrated to accommodate low finite shear strain during deformation.

At all investigated slip rates, calcite develops a crystallographic preferred orientation (CPO) on the (0001) plane, with the c-axis inclined subparallel to the principal stress and the [-1-120] direction forming a girdle perpendicular to it. Texture strength typically increases with slip rate and appears not to be influenced by the presence of water or foliation development in the gouge during deformation. Misorientation analysis suggests twinning as the principal crystallographic active deformation mechanism. Instead, dolomite grains do not develop a CPO.

Microfractures are closely spaced, mainly oriented subparallel to the principal stress and rarely exploit calcite twin planes. The latter typically occur at high angle with respect to fractures, are oriented consistently with the sense of shear and almost orthogonal to the principal stress. Calcite grains commonly exhibit only one twin set.

We interpret the development of a CPO in calcite grains in the layer underlying the slip zone as a strain accommodation mechanism of the imposed slip rate (or shear stress) during the early stages of deformation in a granular material (i.e. fault gouge). More intense CPOs at high slip rates (i.e. 1 m/s) may be a consequence of rapid strain localisation on a narrow slip zone, with the fabric in the underlying gouge not experiencing significant changes. Conversely, at low slip rates the gouge volume undergoing protracted deformation is larger and cataclasis progressively weakens the intensity of the texture until the CPO disappears.

In conclusion, mineral crystallography plays an important role in the material behaviour during the early deformation stages in carbonate fault gouges. An incorporation of twinning and CPO development as strain accommodation mechanisms with other physico-chemical processes active during the seismic cycle will provide a more complete model of gouge friction and microstructural evolution in carbonate rocks.