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Micro- and nano-scale study of deformation induced mineral transformations in Mg-phyllosilicate-rich fault gouges from the Galera Fault Zone (Betic Cordillera, SE Spain)

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Abstract

Naturally and experimentally deformed gouges from sliding surfaces within the Galera Fault Zone were analyzed using scanning and transmission electron microscopy (SEM, TEM) to identify changes in the fault rocks as a consequence of ongoing deformation. The two gouges studied have a particular mineral association that includes planar (mainly smectite and illite) and fibrous clay minerals (sepiolite and palygorskite). Microstructural findings include a radical difference in grain alignment between the two gouges, a phenomenon that strongly influences gouge permeability. Smectite crystals are aligned on the same orientation and show a great number of layer terminations and delamination on the basal planes that contribute to a distributed mode of deformation in the gouge. In contrast, the sepiolite-rich gouge exhibits a grid-like microfabric that results in localized deformation limited to small areas where the needle-like crystals are bent and broken producing "feather-like" structures, without the presence of lattice distortions. Meanwhile, significant chemical results include: (1) Al content identified in sepiolite fibers through analytical electron microscopy (AEM), together with variability in the (110) *d*-spacing of sepiolite across single fibers, suggest the existence of a progressive transformation from sepiolite to palygorskite. (2) Mg content in smectite suggests that a portion of the smectites within the fault plane could have an authigenic origin and may be the result of a transformation reaction from palygorskite, however, the similarity of the 2:1 layer compositions between the smectites in the two contexts do not allow to either confirm nor deny such possibility. (3) Chemical continuity of Mg-decrease and Al+Fe-increase in the octahedral cation content of the sepiolites, palygorskites, and smectites within the gouges indicate a sequence of mineral transformations that is favored by a depleted Mg content and an increase of Al content in the fluid. In this setting, deformation promotes grain size reduction and fluid-rock interaction with the wall rocks resulting in a local supply of Al to the fault gouge that drives phase transformations. Structural differences between smectites and fibrous clay minerals affect important chemical and physical properties of the gouge including their mechanical properties. We propose that the permeability of the gouges in the Galera Fault is strongly affected by their mineralogy. Furthermore, the extent of the mineral authigenesis and mineral transformations could be a controlling factor that progressively changes both the permeability and the strength of the fault.

Keywords: Fibrous clay minerals, mineral transformations, fault zones, mineralogy of fault rocks, sepiolite, palygorskite, smectite, HR-TEM