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Patterns of Illitization in a Large-Scale Fault Zone of the Southern Apennines: Inferences on Shear Zone Evolution

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The transformation of water-rich smectite clay minerals into relatively anhydrous illite is a common reaction in sedimentary basins, where it is thought to be driven by temperature increase associated with increasing depth. However, this mineral transformation has also been observed in the gauge of large faults, and since it involves the release of bound water from smectite it is suspected to have a key control on hydrologic and mechanical processes at subduction complexes.

In this contribution we report on the distribution of smectite and illite in the shear zone of a regional-scale strike slip fault of the Southern Apennines that deforms Plio-Pleistocene marine mudstones. This shear zone was analysed integrating field based observations with X-Ray diffraction analyses, a peeling technique performed on large oriented samples, grain size analyses and a consolidation test on the undeformed wallrock mudstone.

In all observed exposures the sheared mudstones are characterized by a marked darker colouring with respect to the surrounding undeformed material, and compose a 5m wide belt of intensely strained material. Lenses or streaks of relatively undeformed material, discerned by a lighter colour, are enclosed within the deformation zone and have their long axes parallel or moderately oblique to the shear zone boundaries. Both the sheared mudstones and the enclosed light coloured lenses display a pervasive foliation highlighted by the preferred orientation of desiccation cracks forming angles of 135º-180º with the shear zone boundary. The boundaries of the shear zone are extremely sharp and no damage feature was observed outside of the shear zone.

X-ray diffraction analyses indicate that the light coloured undeformed mudstones are composed by interstratified smectite/illite, chlorite and kaolinite, as clay minerals (approximately 40%), and quartz, calcite and microcline forming the non-clay fraction. The composition of the dark, sheared mudstone is identical to that of the undeformed wallrock with the only difference that it lacks smectite; therefore indicating a direct link between the darkening in colour and the disappearance of smectite.

The heterogeneous distribution of illite and smectite within the shear zone was studied integrating outcrop-scale observations with a peeling technique that allows microscope and SEM observation to be made over areas in excess of 60cm2. Several peels where obtained from different localities along the fault and from different portions of the fault zone, providing examples of a wide range of structures representing also different stages in fabric maturity. In general peels display a compositional banding parallel to the P foliation, formed by domains of smectite/illite alternating with illitic domains in which smectite has disappeared. This compositional banding, occurring with sub-millimetre spacing, is displaced by shears oriented in the Y, P and R orientations. Shears cutting through mildly deformed lenses enclosed in the shear zone, especially P and Y shears, present a filling composed by dark illitic mudstone. Microscope observation of this filling material indicates it is finer grained and its particles are aligned along 'flow' trajectories, suggesting a more ductile like behaviour with respect to the light coloured smectite/illite component.

The observed patterns of smectite illitization suggest that temperature is not the primary cause of the mineral transformation inside the fault. The distribution of illite along planes of the P foliation and in the infill of shears indicates that shear stress concentration facilitates the mineral transformation, possibly through the frictional dehydration of smectite. The release of water associated to the disappearance of smectite provides a mechanism for the local generation of high fluid pressures that can considerably facilitate fault movement and the overall mechanical weakening of the fault.