Fluid-sedimentary rock interactions and mineralogical changes related to deformation and fluid circulation along thrust fault (Southern Pyrenees)

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The behaviour of crustal discontinuities is closely linked to fluid circulation, fluid-rock interactions and newly formed minerals, specially phyllosilicates. The present study focuses on two thrust faults located in the southern Pyrenees, Spain, related to the emplacement of the Monte Perdido nappe and affecting Paleocene and Lower Eocene clay-rich sediments. The first studied fault zone (Millaris) corresponds to a décollement fault in the Monte Perdido unit affecting the Millaris marls. It is characterized by a few meters thick shear zone with mineralized veins and highly deformed clays with intense scaly foliation. The second studied fault zone (Torla) corresponds to the major sole thrust of the Monte Perdido, with about 3 km displacement above the underlying Gavarnie unit. The hangingwall and footwall are composed of Paleocene carbonates and Lower Eocene turbidites, respectively. The shear zone, a few meters thick, is mainly developed in the footwall and contains numerous mineralized veins in a highly deformed clay-rich interval.

Each thrust fault zone is characterized by intensely cleaved black shale with different generations of mineralized veins (calcite and quartz). Kinematic markers associated with both the scaly fabric and shear veins indicate top to the South displacement along thrust faults compatible with regional structures. SEM observations, and XRD, microprobe and isotopic analyses have been performed in order to study mineralogical changes and fluid-sediment interactions related to deformation and fluid circulation along the thrusts. Additionally analysis of fluid-inclusion were used to constrain the temperature of the fluids. In both studied area, three generations of veins have been observed. The two first vein generations are syn-kinematic, whereas the third one is post-kinematic, probably due to an increase of interstitial fluid pressure. Calcite is the major mineral in these veins but quartz is also present in the first vein generation. In the Millaris fault zone, isotopic ($\delta^{13}C$ and $\delta^{18}O$) and chemical studies of the calcite veins suggest that the fluid inducing the calcite crystallization did not vary with time and was an interstitial fluid equilibrated with the surrounding rocks. In the Torla deformation zone, the fluids inducing calcite crystallization in veins also had local interstitial origin. A preliminary fluid inclusion study indicates minimum temperature of precipitation of about 180°C. Clay minerals of the surrounding protolith formations are illite and chlorite. The proportion of chlorite is more important in the deformation zones: newly formed chlorite is observed on the intensively deformed black shale as veins or inside the scaly foliation. No evidence of illite transformation has been found at the SEM scale. However, XRD data (IC measurements) suggest that the size of illite crystals decreases in the intensively deformed black shale from the Millaris fault zone.

This study indicates that in these two local and regional thrust fault zones, fluid circulation was limited in scale. The interstitial fluids of the surrounding formations induced the precipitation of calcite, quartz and chlorite in veins during the deformation processes. These mineralogical changes might have modified the rheological properties of the faults.