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Low grade metamorphism fluid circulation in a sedimentary environment thrust fault zone: properties and modeling

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In fold-and-thrust belts, shortening is mainly accommodated by thrust faults that can constitute preferential pathways for fluid circulation. The present study focuses on the Pic de Port Vieux thrust, a second-order thrust related to major Gavarnie thrust in the Axial Zone of the Pyrenees. The fault juxtaposes lower Triassic red siltstones and sandstones in the hanging-wall and Upper Cretaceous limestone in the footwall. A dense network of synkinematic quartz-chlorite veins is present in outcrop and allows to unravel the nature of the fluid that circulated in the fault zone.

The hanging wall part of fault zone comprises a core which consists of intensely foliated phyllonite; the green color of this shear zone is related to the presence of abundant newly-formed chlorite. Above, the damage zone consists of red pelites and sandstones. Both domains feature kinematic markers like S-C type shear structures associated with shear and extension quartz-chlorite veins and indicate a top to the south displacement. In the footwall, the limestone display increasing mylonitization and marmorization when getting close to the contact.

In order to investigate the mineralogical and geochemical changes induced by deformation and subsequent fluid flow, sampling was conducted along a complete transect of the fault zone, from the footwall limestone to the red pelites of the hanging wall.

In the footwall limestone, stable isotope and Raman spectroscopy analyzes were performed. The strain gradient is strongly correlated with a high decrease in $\delta^{18}O_{VPDB}$ values (from -5.5 to -14‰) when approaching the thrust (i.e. passing from limestone to marble) while the deformation temperatures estimated with Raman spectroscopy on carbon remain constant around 300°C. These results suggest that deformation is associated to a dynamic calcite recrystallization of carbonate in a fluid-open system.

In the hanging wall, SEM observations, bulk chemical XRF analyses and mineral quantification from XRD analyses were conducted in order to compare the green phyllonites from the fault core zone with the red pelites from the damage zone. Quartz, muscovite 2M1, chlorite (clinochlore), calcite and rutile are present in all samples. Hematite occurs in the damage zone but is absent in the core zone.

Synkinematic chlorites are abundant in the core and damage zones and are mainly located in veins, sometimes in association with quartz. The temperature of formation of these newly-formed chlorites is 300-350°C according to Inoue (2009) geothermometer.

Mössbauer spectroscopic analyses were performed on bulk rock samples. In the damage zone, Fe^{3+}/Fe_{total} vary between 0.7 and 0.8, whereas in the core zone Fe^{3+}/Fe_{total} is about 0.35. This decrease in Fe^{3+} from the damage zone to the core zone can be related to the dissolution of hematite. In contrast, Fe^{3+}/Fe_{total} in phyllosilicates is clearly related to the chlorite content relative to mica, as Fe^{2+} increases with chlorite content.

All these data allow us to propose a model of fluid circulation in relation with the Pic de Port Vieux thrust activity. The origin of the fluid, its interactions with host-rock and the consequences on fault zone mineralizations will be discussed.

Inoue, A., Meunier, A., Patrier-Mas, P., Rigault, C., Beaufort, D., Vieillard, P., 2009. Application of chemical geothermometry to low-temperature trioctahedral chlorites. Clay Clay Min. 57, 371–382.