



Syn-orogenic fluid flow in the Jaca basin (South Pyrenean Fold and Thrust Belt) from fracture and vein analyses

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This study aims at understanding the origin and nature of syn-orogenic fluid flow in the Jaca basin from the South Pyrenean fold and thrust-belt, recorded in calcite and quartz veins of the Sierras Interiores (Spain) and the turbiditic basin, which cover upper Cretaceous to Late Eocene syntectonic deposits. The fracture network consists of a classical pattern of transverse and longitudinal fractures with respect to folds, that we propose to be related to Layer Parallel Shortening (LPS) and folding respectively. Veins filled equally about the third of fractures in the carbonate shelf and turbidites. Carbon and oxygen isotopes of calcite veins mostly indicate precipitation from isotopically buffered water, consistent with high water-rock interaction. In the Sierras Interiores, petrographical observations and fluid inclusion microthermometry are consistent with two distinct stages of precipitation. The first stage is characterized by relatively low T_h and low salinities (155-205° C and 0.5-3.2 wt% eq. NaCl respectively). The second stage, characterized both by the formation of mode-I joints and by mode-I reactivation of preexisting veins, shows higher T_h and salinities (215-270° C and 2.2-5.7 wt% eq. NaCl respectively). Low salinities recorded during the first stage suggest dilution of marine water by fresh water expelled by the smectite to illite transformation at $T < 200^\circ\text{C}$. Waters recorded in the second stage are interpreted to have interacted with underlying Triassic evaporites and flowed along major thrusts before vein precipitation, which are locally in thermal disequilibrium with host-rocks. We suggest the transition from a rather closed hydrological system during the first stage of vein formation, interpreted to have occurred during Eaux-chaudes thrusting (upper Lutetian-Bartonian), to a more open hydrological system during the second stage, which likely occurred during Gavarnie thrusting (Priabonian-early Rupelian). This evolution exhibits many similarities with other fold-and-thrust belts, except in the limited involvement of meteoric water. Finally, we also document the migration in space and time of hydrothermal pulses along the South Pyrenean Foreland Basin, related to the westward propagation of major thrusts during the Pyrenean orogeny.