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Evolution of fluid flow systems during the localization of the deformation: the example of the External Crystalline Massifs, Western Alps.

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Fluid circulations in the crust are known to be channelized through active faults or shear zones. Away from highly deformed zones, fluid circulations remain local and fluids are mostly at geochemical equilibrium with host-rocks. If each of these two end-member systems, open and closed, has been largely described in different areas, the transition in space and time from closed to open systems remains poorly documented.

Here, we focus on the Alpine collisional crustal wedge, resulting from the inversion of the Liassic proximal European continental margin, after its burial to mid-crustal depth (greenschist metamorphic facies) during Oligo-Miocene times, beneath the Penninic units. The crust was shortened with a thick-skinned style, with cover dysharmonically folded above distributed basement shear zones. In weakly shortened parts of the alpine arc (e.g. Oisans), shear zones did not propagate into the cover where the deformation is still very diffuse whereas they extended upward into the cover in sections of the alpine arc that experienced more shortening (e.g. Mont-Blanc).

In this contribution, we first present coupled microstructural and geochemical analyses of both basement and cover rocks in two inherited basins from western Alps (Oisans and Grandes Rousses External Crystalline Massifs, ECM). Isotopic (18O and 13C) and microthermometric analyses coupled to SEM and cathodoluminescence observations suggest that, in cover rocks, fluid circulations remained restricted to the stratigraphic unit scale. However, trace element analyses highlight an upward percolation of small amounts of basement-derived fluid into cover rocks above basement shear bands. However, in the absence of basement shear zone propagation into the cover, the percolation of basement-derived fluids was restricted to a few tens of meters. Finally, from coupled microthermometric and isotopic analyses, we give better constraints on the fluid pressure and temperature. Those P-T conditions (250-400 °C and 2-5 kbar) highlight that basin inversion initiated near metamorphic peak conditions.

By comparing our results with available fluid data for other ECM, we propose a conceptual model of the evolution of the crustal fluid circulation in the ECM with progressive shortening. This model highlights that investigation of metamorphic fluids sources and pathways can be an important key to the understanding of deformation pattern, as for the involvement of basement in shortening. In southern ECM (Oisans), in the absence of channelizing deformation structure for fluid flow in cover rocks, small amounts of basement-derived fluids percolated into the cover, without controlling the vein mineral isotopic signal. On the contrary, further North (Aar massif), basement shear zones propagated into the cover and large-scale circulation of exotic fluids was recorded by isotopic data in cover rocks. Moreover, fluid circulations were also channelized into the main thrusts of large cover nappes (e.g. Glarus Thrust).

Although the structural styles are different in details, southern ECMs may illustrate an early stage of shortening compared to northern ECMs. Therefore, the above-presented scenario can be read as a likely evolution of fluid systems through time and progressive localization of the collisional shortening.