Timing of fault gouge formation and fluid-rock interaction during tectonic inversion of the Penninic Frontal Thrust (SW Alps)

Antonin Bilau1,2, Yann Rolland1,2, Stéphane Schwartz2, Nicolas Godeau3, Abel Guihou3, Pierre Deschamps3, Cécile Gautheron4, Rosella Pinna-Jamme5, Benjamin Brigaud5, Xavier Mangenot5, Aurélie Noret4, Jérémie Melleton6, and Thierry Dumont2

1EDYTEM, Université Savoie Mont Blanc, 73, France (antonin.bilau@univ-smb.fr)
2ISTerre, Université Grenoble Alpes, 38041 Grenoble, France.
3GEOPS, Université Paris-Saclay, 91405 Orsay, France.
4CEREGE, Université Aix-Marseille, 13545 Aix-en-Provence, France.
5CALTECH, Geological and Planetary Sciences, 91106, Pasadena, CA, USA.
6BRGM, 45060 Orléans, France.

In the last decade, important improvements in dating methods have been made and make it possible to go into the details of fault gouge formation and evolution. Common minerals like calcite and hematite can now bring detailed information on timing of fault development and fluid-rock interaction. We applied those novel techniques to a tectonically well constrains alpine context, though still lacking key chronological constrains. The targeted fault zone is the Penninic Frontal Thrust (PFT) of SW Alps, which is a major tectonic boundary that juxtaposed the metamorphic internal Alps over the unmetamorphosed external Alps, primarily as a thrust during the Oligocene (Simon-Labric et al., 2009). The PFT was later reactivated as an extensional detachment in the Mio-Pliocene, though the age of this reactivation remained unconstrained. Sue and Tricart (2003) showed that ongoing extensional seismic activity along the PFT, corresponding to the High-Durance Fault System (HDFS), is characterized at the surface, by an extensional fault network. In this context, the HDFS corresponds to extensional reactivation of the PFT as a consequence of Pelvoux external crystalline massif exhumation.

In this study, we coupled field tectonic, in-situ calcite U-Pb and hematite (U-Th-Sm)/He dating to stable and clumped isotope analysis to infer the HDFS activation age and to investigate the related fluid circulations. Isotopic signature (δ13C and δ18O) of compressional veins, en-echelon extensional veins and cataclasite fault gouge have been determined (Bilau et al., 2020).

This study allows pinpointing the evolution of deformation and fluid-rock interaction in the PFT footwall during its progressive extensional exhumation. The older U-Pb ages obtained on the cement of the gouge fault range between 5 to 3.5 Ma and taking into consideration uplift rate, comparison to currently seismicity depth and calcite brittle/ductile transition temperature, calcite crystallization may have occurred between 5 to 2 km. The hematite crystallization appears at shallower levels in the latest stages of the fault displacement at 3-1 km depth. A transition in the
nature of fluids, controlling the redox state, can be highlighted here. This transition occurs between the calcite and hematite forming events at 2-3 km depth, which is probably related to a significant influx of meteoric fluids into the drainage of the fault system.