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Calcite - Hematite dating, stable and clumped isotopes record the history of fault activity, exhumation and climate in the Internal Alps (Penninic Frontal Thrust and Briançonnais Zone)

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Faults are vectors of large-scale fluid circulations. Multiple circulation events can be recorded within fault breccias. The isotopic signature of the precipitated minerals provides information on the origin and nature of the involved fluids.

In the Alps, along the Penninic Frontal Thrust (PFT) in the 'Briançonnais Zone' (BZ), a calcite + hematite paragenesis has been observed in the High-Durance-Fault System breccias. Last Myrs exhumation of the BZ has been constrained using a multidisciplinary approach of fault breccias comprising a petrological study, a geochemical analysis of calcite (stable isotopes and clumped isotopes analysis) and dating of both minerals using the U-Th-Pb system.

U-Pb ages on calcite obtained on extensional faults reactivating the PFT range within 3.5-2.5 Ma. A complementary age of 5.5 Ma has been obtained to the East, within the BZ, which indicates that the extensional seismotectonic regime that is currently recorded in the area has been active since at least that time. The calcites have a $\delta^{13}C$ and $\delta^{18}O$ signature close to that of calcites from the External Crystalline Massifs, indicating a more open system with a Δ_{47} calcite crystallisation temperature of around 130°C and a $\delta^{18}O_{fluid}$ signature of -4‰. These hot fluids are likely mobilised by faults when merging on relatively deep portions (>3 km) of the PFT. (U-Th)/He ages on hematite in the BZ range from 12.7-8.4 Ma, and from 2 Ma to 0.1 Ma within the PFT. Hematite records the ingress of meteoric fluids during the last phase of exhumation, while the zone is dominated by the influence of surface-derived fluids. The crystallization of hematite is related to the alteration of a ferralitic paleosurface developed in a Mediterranean climate. Based on D_{47} ratios, crystallization temperatures of ~35°C are recorded (similar as hydrothermal springs in the region along the same fault system) with related $\delta^{18}O_{fluid}$ signature of -12‰, corresponding to meteoric fluid which precipitated at an altitude of 1900m. These data indicate that an altitude similar to the present one was already present 2 Ma ago, while the transition from Mediterranean climate to a colder glacier-dominated climate resulted in the digging of valleys since then.