Timescale of deformation and fluid circulations in the external crystalline massifs of the Western Alps

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Fluid/rock interactions associated with deformation are difficult to date because they generally occur in open and multistage systems. In Alpine clefts (open fissures partly filled by hydrothermal crystals), hydrothermal monazite can reach several millimetres, providing a unique opportunity to investigate the time, duration and periodicity of hydrothermal activity in link with deformation. In the external crystalline massif of the Western Alps (Lauzière granite), a multi-method approach reveals unusually hot hydrothermal conditions in a vertical cleft that is oriented perpendicular to sub-vertical mylonitic microstructures of the host granite. This granite shows partial retrogression at temperatures of <400°C during Alpine tectonometamorphism. The investigated Alpine cleft is mainly filled with quartz, albite, adularia, chlorite, and contains numerous species of accessory minerals including mm-sized monazite. Cleft monazite ages were determined by in-situ isotopic dating on different compositional domains in four grains. The mean Th-Pb age at 12.4 ± 0.1 Ma (MSWD = 1.7; N= 86) indicate that hydrothermal monazite grain precipitated over a relatively short geological time. Novel microthermometric data and chemical compositions of fluid inclusions obtained on monazite and on quartz crystals from the same cleft indicate early precipitation of monazite from a hot fluid at T>410°C, followed by a main stage of quartz growth at 300-320°C and 1.5-2.2 kbar. Comparison of monazite crystallization ages with ZFT data in samples taken at 30 and 100 meters distance from the cleft, indicates that the hot fluid infiltration (T>410°C) took place when the host-rock had already cooled to T<280 °C. The advective heating, due to the hot fluid flow in the colder host-rock, is recorded by the ZFT in the cleft hanging wall, with a younger age at 10.3 ± 1.0 Ma compared to the ZFT far from the cleft (14-16 Ma). The results attest of highly dynamic fluid pathways, allowing the circulation of deep mid-crustal fluids, 150-250°C hotter than the host-rock, which affect the thermal regime only at the wall-rock of the Alpine-type cleft. Such advective heating may impact the ZFT data and represent a pitfall for exhumation rate reconstructions in areas affected by hydrothermal fluid flow.