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Advective heating in Alpine fractures during exhumation of the Lauzière granite in the external crystalline Belledonne massif

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In the Lauzière granite (external crystalline massif, Belledonne, Alps, Wetsern Alps), a multidisciplinary approach was used to constrain the timing of hydrothermal activity and its influence on the geothermal gradient of the neighbouring rocks. The samples were collected within a metric cleft (a fissure partly filled with hydrothermally grown minerals) and within the granite host-rock, taken at different distances from the cleft. The granite shows mylonitic microstructures and different degrees of alpine retrogression (350-300 °C). The cleft is mainly filled by quartz, albite, adularia, chlorite. It also contains numerous species of accessory minerals such as anatase, rutile, ilmenite, hematite, apatite, monazite or xenotime that can reach several millimeters in size. Clef monazite age was determined by in-situ isotopic Th-Pb dating on different compositional domains of four grains. Within a single grain, monazite ages, obtained in domains with distinct compositions, overlap. This indicates that hydrothermal monazite grain precipitates over a relatively short geological time period around a mean age of 12.4 $\pm$ 0.1 Ma (MSWD = 1.7; N= 86). In order to constrain the conditions of monazite precipitation, fluid inclusions analyses have been attempted in quartz and monazite. Microthermometric data for fluid inclusions indicate that monazite precipitated in the earliest stage of the vein formation from a hydrothermal fluid with a temperature probably ($\sim$450-500 °C). Whereas few quartz fluid inclusions record this early hot fluid, most of them indicate a main quartz growth phase at temperatures around 300-330 °C and 1.6-2.1 kbar, which convert into a geothermal gradient of 40-50 °C/km. In the host-rock, exhumation age and the impact of fluid infiltration were investigated from zircon fission track (ZFT) dating in the host-rock. In samples far from the cleft, ZFT ages indicate that metamorphism was high enough to reset the pre-alpine ages: the Lauzière granite mainly cooled down to temperatures of <240-280 °C at around 16.3 $\pm$ 1.9 to 14.3 $\pm$ 1.6 Ma. At the cleft contact, the younger ZFT ages at 10.3 $\pm$ 1.0 Ma indicate that advective heating due to hydrothermal activity was enough to partly reset the ZFT age. The thermochronological data and fluid inclusion analyses indicate a limited fluid flux, and hydrothermal precipitation within the cleft over a relatively short-duration (<3 My). This study also confirms the crucial role of fluid circulations on ZFT resetting and the possible impact they can have on exhumation reconstruction.