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Stable isotope and Ar/Ar evidence of prolonged multi-scale fluid flow during exhumation of orogenic crust: example from the Mont Blanc and Aar massifs (NW Alps)

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The spatial and temporal scales and the geometry of fluid pathways in a collisional orogen are investigated using stable isotope analysis (O, C, H) and 40Ar/39Ar dating of vein minerals formed at c. 11-16 Ma in the Mont Blanc and the Aar External Crystalline Massifs. In both massifs 40Ar/39Ar dating of veins adularia provides evidence for progressive crystallization from 16 to 9 Ma, and mainly at 11-12 Ma following veins opening during shear zone activity. The fluid flow duration thus ranges from 4 to 5 Ma in the two massifs. The δ18O values of vein quartz and calcite are similar to those of undeformed crystalline and sedimentary host-rocks, suggesting rock buffering, while carbon isotope ratios of vein calcites fall into three compositional groups. A-type veins have δ13C values that are buffered by the Helvetic metasediments, which suggests that these veins formed in a closed-system from a locally-derived CO_2-rich fluid. The fluid in equilibrium with C-type veins has depleted δ13C values similar to mantle-CO_2, while the intermediate δ13C values of B-type veins suggest mixing between the A-type and C-type fluids. These results are in agreement with crustal- to lithosphere-scale upward vertical fluid flow along vertical shear zones related to the strike-slip system bounding the Adriatic block since 16-20 Ma, connecting a deep-seated fluid to some downward flow in the sedimentary cover of External Crystalline Massifs.