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Tracing fluids in metamorphic rocks with oxygen isotopes

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Oxygen isotopes are an efficient way of tracing fluid flow in metamorphic rocks, provided that different mineral generations and domains can be analysed. This is best achieved by in situ secondary ion mass spectrometry (SIMS) analysis. The use of oxygen isotopes to trace fluids in evolving metamorphic systems requires knowledge of closed system isotopic fractionation and changes in mineral assemblage over the P-T evolution of the sample. We have developed the PTLOOP package to model open and closed system behaviour along P-T paths (Vho et al. 2020).

We have used the oxygen isotopic composition of major rock-forming minerals such as garnet, mica, serpentine and olivine to study fluid flow and dynamics during subduction. In subducted serpentinites, the isotopic composition of serpentine and metamorphic olivine allows the identification of structures (shear bands, shear zones and veins) where isotopic disequilibrium is indicative of fluid channelling (Ulrich et al. 2024). Oxygen isotopes are also used to identify metastable phases such as the preservation of oceanic lizardite in high-pressure serpentinites with implications for delayed fluid release (Vesin, Ulrich et al. 2024).

The low ∂^{18}O fluids released by serpentinite dehydration can be traced in the overlying sediments, where both channelled and pervasive flow can be recognised. Zones of high fluid flow and hence higher permeability do not necessarily correspond to lithologies, but may be favoured by lithological boundaries. Time-integrated pervasive fluid flow on the order of 10^5 cm^3/cm^2 can occur over kilometric scales, particularly in metasediments (Bovay et al. 2021). We propose that (transient) high permeability at high pressure is caused by volume changes associated with metamorphic reactions, such as the breakdown of lawsonite.

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