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An empirical calibration of the serpentine-water oxygen isotope fractionation at T = 20 to 90 °C

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Serpentinization plays an important role in fluid and mass transfer between the ocean, the crust, and the mantle, in biogeochemical processes, and CO_2 sequestration within oceanic and continental settings. The physical-chemical conditions of serpentinization, such as temperature and fluid source, are often investigated using oxygen isotopes. However, the ability to precisely constrain such parameters is limited by the accuracy of calibrations for oxygen isotope fractionation between serpentine and water – i.e. 1000 lnα(Srp-w) – which disagree by up to 20‰ when extrapolated to T < 200 °C [1-5]. In this study, we present a new empirical calibration of 1000 lnα(Srp-w) aiming to improve applications of oxygen isotope thermometry to very low-T serpentinization (T < 100 °C).

We used the high-spatial resolution capabilities of Secondary Ion Mass Spectrometry (SIMS) to analyze oxygen isotope ratios in mineral pairs of calcite+serpentine, quartz+serpentine and talc+serpentine co-crystallized at scales ≤ 50 µm in six serpentinite samples from the Samail ophiolite (Oman). SIMS analysis shows that the mineral pairs are relatively homogeneous in oxygen isotope ratios with variability in $\delta^{18}O$ values ≤ 2‰ (2s). Clumped isotope thermometry and petrological constraints indicate crystallization temperatures from ~20 to 90 °C for the investigated samples [6,7]. These independent constraints on temperature allowed us to derive 1000 lnα(Srp-w) by combining mineral-serpentine oxygen isotope fractionations measured by SIMS with published mineral-water oxygen isotope fractionations. Our empirical calibration of 1000 lnα(Srp-w) = $1.12 \pm 0.42 \times 10^6/T^2$ (T in K), from T = 20 to 90 °C, is within uncertainty of former high-temperature empirical calibrations [1,4] extrapolated to T < 100 °C.

The new 1000 lnα(Srp-w) calibration enables more accurate reconstructions of fluid-rock interactions occurring during low-temperature serpentinization processes in various tectonic settings.

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