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Strategies for oxygen isotope thermometry for high-temperature rocks in the age of SIMS

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Thermometry based on equilibrium isotope fractionation was the first, and continues to be the most ubiquitous, application of the oxygen isotope system. However, recognition that oxygen isotope compositions of rocks and minerals can be heterogeneously reset by diffusion and recrystallization complicates isotope thermometry in high-temperature rocks. Secondary ion mass spectrometry (SIMS) can target mineral zones and microstructural features to reveal $\delta^{18}O$ variations correlated with growth, recrystallization, diffusion, and/or deformation. Here we review examples that provide strategies for identifying and measuring equilibrium $\delta^{18}O$ fractionations that are suitable for oxygen isotope thermometry in deformed midcrustal rocks.

The exhumed footwalls of metamorphic core complexes provide test cases in which midcrustal rocks have potentially been affected by high thermal gradients and fluids. In the Whipple Mountains core complex, we measured quartz and epidote $\delta^{18}O$ *in situ* by SIMS for samples at different structural depths below the main detachment fault. To assess possible microstructural controls on isotopic equilibrium, we compared epidote-quartz inclusion versus (dynamically recrystallized) epidote-matrix quartz $\delta^{18}O$ pairs. We found similar fractionations for all types of mineral pairs at each sampled structural depth. Comparison of δ-δ plots for different structural depths revealed a large spread in apparent equilibrium temperature near the Whipple detachment converging toward a single, likely equilibrium, temperature with increasing distance below the detachment. In footwall mylonites of the Buckskin-Rawhide core complex, we used SIMS to measure *in situ* $\delta^{18}O$ of quartz, plagioclase, K-feldspar, and biotite. SIMS transects of feldspar porphyroclasts identified primary magmatic cores and recrystallized rims, which are texturally and compositionally linked to myrmekite and biotite neoblasts. Similarity of Pl-Bt and Kfs-Bt $\delta^{18}O$ apparent temperatures suggested that fluid-assisted feldspar recrystallization and biotite crystallization occurred at 400-440°C. Mineral pairs involving quartz gave much lower and more variable apparent temperatures, the hallmarks of disequilibrium. In both the Whipple and Buckskin core complex rocks, forward modeling of simple temperature-time histories with Fast Grain Boundary software [1] provided an additional tool to assess the potential contribution of diffusion toward intragrain oxygen isotope zonation and disequilibrium.

[1] Kropf, Bonamici & Borchers (2021) *Computers & Geosciences* 151, 104753.