Modern and ancient hydrosphere-rock interactions constrained from triple oxygen isotope and in situ $\delta^{18}O$ measurements

DAVID ZAKHAROV[1, 2], RYOJI TANAKA[3], DAVID BUTTERFIELD[4], MARK REED[2], JAMES PALANDRI[2], ILYA BINDEMAN[2], ANNE-SOPHIE BOUVIER[1] AND JOHANNA MARIN-CARBONNE[1]

[1]Institute of Earth Sciences, University of Lausanne, Switzerland; david.zakharov@unil.ch
[2]Department of Earth Sciences, University of Oregon, USA
[3]IPM, Okayama University, Misasa, Japan
[4]University of Washington, NOAA/PMEL, USA

We apply triple oxygen isotope ratios to examine water-rock reaction in modern and ancient marine hydrothermal systems. Values of $\Delta^{17}O$, measured at per meg precision, complement $\delta^{18}O$ values by enabling study of sources of fluids, mixing, temperature of alteration, progress of water-rock reaction, near-surface boiling and effects of imposed metamorphism. We measured geothermal fluids from the Icelandic systems [see 1] and vent fluids from the Axial Seamount volcano of the Juan de Fuca ridge. These measurements define the trajectories of triple oxygen isotope exchange during water-rock reaction at >250 °C. On average the fluids are 0.01-0.02 ‰ lower in $\Delta^{17}O$ and 0.5-2 ‰ higher in $\delta^{18}O$ than the local sources. We also observe ±20 ‰ fractionation of δD in Icelandic fluids owing to shallow boiling, but no significant $\Delta^{17}O$ fractionation is observed [1]. The vent fluids from the Axial Seamount system were collected at T from 173 and 341 °C; their Mg concentrations span 2-23 mM and negatively correlate with their $\delta^{18}O$. The progress of seawater-basalt reaction is defined with the slope of 0.513 ± 0.007 (mean ± SE, n=11) constructed in $\delta^{17}O$-$\delta^{18}O$ coordinates and by the lowest $\Delta^{17}O$ value of –0.026 ± 0.006 ‰. This slope characterizes the contribution of hydrothermal alteration into the triple oxygen isotope budget of terrestrial hydrosphere. In addition to the $\Delta^{17}O$, we measured $\delta^{18}O$ *in situ* by SIMS in single quartz crystals that were extracted from the zones of high permeability at the pillow basalt-sheeted dike transition intersected by the IODP drill hole at site 504B. The studied quartz crystals contain CL-bright and CL-dark zones with distinctly different $\delta^{18}O$ values of 8.0±0.8 ‰ and 15.4±0.5 ‰. They likely record multiple regimes of hydrothermal circulation of seawater at around 330 °C and 160 °C. These *in situ* measurements provide a record of cooling history of the oceanic crust and help to interpret the $\Delta^{17}O$ data. Ref: [1] Zakharov et al. (2019) Chemical Geology, **530**, 119312