



Variations of oxygen isotope signatures in hydrothermal systems

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Oxygen isotope signatures from quartz in hydrothermal veins and metasomatized rocks are widely used to constrain fluid sources and paths. Previous theoretical studies have focused on isotopic evolutions during isothermal fluid flow. However, mass and energy transport in dynamic hydrothermal systems is typically non-isothermal with flow across thermal fronts and gradients. We present results from numerical simulations describing how temperature changes, transport phenomena, kinetic vs. equilibrium isotope exchange, and isotopic source signals determine mineral oxygen isotopic compositions during fluid-rock interaction (Fekete et al., 2018). The simulations reveal a previously unrecognized, significant enrichment in ^{18}O isotopes in fluids and minerals at thermal fronts. The maximum value from this enrichment process depends on the initial isotopic composition of fluid and mineral, the fluid-rock ratio and the maximum change in temperature, but is independent of the isotopic composition of the incoming fluid, because the thermally induced isotope front propagates faster than the signal related to the initial isotopic composition of the incoming fluid. These two fronts are most prominent for fast isotope exchanges between fluid and rock. In kinetically limited scenarios, the shape and maximum values at these two fronts are altered and a third isotopic front develops, which travels fastest with the pore velocity of the incoming fluid. Variations of oxygen isotope signatures can further be influenced by phase separation, which can lead to fractionation processes and non-uniform temperature profiles along the flow path. The simulations show how the resulting stable isotope signatures can easily be misinterpreted, but on the other hand document how high-resolution in-situ techniques such as secondary ion mass spectrometry (SIMS) combined with quantitative models can provide new insights into the transient thermal and hydrological evolution of a system.

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