

Tracking water-rock interaction in fractured crystalline rocks by Li isotope fractionation

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The successful operation of enhanced geothermal systems (EGS) is mainly dependent on the fracture surface area created during hydraulic reservoir stimulation. Fluid circulation within a stimulated reservoir alters the created fracture surface area by mineral dissolution/precipitation reactions. Ideally, the stimulated fracture surface area can be estimated by quantifying the corresponding reaction rates. The use of Li isotope is a promising tool because, owing to their large mass difference, the two stable Li isotopes (⁶Li, ⁷Li) significantly fractionate during alternation of primary silicate minerals and formation of secondary minerals.

We present Li isotope measurements of water samples collected during drilling of the 57 km long Gotthard rail base tunnel in Switzerland, to explore the use of Li isotope measurements to track water-rock interactions in fractured crystalline rock at temperatures of up to 50°C. Our 17 samples originate from water conducting fractures within two specific granitic rock units, which are characterized by a similar rock mineralogy, but significantly different fluid composition. In particular, the aqueous Li concentration observed in samples from the two units varies from 1.5-3.5 mg/L to 0.01-0.05 mg/L. While $\delta^7\text{Li}$ measurements from the unit with high [Li] showed very little variation ($\delta^7\text{Li}=8.5\text{-}9.1\text{‰}$), a large variation was observed for the samples from the unit with low [Li] ($\delta^7\text{Li}=10\text{-}41\text{‰}$). This observation demonstrates that Li isotope fractionation is highly sensitive to aqueous [Li]. Moreover, $\delta^7\text{Li}$ values from the low [Li] unit correlate well with reaction progress parameters such as the pH and the [Li]/[Na] ratio, suggesting that $\delta^7\text{Li}$ values are mainly controlled by the residence time within the fracture. Consequently, 1D reactive transport modeling was performed to simulate mineral reactions and associated Li isotope fractionation along a particular water conducting fracture using TOUGHREACT. Preliminary modeling results infer that for well-defined systems with low [Li] and thus strong $\delta^7\text{Li}$ variations reactive fracture surface areas can actually be estimated (i.e., calibrated) by matching measured $\delta^7\text{Li}$ values.