Hydration of the Icelandic crust traced by hydrogen isotopes – Implications for the water budget of the oceanic crust

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Hydration and subduction of oceanic crust plays a critical role in the Earth's water cycle as the oceanic crust is a major transport medium of water into the mantle wedge and the convecting mantle. However, hydration of the oceanic crust is often difficult to quantify. For example, marine sediments covering the seafloor as well as low core recoveries with depth limit the access to the igneous oceanic crust. Thus, active geothermal systems situated at on-land spreading centers (e.g., Iceland) provide a unique opportunity to study the hydration of the oceanic crust, with well constrained systems and boreholes reaching depths of >4 km.

Here, we present hydrogen isotope (δD) data of altered basalt for two Icelandic geothermal systems: the meteoric water and seawater fed geothermal systems at Krafla and Reykjanes, respectively. The δD values of altered and hydrated basalts from these localities, which exhibit significantly higher water contents (up to 4.15 wt.%) than pristine (non-hydrated) basalts, vary greatly from -125 to -100‰ at Krafla and from -72 to -59‰ at Reykjanes.

Comparison of isotope modeling results to the natural data demonstrates that δD variations and hydration of basalt are controlled by (1) the isotope composition of the source fluid, (2) isotope fractionation between aqueous geothermal fluids and the alteration minerals formed, and (3) the type and quantity of alteration minerals formed that depend on both the extent of fluid-rock interaction and temperature.

Using the same modeling approach, we assessed the hydration state and δD values of the oceanic crust as a function of depth. We show that 900 to 1165 Tg H_2O/yr is added to the igneous oceanic crust upon alteration by seawater of which 60-70% is hosted in the upper part (<2 km) of the oceanic crust. The corresponding δD composition of the hydrated crust was calculated to range from ~ -58 to -27‰.