

Carbon isotope systematics of Icelandic low-temperature geothermal waters

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Dissolved inorganic carbon (DIC) is among the major elements in geothermal fluids. In order to trace the sources and reaction of dissolved inorganic carbon in <100°C geothermal water, the stable carbon isotope systematics in Iceland were studied together with geochemical isotope modeling. Samples of geothermal water were collected and analyzed for major and stable carbon isotope composition. The waters had temperatures of 3-97°C, pH of 6.18-10.15 and DIC of 1.8-2853 ppm. The stable carbon isotopes ratios were $\delta^{13}\text{C}$ -1.46 to -13.96‰.

The source of DIC in the geothermal water is considered to be the meteoric source water, rock dissolution and organic matter. In addition, progressive water rock interaction and carbonate (calcite) formation may alter the $\delta^{13}\text{C}$ systematics. In order to quantify the source and reactions of DIC three approaches were applied: carbonate mineral saturation, component mixing model and reaction path isotope modelling. The geothermal waters were observed to be calcite saturated, however, the source of the carbon in the water and the possible formation of calcite, along with the stable carbon isotope systematics cannot be explained simply by rock dissolution, atmospheric CO_2 input and organic matter decay. Instead, progressive basalt dissolution, aqueous speciation, and calcite formation play a major role in carbon isotope systematics and the carbon concentration of the low-temperature geothermal water. For waters containing low CO_2 concentrations (<50 ppm) and low $\delta^{13}\text{C}$ values (-5 to -15‰) the CO_2 is considered to be derived from both atmospheric source and primary rock dissolution. The variations of $\delta^{13}\text{C}$ ratios are related to the variations of primary rock $\delta^{13}\text{C}$ ratios as well as carbon isotope fractionation upon progressive water-rock interaction and the subsequent pH increase that leads to $\text{H}_2\text{CO}_3(\text{aq})$ ionization to form HCO_3^- and CO_3^{2-} and calcite formation. However, waters that contain high CO_2 concentrations and high $\delta^{13}\text{C}$ values cannot be explained without the introduction of a highly concentrated CO_2 source with a $\delta^{13}\text{C}$ value of ca. -1 to -3‰. These heavy values cannot be explained by simple carbonate dissolution as such results in too low DIC concentrations. Alternatively, a mantle source can be the cause, however, the mantle $\delta^{13}\text{C}$ ratio is commonly considered lighter or -4 to -5‰.