Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.17751

Mantle CO_2 fluxes and carbonate fixation in volcanic hydrothermal systems in Iceland

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Most of the Earth's natural CO_2 degassing from the mantle to the surface occurs within the major rift zones. Fixation of CO_2 in crustal carbonates may impact the efficiency and scale of such CO_2 emissions. However, the amount of CO_2 fixed and emitted within rift zones remains mostly unconstrained. Using the Iceland rift as an analogue to the submerged mid-Atlantic ridge, we use carbon abundance and isotope systematics in hydrothermal fluids, whole rocks and carbonates from rift-related geothermal systems to unravel the origin of CO_2 and quantify crustal fixation into carbonates within rift settings.

The targeted geothermal systems included the seawater dominated system at Reykjanes (SW Iceland) and the meteoric water dominated systems at Nesjavellir (SW Iceland) and Krafla (N Iceland). Hydrothermal fluids, altered whole rock and carbonate grains were collected from the wells drilled into the subsurface of these systems. Fluids showed large variations in the CO_2 concentration (267-3098 ppm) but insignificant $\delta^{13}C$-CO_2 differences (-4.8 to -2.5‰). In contrast, large $\delta^{13}C$ variations of carbonates (-14.5 to +0.5 ‰) were observed. Carbon contents of altered rocks ranged from <0.01 to 4.33 wt.%. Thereby, carbon addition occurred within the upper 1000 m of the geothermal system whereas major losses of carbon were found at depths >1500 m.

Coupling the dataset with isotope and geochemical modeling revealed that carbon originates from a mantle source. Depressurization boiling of ascending hydrothermal fluids and water-rock interaction was found to be the main mechanism leading to carbonation. Only <1 to ~20% of the total mantle CO_2 degassing through the systems is sequestered into carbonates whereas the majority of the CO_2 is emitted to the surface through hydrothermal fluids, soil degassing and dissolved into groundwater. Active high-temperature geothermal systems in rift zones are thus inefficient in sequestering CO_2 and that surface CO_2 emissions closely resemble mantle flux and carbon isotope content fed into the systems.