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Geochemical tracing of CO_2 mineralisation at CarbFix2 storage reservoir over six years of CO_2 injection using inherent tracers

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Mineralising CO_2 in the subsurface is a rapid and secure approach to long-term carbon storage, providing a permanent solution to help mitigate atmospheric CO_2 levels [1]. The CarbFix2 carbon capture and storage (CCS) project [2] aims to continuously inject dissolved CO_2 and H_2S into deep basaltic rocks at Hellisheiði geothermal field, Iceland. The injected CO_2 reacts with cations released from the dissolution of silicate minerals in the mafic rocks, leading to the formation of stable carbonate minerals [1]. An extensive study of inherent geochemical tracers at CarbFix2 site in 2018 studied the CO_2 mineralisation in the subsurface reservoir. The lower $CO_2/^3He$ ratios and elevated $\delta^{13}C_{CO2}$ values in gases from the monitoring wells are consistent with the previous estimates of CO_2 mineralisation, while other scenarios are compatible with the data as well considering assumptions and uncertainties [3]. Additionally, $\delta^{18}O_{H2O}$ could act as a non-reactive inherent tracer of injected fluids.

To assess the long-term reliability of inherent geochemical tracers of the carbonate mineralisation process, fluids the from same injection site and monitoring wells were sampled in 2021 and 2024. Gases from the monitoring wells reveal slightly higher $CO_2/^3He$ ratios and lower $\delta^{13}C_{CO2}$ compared to 2018. This may be caused by changes in mixing ratios between injectate and other reservoir fluids, changes in mixing fluid compositions, or a gradual decline in the rate of CO_2 mineralisation. $\delta^{18}O_{H2O}$ values of both the injected brine and monitoring well fluids are enriched relative to the equivalent 2018 waters. However, the difference between the injected and post-mineralisation waters is no different to 2018 water, suggesting that the degree of high temperature water-rock interaction in the reservoir has not manifestly changed. The data confirms the potential of inherent geochemical tracers to track long-term CO_2 mineralisation in the subsurface and may provide insights into temporal variation in CO_2 mineralisation efficiency.

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[2] Gunnarsson, I., et al., International Journal of Greenhouse Gas Control, 2018. 79: p. 117-126.

[3] Holdsworth et al., Goldschmidt 2025