

Tracking CO₂ injection, migration and fate at Carbfix2 using stable isotopes

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Over the last decade Carbfix have been injecting CO₂ into Hellisheiði geothermal reservoir for storage as carbonate minerals (Fig. 1). Recent studies suggest that over 60% of the 10,000 tonnes injected annually is mineralising within 4-9 months [1, 2]. These mineralisation yields are calculated using a combination of fluid flow tracers and mass balance equations, whereby CO₂ loss between Carbfix2 injection and monitoring wells is inferred to be the percentage of CO₂ mineralised [3].

The aim of this study is to verify CO₂ mineral storage at Carbfix2 using new stable isotope data ($\delta^{18}\text{O}$, δD and $\delta^{13}\text{C}$) from Hellisheiði geothermal field.

The two main reactions required for mineral storage at Carbfix2; dissolution of host basalts to release divalent cations (Ca, Mg and Fe) and secondary calcite mineralisation [4]; will alter the stable isotope values of Hellisheiði reservoir fluids (e.g. Fig. 2). Assuming these reactions occur at isotopic equilibrium, the direction and magnitude of these isotopic shifts can provide direct evidence of CO₂ fate (i.e. mineralisation reactions).

We will discuss the various competing processes that control isotope values (e.g. Fig. 2), including mineralisation, water-rock interaction and hydrothermal phase separation.

Our results show that Carbfix2 monitoring well waters become progressively more depleted in $\delta^{18}\text{O}$ with distance from the injection well. $\delta^{18}\text{O}$ depletion is concordant with CO₂ exchange or calcite mineralisation in the reservoir. Quantifying these affects is hindered by the overprinting of final $\delta^{18}\text{O}$ values from initial water-rock interaction enrichment. Water DIC and CO₂ gas in the monitoring wells are enriched in $\delta^{13}\text{C}$ compared to other production wells at Hellisheiði, which is also indicative of mineralisation.

This work highlights the merits of stable isotope measurements as monitoring tools at CCS sites. Measurements can be used as a direct tracer of CO₂, whilst also identifying other important reservoir characteristics and processes.

References

[1] Clark *et al.* (2020), *Geochim. Cosmochim. Acta* 279, 45–66

[2] Gunnarsson *et al.* (2018), *Int. J. Greenh. Gas Control* 79, 117-126

[3] Matter *et al.* (2014), *Energy Procedia* 63, 4180-4185

[4] Matter *et al.* (2016), *Science* 352, 1312-1314

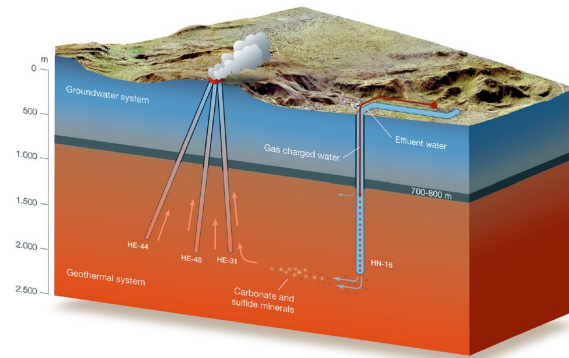


Figure 1: Schematic cross section of the Carbfix2 reservoir demonstrating the injection of CO₂ charged waters and flow towards monitoring wells [2].

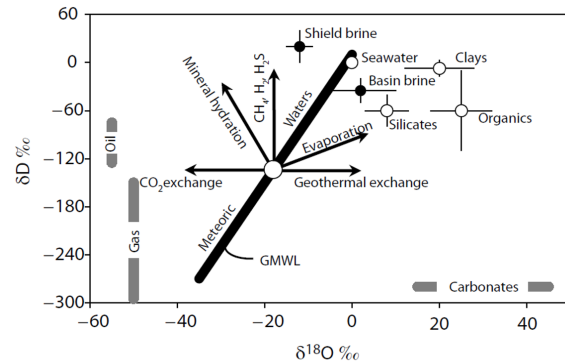


Figure 2: $\delta^{18}\text{O}$ and δD values of the main crustal reservoirs and the direction of isotopic shifts caused by common subsurface processes [5].