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Constraining CO_2 Mineralisation Mechanisms in Basaltic Reservoirs at Hellisheidi, Iceland

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Carbon storage in basalts has been proposed as a secure and highly efficient method for long-term atmospheric carbon mitigation [1]. However, our understanding of CO_2 mineralisation at field-scales remains limited and direct evidence for the precipitation of carbonate minerals resulting from anthropogenic CO_2 injection into basaltic reservoirs is still scarce [2].

CO_2 has been continuously injected into basaltic crust at the Hellisheidi geothermal field in Iceland since 2014 [3]. This pioneering initiative aims to utilise the reactive basaltic bedrock to facilitate the rapid conversion of dissolved CO_2 into stable carbonate minerals. In this study, we present *in situ* C and O isotopic analysis of calcite samples retrieved from basalt drill cuttings from the Hellisheidi field prior to injection and calcite precipitates recovered post-injection in order to determine the reservoir conditions during calcite precipitation.

Whilst complex mineral growth zoning is discernible in a few calcite samples via SEM-CL, the majority of specimens lack evident growth zones. Calcite samples retrieved from varying depths exhibit distinct isotopic compositions, indicating disparate formation temperatures within the subsurface. Furthermore, isotopic variations observed both between and within individual grains from the same depth suggest possible fluctuating environmental conditions during precipitation.

Through integration of these data with the geochemical signatures of reservoir fluids, we have identified the fluid sources and the formation conditions associated with these calcite generations. The results clarify the extent to which mineralisation mechanisms fluctuate in response to variation in CO_2 fluxes and provide key knowledge for optimising the mineralisation efficiency through strategic injection into specific thermal regimes and the calibration of brine salinity.

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