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Advancing Carbonatation in Basaltic Offshore Environment: Breakthroughs from Low Temperature Experiments and Simulations

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Long-term storage of anthropogenic carbon is of primordial importance to limit atmospheric CO_2 effect on global climate warming. In this context, in-situ CO_2 storage through carbonate mineralization is gaining increased interest from both academia and industry. The CarbonStone R&D TotalEnergies project aims to study the potential of this carbonatation process in an offshore mafic context at low temperature (<100 °C) to open large geographic opportunities to be in the vicinity of CO_2 emitters.

Laboratory experiments coupled with computational simulations are conducted in order to determine carbon sequestration efficiency for the targeted conditions. This work investigates the impact of temperature, water characteristics, primary rock dissolution, secondary minerals precipitation, and transport. It aims at (1) identifying first order parameters driving carbonatation at µm – dm scale, (2) assessing the effect of low temperature on the overall reaction kinetic, (3) considering fluid dynamic and transport, and (4) optimizing numerical models at laboratory scale for future pilot-scale upscaling.
Two different setups are used: batch/static and flow-through/dynamic, along with 0D and 1D PHREEQC thermodynamic simulations.

Batch experiments at 70 and 120 °C were conducted, with identical seawater compositions starting water-to-rock ratio, Mg-Fe rich basaltic rock composition and powder size, CO_2 partial pressure, and total pressure. PHREEQC simulations matched these conditions.
Carbonate formation was observed for the static experiments at 120 and 70 °C after 4 months of reaction. Only Fe-Mg-carbonates were detected, with Mg-rich ones at 120 °C and Fe-rich ones at 70 °C. They represent ~10 wt% at 120 °C and <1 wt% at 70 °C. SEM-EDS analyses, XRD, and microprobe results will be discussed. No clays nor zeolites were observed after reaction. Kinetics simulations largely align with these observations. Initial comparisons put in evidence the importance of defining primary minerals accurately to align with experiments results, as dissolution is the main reaction driver under the given conditions.

These observations of experimentally produced carbonate species in offshore-like conditions are promising for pilot implementation in extended low temperature (120 to 70 °C) exploration domains. Ways forwards include studying kinetics at lower temperature conditions, specifically targeting 45 °C.