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Influence of temperature and evaporation-recharge cycles on basalt weathering rates

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The weathering of silicate minerals naturally removes carbon dioxide (CO_2) from the atmosphere over geological timescales and is being explored as a climate change mitigation strategy. Enhanced Rock Weathering (ERW) is a technique that strives to accelerate this natural process by spreading finely-ground reactive silicate rocks like basalt at the Earth's surface, with the goal to increase CO_2 removal on shorter, decadal timescales. However, quantifying the rate and efficiency of ERW on atmospheric CO_2 removal is challenging due to the complexity of natural gas-fluid-mineral interactions. To investigate the geochemical processes that impact CO_2 removal efficiency during mineral weathering, column experiments containing crystalline basalt were conducted. These columns were exposed to different recharge patterns, evaporation rates, and temperatures (5 to 35°C) in order to mimic a large variety of natural climatic conditions. Our results show the highest weathering rate for experiments performed at high temperature (i.e., 35°C), with a constant water content and daily recharge. When the time between the recharge increased or when the water content in the column decreased by evaporation, the weathering decreased. Overall, differences in recharge and evaporation cycles exerted greater influence on the weathering rate than temperature. Magnesium isotope fractionation was observed between the solid ($\delta^{26}Mg_{DSM-3}$ = -0.25‰ ± 0.12‰) and the fluids recovered during the basalt weathering experiments (average $\delta^{26}Mg_{DSM-3}$ = -0.74‰, ± 0.1‰). Interestingly, the $\delta^{26}Mg$ values measured in the fluids were similar in all experiments, and were independent of temperature, the recharge interval or the evaporation extent, indicating that these parameters were not a major control on isotope fractionation within the ranges explored in this study. Overall, this study provides important insights into the impact of climate variables on basalt weathering, contributing to a better understanding of both natural weathering processes and the potential of ERW as a climate change mitigation strategy.