

Impacts of water availability on mineral dissolution and carbonation

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Mineral weathering and carbonation reactions are naturally occurring processes that remove CO₂ from the atmosphere and can be engineered to help mitigate climate change. In these CO₂-consuming reactions, water plays a crucial role as both a reactant and a transport medium. However, the availability of water may be limited in certain environments. For example, in unsaturated zones on Earth's surface, water may be present primarily as humidity and adsorbed as a thin film on mineral surfaces; or as high-ionic-strength solutions with reduced water activity (a_w) where brines and salt lakes develop. These water-limited conditions may also be encountered during engineered CO₂ sequestration. Processes and rates of chemical weathering and mineral carbonation in these water-limited conditions are not fully understood. In our study, we investigate the impact of water availability on the dissolution and carbonation of wollastonite (CaSiO₃) and brucite (Mg(OH)₂). These minerals were selected due to their relatively high reactivity and wide use in CO₂ removal strategies. Using batch experiments and in situ atomic force microscopy (AFM), we analyse how a_w in saline solutions influences dissolution rates and the reaction mechanism. Additionally, controlled-humidity reactors are employed to examine brucite (124–250 μm) carbonation under varying relative humidity (RH) and temperature conditions. Preliminary results showed that carbonation rates of brucite are highly humidity-dependent: at 20°C and high humidity (94–100% RH), carbonate formation was detected within hours, whereas at lower humidity (75–85% RH), it took over a month. Temperature was also found to accelerate brucite carbonation rate, as an increase from 20°C to 55°C significantly shortened the time needed for carbonate peaks to be detected on FTIR spectra at 85% RH from over a month to a few days. By integrating findings from these experiments, this study will improve our mechanistic understanding of mineral dissolution and carbonation in water-limited environments and provide insights for optimizing engineered CO₂ sequestration strategies.