



Novel biological approaches to carbon mineralization

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Innovative approaches for accelerating and manipulating fundamental geochemical processes are necessary to develop carbon mineralization as a viable strategy for the mitigation of greenhouse gas emissions. Mg-carbonate formation is of interest for both *ex situ* and *in situ* CO₂ sequestration strategies¹. Accordingly, we have investigated approaches to accelerate these water-rock reactions that produce Mg-carbonate minerals using biological approaches. For instance, CO₂-limited conditions are encountered in many systems relevant to CO₂ sequestration and represent a severe limitation on carbon mineralization. In carbonation experiments, the supply of CO₂ was increased with the use of carbonic anhydrase, an enzyme that catalyzes the hydration of aqueous CO₂. The presence of carbonic anhydrase had a dramatic impact on carbonation rates of brucite [Mg(OH)₂]², a mineral of interest for carbon sequestration³. In a CO₂-rich aqueous environment, cyanobacteria were able to induce hydrated Mg-carbonate precipitation in microcosm experiments through the alkalization of their microenvironment and concentration of cations on their cell membranes, which also provide regularly spaced, chemically identical sites for mineral nucleation⁴. In both lines of investigation, the resulting precipitates were metastable hydrated Mg-carbonate minerals rather than magnesite [MgCO₃], the most stable Mg-carbonate and therefore the preferred product for sequestering CO₂. Consequently, we have investigated approaches to improve magnesite precipitation rate in these low temperature environments.

Inopportune, rates of magnesite precipitation are severely limited at temperatures below 60 °C due to the strong hydration of Mg²⁺ ions in solution⁵. Yet, carboxyl functional groups (R-COOH) are able to cause desolvation of Mg²⁺ ions^{6,7}. In microcosm experiments using polystyrene microspheres with a high density of carboxyl groups, we were able to precipitate magnesite at room temperature from slightly supersaturated solutions in tens of days. Precipitates were positively identified as magnesite using transmission electron microscopy and selected area electron diffraction of a thin section produced by focus ion beam milling. These experiments represent an acceleration in magnesite formation of several orders of magnitude in comparison to naturally occurring magnesite at near-surface conditions and without requiring energy input (e.g., high temperature reactions). Our current focus is to further elucidate this reaction pathway and upscale precipitation for sequestering anthropogenic CO₂.

[1] Power et al. (2013) *Rev. Mineral. Geochem.* **77**: 305-360. [2] Power et al. (2013) *Int. J. Greenh. Gas Control.* **16**: 145-155. [3] Harrison et al. (2013) *Environ. Sci. Technol.* **47**: 126-134. [4] Power et al. (2007) *Geochem. Trans.* **8**, 13. [5] Hänchen et al. (2008) *Chem. Eng. Sci.* **63**: 1012-1028. [6] Roberts et al. (2013) *Proc. Natl. Acad. Sci. U.S.A.* **110**: 14540-14545. [7] Kenward et al. (2009) *Geobiology* **7**: 556-565.