Reactivity of CO$_2$ in the Subsurface

**Investigators**
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**Objective**
The goal of this research program is to discover novel techniques for accelerating the conversion of carbon dioxide into carbonate minerals that can be sequestered underground. The research team will focus on understanding the chemical reactions that occur when CO$_2$ is injected into silicate rocks rich in magnesium and calcium. Using field studies and laboratory analyses, researchers will determine the optimum geochemical conditions for converting captured CO$_2$ into carbonates, and will test various organic acids and natural enzymes that could significantly increase reaction rates, thereby speeding up the formation of carbonates for permanent underground storage.

**Background**
About 60% of global CO$_2$ emissions come from power plants and industrial smokestacks. This study focuses on two promising techniques for storing these emissions underground: (1) the injection of CO$_2$ into deep saline solutions; and (2) mineralogical sequestration – the permanent trapping of CO$_2$ in stable carbonate minerals. Mineralization results from the chemical reaction of CO$_2$ with magnesium- and/or calcium-rich silicates found in two types of rock: mafic (basalts) and ultramafic (peridotites and serpentinites). See Figure 1.

**Figure 1:** Cross-section illustration of two geological settings for carbon sequestration: dissolved CO$_2$ in deep saline aquifers; and mineralized CO$_2$ in ultramafic and mafic rocks.
Approach
Despite increased interest in mineralogical sequestration, fundamental gaps in our understanding of the process remain. The research team will examine how geochemical reactions change the porosity, permeability and other physical properties of rocks when CO2 is injected into saline aquifers and reactive silicate rocks. Quantifying these reactions could be a major step forward in the management and monitoring of sequestered CO2 plumes. The process steps of interest for assessing the fate of subsurface CO2 fall into four general categories:

1. Dissolution of CO2 into aqueous solutions;
2. Dissolution of primary minerals in the sedimentary aquifer and caprock, and coupled formation of secondary minerals (including silica, clay and carbonate) that impact porosity, permeability and fracture properties of the porous media, resulting in CO2 sequestration and/or leakage; and
3. Release or immobilization of toxic metals and organic compounds through chemical reactions; and
4. Dissolution of calcium and magnesium silicates in mafic and ultramafic rocks, and coupled formation of secondary carbonate and metal (oxy)hydroxide phases that represent opportunities for permanent sequestration of CO2 and toxic metals.

Laboratory studies will be guided by parallel field studies of CO2-brine mixtures in sedimentary aquifers (e.g., Bravo Dome in New Mexico) and in crystalline rocks that have undergone mineral carbonation (e.g., Red Mountain, California). See Figure 2. Researchers will apply a variety of analytic techniques, including thermodynamic and kinetic modeling, mineralogical studies, surface chemistry, isotopic tracers, reactive transport modeling, and geological experience and observations. A major goal is to find new ways to increase the relatively slow dissolution kinetics that occur when acidic solutions react with silicate minerals and CO2 to form carbonates. The results will improve our understanding of the timescales of mineral carbonation and could lead to new strategies for enhancing storage of CO2 in the aqueous and solid phases.

Figure 2: Magnesite mineralization in the Red Mountain Mining District, CA. A. View of Red Mountain looking NE, vertical exposure is ~400 meters. Red outcrops are weathered partially serpentinized ultramafic rocks. White areas are extensive mine tails of magnesite. B. Prospect pit exposing a meter-wide magnesite vein. C. Brecciation of ultramafic wall rock marginal to magnesite vein.

References