

Consideration of formation buffering potential and reactive mineral availability pertaining to geological storage of carbon dioxide

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One promising strategy for decreasing CO₂ emissions to the atmosphere is carbon capture and storage in deep saline formations. Modelling efforts and the experimental measurements that support these efforts are critical to determining the fate of injected CO₂. The focus of this work is CO₂-water-rock interactions as they pertain to formation buffering potential and reactive mineral availability. In addressing formation buffering potential, PHREEQC was used to model pH evolution in siliciclastic and carbonate rocks. The initial mineral and formation water compositions were determined from analyses of core samples and brines from several formations in the Alberta sedimentary basin in western Canada. Simulation parameters correspond to injection conditions of 50°C, CO₂ pressure of 100 bar and high ionic strength. The aim of this modelling is to evaluate host formation mineralogy based on the ability to buffer the acid created by CO₂ injection.

Our second goal is to better define mineral abundance and availability in siliciclastic sedimentary rocks, to support the development of relationships for upscaling reactive transport. Energy dispersive X-ray spectroscopy and back-scattered electron microscopy were used to identify minerals and characterize the spatial distributions of potentially reactive minerals in thin sections from the Alberta Basin. Minerals of mean atomic mass greater than quartz, which include those that are reactive under acidic conditions, occur as entire grains in sandstones and shaly sandstones. Kaolinite is found to cement quartz grains and line pore spaces, decreasing primary porosity and obscuring contact between pore fluids and reactive minerals. There is less kaolinite in conglomerate sandstones but reactive minerals are sparse and typically found as inclusions, thus limiting their contact with pore fluids. The sandstone specimens have between 1% and ~5% reactive minerals, but these estimates of mineral abundance overestimate the percentages of reactive minerals accessible to pore fluids by as much as a factor of five. Incorporation of these results into reactive transport models will allow for more accurate representation of formation reactivity with injected CO₂.

Reactive transport and pore-size controlled solubility in porous rocks

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Nano-scale pores in sediments and soil can modify the effective solubility of minerals, allowing highly supersaturated fluids to exist within the porous medium; this mechanism suggests that precipitation or dissolution can occur when fluid flows from small pores into larger ones, or vice versa. Pore-size controlled solubility (PCS) is a process which stems from the surface tension associated with crystals growing in rigid pores. In many ways analogous to the capillary pressure at a liquid-vapor interface within a pore, this surface tension gives rise to an excess pressure within the crystal, which can be related both to solubility and pore size. Here, we demonstrate how PCS can be incorporated into continuum equations for fluid transport and porosity evolution in simple porous media. Using numerical simulations, we demonstrate that the PCS mechanism can account for the filling of large pore spaces during transport through a heterogeneous rock matrix and represents an effective mechanism for fracture mineralization. In addition, evidence for PCS from scanning electron microscope (SEM) analyses of sedimentary rocks is also presented.