

Evaluating permeability change due to altered pore geometry in CO₂ sequestration systems

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Background

Experimental, numerical, and field investigations of CO₂ injection into deep saline aquifers indicate alteration of formation mineralogy and permeability in CO₂-affected regions. Permeability typically increases in carbonate-hosted systems with the formation of preferential flow pathways and typically decreases in feldspar-rich systems due to formation of secondary clay minerals.

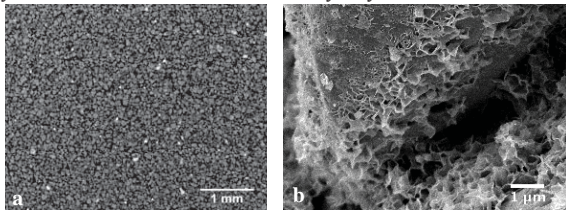


Figure 1 a: XMT image of packed arkosic sediment core
b: SEM image of alteration minerals on feldspar grain surface

Approach

With X-ray Microtomography (XMT, Fig. 1a) and Scanning Electron Microscopy (SEM, Fig. 1b) images of cores before and after they are subjected to CO₂-saturated water/brine experiments at elevated temperatures and pressures, we observe pore-scale alteration of flow path geometry. The reconstructed XMT images are thresholded to separate pore space from solids and divided into Representative Elementary Volumes (REVs, Fig. 2) to calculate permeability fields over large sections of the core with lattice-Boltzmann methods. Real-time monitoring of core permeability and geochemical modeling of core mineralogy and sampled solution chemistry yield additional, vital data to observe the rates and characteristics of mineral and permeability alteration throughout the experiment.

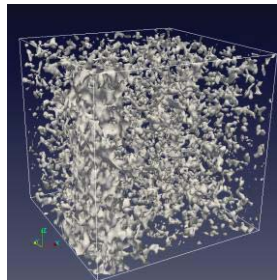


Figure 2: REV reconstructed from XMT images.

Results

This combined experimental and numerical approach is used to characterize and predict permeability modification resulting from CO₂ injection for several rock types, including arkose, dolostone, and basalt. This approach avoids bulk porosity-permeability relationships commonly used in reactive transport modeling to predict permeability changes and instead focuses on physical changes due to chemical alteration at the pore scale.

Assessing the importance of extracellular iron scavenged on phytoplankton cells with synchrotron x-ray fluorescence microscopy

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Iron is an essential micronutrient for phytoplankton, and it has been shown to limit primary production in large swaths of the ocean with low external inputs. Dissolved iron occurs primarily as Fe(III) in the oxic surface waters of the ocean, and ferric iron is nearly insoluble under these conditions. Thus iron is prone to precipitate and scavenge onto particle surfaces. Oceanographers have long considered that a non-negligible fraction of iron associated with ocean plankton may be extracellularly adsorbed rather than associated with intracellular biological moieties. A number of studies have been conducted to investigate the behavior of this iron, and several operationally-defined chemical rinses have been developed and utilized to remove this extracellular fraction prior to elemental analyses. I have analyzed numerous plankton cells from both natural open-ocean environments and laboratory cultures with synchrotron-based hard x-ray fluorescence (SXRF) microprobes, occasionally in conjunction with the above-mentioned rinses. By and large, the spatial distributions of iron and other bioactive elements in these cells suggest that the extracellular adsorbed fraction is only a minor component of cellular iron contents. I will present data from both lab and field studies in support of this observation, discuss reasons for its occurrence, and suggest ways to reconcile these observations with geochemical evidence for Fe scavenging in the ocean.