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**Application of a pore-scale reactive transport model to a natural analogue
for reaction-induced pore alterations**

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Abstract

Dissolved CO₂ in the subsurface resulting from geological CO₂ storage may react with minerals in fractured rocks, confined aquifers, or faults, resulting in mineral precipitation and dissolution. The overall rate of reaction can be affected by coupled processes including hydrodynamics, transport, and reactions at the (sub) pore-scale. In this work pore-scale modeling of coupled fluid flow, reactive transport, and heterogeneous reactions at the mineral surface is applied to account for permeability alterations caused by precipitation-induced pore-blocking. This work is motivated by observations of CO₂ seeps from a natural CO₂ sequestration analog, Crystal Geyser, Utah. Observations along the surface exposure of the Little Grand Wash fault indicate the lateral migration of CO₂ seep sites (i.e., alteration zones) of 10-50 m width with spacing on the order of ~ 100 meters over time. Sandstone permeability in alteration zones is reduced by 3 to 4 orders of magnitude by carbonate cementation compared to unaltered zones. One granular porous medium and one fracture network systems are used to conceptually represent permeable porous media and locations of conduits controlled by fault-segment intersections and/or topography, respectively. Simulation cases accounted for a range of reaction regimes characterized by the Damköhler (Da) and Peclet (Pe) numbers. Pore-scale simulation results demonstrate that combinations of transport (Pe), geochemical conditions (Da), solution chemistry, and pore and fracture configurations contributed to match key patterns observed in the field of how calcite precipitation alters flow paths by pore plugging. This comparison of simulation results with field observations reveals mechanistic explanations of the lateral migration and enhances our understanding of subsurface processes associated with the CO₂ injection. In addition, permeability and porosity relations are constructed from pore-scale simulations which account for a range of reaction regimes characterized by the Da and Pe numbers. The functional relationships obtained from pore-scale simulations can be used in a continuum scale model that may account for large-scale phenomena mimicking lateral migration of surface CO₂ seeps.

Keywords: Pore scale; reactive transport; Natural analog; cementation; Crystal Geyser

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