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A Fundamental Study of Convective Mixing Contributing to Dissolution Trapping of CO_2 in Heterogeneous Geologic Media using Surrogate Fluids and Numerical Modeling

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Geologic sequestration of carbon dioxide is considered as an important strategy to slow down global warming and hence climate change. Dissolution trapping is one of the primary mechanisms contributing to long-term storage of supercritical CO_2 ($scCO_2$) in deep saline geologic formations. When liquid $scCO_2$ is injected into the formation, its density is less than density of brine. During the movement of injected $scCO_2$ under the effect of buoyancy forces, it is immobilized due to capillary forces. With the progress of time, entrapped $scCO_2$ dissolves in formation brine, and density-driven convective fingers are expected to be generated due to the higher density of the solute compared to brine. These fingers enhance mixing of dissolved CO_2 in brine. The development and role of these convective fingers in mixing in homogeneous formations have been studied in past investigations. The goal of this study is to evaluate the contribution of convective mixing to dissolution trapping of $scCO_2$ in naturally heterogeneous geologic formations via laboratory experiments and numerical analyses. To mimic the dissolution of $scCO_2$ in formation brine under ambient laboratory conditions, a group of surrogate fluids were selected according to their density and viscosity ratios, and tested in different fluid/fluid mixtures and variety of porous media test systems. After selection of the appropriate fluid mixture, a set of experiments in a small test tank packed in homogeneous configurations was performed in order to analyze the fingering behavior. A second set of experiments was conducted for layered systems to study the effects of formation heterogeneity on convective mixing. To capture the dominant processes observed in the experiments, a Finite Volume based numerical code was developed. The model was then used to simulate more complex heterogeneous systems that were not represented in the experiments. Results of these analyses suggest that density-driven convective fingers that contributes to mixing in homogeneous formations may not be significantly contributing to mixing and hence dissolution trapping in heterogeneous formations. However, further experimental and modeling investigations are needed to investigate how the geologic architecture that defines the spatial distribution of low permeability zones contributes to overall dissolution trapping.