LABORATORY MEASUREMENTS OF LARGE-SCALE FLOWS IN CARBON SEQUESTRATION

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The long-term fate of supercritical (sc) CO2 injected into deep geologic saline aquifers is critical to the success of carbon sequestration, an important option for reducing the emissions of this most prevalent greenhouse gas. Less dense than the native brine, scCO2 floats to the top of the aquifer where it is trapped as a metastable pool by a geologic feature such as a low permeability cap rock. Dissolution into the underlying brine creates a CO2-brine mixture that is denser than the native brine, eliminating buoyancy and removing the threat of CO2 escaping back to the atmosphere. If molecular diffusion were the only dissolution mechanism, the CO2 waste stream from a typical large coal-fired electrical power plant may take upwards of 10,000 years to no longer pose a threat, however, a convective instability of the dense diffusion boundary layer between the scCO2 and the brine can dramatically increase the dissolution rates, shortening the lifetime of the scCO2 waste pool to perhaps 100 years. Using an analogue fluid system, we have performed bench top, similitude-scaled 2D and 3D experiments to provide benchmark data for reservoir-scale simulations of both the transient diffusive behavior and the quasi-steady convective behavior of this important process.

Our 2D experiments provide both a quantitative measure of the dissolution rates and qualitative imaging of the flow field bringing to light several processes: the initial instability to a pattern of closely spaced downward moving fingers of dense fluid; the pattern coarsening process as fingers convect horizontally, collide and merge; and at long times, the nucleation of new fingers which defines the quasi-steady state of the pattern and the dissolution rate. Although lacking imaging, our 3D experiments provide high resolution measurements of the dissolution rate. For systems with isotropic permeability, we present results for the transient and steady-state dimensionless mixing rates which are crucial to estimating the lifetime of scCO2 waste pools. In addition, we will comment on experimental evidence for a potentially new secondary instability important to a fundamental understanding of the CO2-brine dissolution rate. We also present preliminary results for the dissolution rates in systems with layered, anisotropic permeability. The results of these experiments provide important data for benchmarking difficult, large-scale simulations of CO2 sequestration sites.