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Impacts of Buoyancy and Pressure Gradient on Field-Scale Geological Sequestration of CO_2 in Saline Formations

One limiting factor of CO_2 sequestration capacity in saline formations is the buoyancy force acting on top and fault seals—thicker CO_2 columns increase leak risk. Column height is governed by subsurface structure and plume migration behavior. To evaluate controls on capacity and long-term fate of sequestered CO_2, 3-dimensional flow simulations using TOUGH2 code were run using generalized geologic models statistically representative of the high-permeability, Oligocene-age Frio Formation of the upper Texas Gulf Coast. All models included an initial injection phase followed by a ‘rest’ period.

Buoyancy and injection rate (lateral pressure gradient) dominate plume development. In cross section, CO_2 injected at the base of a unit rises buoyantly to the top until it encounters a laterally continuous, low-permeability shale. Cross-section and map views of a model of dipping strata show that buoyancy creates minor, updip-biased plume asymmetry during injection. Following cessation of injection (and associated pressure gradient loss), the plume ceases any significant downdip movement and begins to migrate updip. Low residual gas saturation values (5%) have minor impact on updip plume migration, but moderate values (25–30%) cause rapid loss of mobile plume mass, significantly diminishing updip migration and countering buoyancy after moderately short migration distances.

Buoyancy and residual saturation behavior are thus anticipated to play key roles in sequestration capacity and effectiveness in large-scale sequestration. Sequestration sites with nearly flat lying strata and high residual saturation values are likely to increase both capacity and effectiveness. Continued modeling will focus on regional-scale pressure buildup and plume migration in idealized Gulf Coast structures.