GRAVITY CURRENTS ARRESTED BY CONVECTIVE MIXING

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The large-scale injection of carbon dioxide (CO2) into deep saline aquifers is a promising tool for reducing atmospheric CO2 emissions to mitigate climate change. Trapping of the buoyant CO2 after injection is essential in order to minimize the risk of leakage into shallower formations through a pre-existing well or fracture, or via the activation of a fault. However, traditional reservoir-simulation tools are currently unable to resolve the impact of small-scale trapping processes on fluid flow at the scale of a geologic basin.
Here, we use analog experiments and high-resolution numerical simulations to study solubility trapping of the CO2 via convective dissolution, where dense fingers of CO2-rich groundwater carry CO2 away from the buoyant plume as it dissolves. We study the impact of convective dissolution on a buoyant gravity current migrating up-dip in a sloping aquifer. We benchmark the simulations against the experiments, comparing the shape of the plume and the position of the leading edge as a function of time. We then use the simulations to show that the accumulation of dissolved CO2 in the water beneath the buoyant plume limits the rate of convective dissolution when the rate of up-dip migration is slow relative to the speed at which the fingers fall. We compare these results with a simple upscaled model, which is able to reproduce the macroscopic features of this complex physical process both qualitatively and quantitatively. We then estimate the dimensionless rate of solubility trapping for several large saline aquifers in the United States in order to assess the importance of solubility trapping in practice.