Geophysical Research Abstracts
Vol. 15, EGU2013-5723, 2013
EGU General Assembly 2013

Dynamics of Convective Dissolution from a Migrating Current of Carbon Dioxide

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During geologic storage of carbon dioxide (CO_2), trapping of the buoyant CO_2 after injection is essential in order to minimize the risk of leakage into shallower formations through a fracture or abandoned well. Accurate models for the subsurface behavior of the CO_2 are essential for the design, implementation, and long-term monitoring of injection sites, but 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 study the impact of solubility trapping driven by convective dissolution on the up-dip migration of a buoyant gravity current of CO_2 in a sloping aquifer. We do so using high-resolution numerical simulations that fully resolve the dense, sinking fingers of CO_2-rich brine that drive the convective dissolution process. We analyze the dynamics of the dissolution flux along the moving CO_2-brine interface, including its decay as dissolved CO_2 accumulates in the brine beneath the buoyant current. We show that the dynamics of the flux and the macroscopic features of the migrating current, including its shape, its mass, and the position of its leading edge, can be reproduced by using upscaled parameters in a one-dimensional sharp-interface model.