DFD13-2013-002045

Abstract for an Invited Paper
for the DFD13 Meeting of
the American Physical Society

Porous-medium convection: new problems from CO2 sequestration

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Large scale injection and storage of supercritical carbon dioxide (CO2) into deep saline aquifers is proposed to offset anthropogenic emissions and mitigate climate change. Many aspects of the resultant porous flows provoke fundamental fluid-mechanical problems. The rise and spread of the buoyant CO2 plume beneath an overlying impermeable stratum is a classic gravity current, but with the undesirable extra possibility of upward leakage through fractures. Fortunately, long-term trapping mechanisms exist. One such, dissolution of CO2 into the underlying brine, produces a denser solution which thus convects reassuringly downwards. Consideration of the convective flux prompts re-examination of high-Ra convection in a porous medium, which is found to have a strikingly different asymptotic form from that in a pure fluid. The high-Ra regime of Rayleigh-Darcy convection has an ordered interior with a linear mean temperature gradient and a superposed vertical columnar heat-exchanger flow whose wavelength is consistent with the $Ra^{-5/14}$ scaling predicted by an asymptotic stability analysis. Quantification of the convective dissolution flux allows evolution towards saturation in confined aquifers, or the erosion of a gravity current in open aquifers, to be calculated.