Rayleigh-Taylor convection in a granular porous medium: An experimental study

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Résumé

A large fraction of greenhouse gases (about 60%) released into the atmosphere are due to CO2 emissions from industrial processes and the burning of fossil fuels (1). One of the strategies employed to reduce the emissions is trapping them securely in the subsurface (2, 3, 4). Dissolution trapping, in particular, involves injecting the CO2 into a deep aquifer where the supercritical CO2 (sCO2) partially dissolves in the aquifer brine beneath it, forming a CO2 enriched layer within the aqueous phase. The density contrast between the CO2 -enriched brine at the top of the liquid domain and the ambient aquifer brine below results in natural convection of CO2 (2, 3, 4). This makes the ambient brine come up, thereby accelerating further dissolution of the sCO2 into the fresh brine.

The study of Brouzet et al. shows that traditional continuum scale, Darcy law-governed, models underestimate the timescales of this convective dissolution's dynamics, owing to pore scale coupling between convective flow and dissolved CO2 transport (5). We present here a 2D experimental study using miscible analog fluids with a contrast in densities to understand the convective transport of the dissolved sCO2. The fluids and the granular medium are refractive index matched, which renders the medium transparent and allows measuring the pore scale concentration field at various Rayleigh (Ra) and Darcy numbers (Da). This is done by changing the density of the fluids and the size of the solid grain. Darcy scale simulations, run with the same continuum scale parameters as the experiments, are compared to the experimental dynamics. They underpredict the experimental findings by several orders of magnitude, which is consistent with the findings of Brouzet et al. This holds true even when the $Ra\sqrt{Da}$, which quantifies the size of the most unstable wavelength with respect to the inverse of the typical pore size, is much smaller than 1, i.e., when obvious causes for the failure of the continuum scale description can be excluded.

References:

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