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Pore-scale study on density-driven flows with heterogeneous chemical reactions in porous media

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Geological storage of CO₂ in subsurface saline aquifers is a promising way to reduce CO₂ emissions. During this process, CO₂ first dissolves into pure brine, forming an acidic and denser mixture that falls down under the gravity and reacts with the rock [1, 2]. From the fundamental science point of view, the above process is indeed flow and reactive transport processes in porous media.

Pore-scale studies on the density-driven flows with heterogeneous chemical reactions are conducted numerically in the present work based on the lattice Boltzmann method [3]. The main objective is to investigate the effect of chemical reactions on the interfacial instabilities. Rayleigh-Taylor instability caused by the density contrast between the incoming and displaced fluids is observed in the simulations of pure density-driven flows (without chemical reactions) for both two- and three-dimensional porous media, which agrees well with the previous experimental and theoretical studies [4]. In addition, density-driven flows with heterogeneous chemical reactions are further simulated. The results indicate that heterogeneous chemical reactions at the fluid-solid interface can suppress the gravitational instability. Considering that the chemical reactions can consume the CO₂ in the incoming fluids, which reduces the density of the incoming fluids, Rayleigh-Taylor instability caused by the density ratio will be suppressed by the reactions. The overall instability in this system depends on the competition between the density contrast and the chemical reaction rate at the fluid-solid interface.

References

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