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Carbon sequestration in porous materials: Uniform CO2 flooding and reaction front

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Injection of a CO_2-rich phase into a porous material initially saturated with water solution (i.e., drainage) leads to CO_2 dissolution and mass-transfer into the resident water solution. As a result of the accompanying decrease in solution pH, the solid matrix can be in chemical disequilibrium and induce dissolution-precipitation reactions such as carbonation (i.e., carbonate mineral formation) on the wetted surfaces. In turn, the chemical disequilibrium leads to continued undersaturation and dissolution of CO_2 and a substantial net mass-flux from the CO_2-rich phase to the solution phase. Such immiscible drainage with mass-transfer is a scenario shared with major capture and/or sequestration systems, ranging from a carbonation in cement-based-materials [1] and in natural aquifers composed of ultramafic rocks (e.g., basalts) [2] to selective capture and separation in industrial porous materials [3] and to caprock integrity estimations in subsurface CO_2 storage [4].
Under certain conditions, viscous fingering instabilities can emerge from the initially planar front and develop to preferential flow pathways for the CO_2-rich phase. These flow pathways can then lead to a bypass of the bulk medium and eventually failure in substantial capture or sequestration of CO_2 methods [5]. In this study, using *in situ* CO_2 flooding experiments in a Portland cement-based mortar acquired using X-ray micro-computed tomography [6] and theoretical analysis of linear stability, we characterize the conditions for the emergence of viscous fingering. We find non-trivial effects of the mass-transfer term, which strongly depends on the degree of saturation. The results contribute to improving Carbon Capture and Storage (CCS) techniques in both natural and engineered porous materials and to the advancement of carbon-negative materials, which are crucial for mitigating climate change.

Participation

In-Person

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