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Pattern formation in carbonate precipitation in confined geometry

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Carbon capture and storage (CCS) is a promising technology to significantly reduce the amount of carbon dioxide (CO₂) emissions in the atmosphere. In CCS, CO₂ is captured at concentrated point sources and injected deep underground for permanent storage. Geochemistry is an important consideration in CCS projects since the injected CO₂ will dissolve in the ambient brine and interact with the host rock, resulting in either rock dissolution or mineral precipitation. In contrast with the wealth of studies on CO₂-driven dissolution, mineral precipitation is less well understood. This is partly due to the conventional wisdom that mineralization occurs on a much longer timescale compared to dissolution. However, recent field studies have demonstrated significant, fast mineralization when CO₂ is injected in reactive rocks such as basalt (Matter et al., 2016). The mineralization alters the permeability around the injection well, and it has significant implications for the injectivity of the storage operation.

Here, we investigate the interplay between CO₂ injection, carbonate precipitation, and permeability evolution via simple microfluidic experiments. Specifically, we perform constant-rate injection of sodium carbonate into a radial Hele-Shaw cell filled with calcium chloride. Sodium carbonate readily reacts with calcium chloride to form calcium carbonate precipitate. We perform the experiments over a wide range of Péclet numbers (i.e. relative importance between advection and diffusion). At a low Péclet number, we observe a stable precipitation band that expands radially outward. However, at higher Péclet numbers, we observe viscous fingering-like precipitation patterns at the precipitation band, even though the fluids are of the same viscosity. This hydrodynamic instability arises as a result of precipitation, which locally decreases the effective mobility of the defending fluid. The precipitates generated at the interface of the fingers travel much slower than the precipitation band, which allows them to capture other precipitates through collision and aggregation. Therefore, our results demonstrate that the interplay between hydrodynamics and reaction can have an important control on permeability evolution in CO₂ storage in reactive formations.

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References

Time Block Preference

Time Block C (18:00-21:00 CET)

Participation

Online

Primary authors: Ms SHAHSAVAR, Negar (Ph.D. Student); Prof. FU, Xiaojing; Prof. ZHAO, Benzong

Presenter: Ms SHAHSAVAR, Negar (Ph.D. Student)

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