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How does access to continuous brine sources in saline aquifers enhance salt precipitation dynamics during geological CO2 storage?

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Meeting the long-term expectations of Carbon Capture and Storage (CCS) technology hinges on injecting massive volumes of CO2 annually into deep saline aquifers. These aquifers, due to their storage capacity and proximity to emission sources, are prime candidates for CO2 sequestration. The near-wellbore environment experiences significant thermo-hydro-mechanical-chemical (THMC) perturbations, necessitating a comprehensive understanding through experimental tests and simulations to maximize the safety and cost-efficiency of CO2 storage. The injection of large volumes (on a million-ton scale) of supercritical CO2 into the geological formations causes evaporation of formation water near wellbores and precipitation of salt crystals inside the porous medium. CO2-induced salt precipitation can substantially threaten sequestration in saline aquifers. While existing works primarily focus on predicting salt location and amounts, our study delves into the physics, growth dynamics, and behavior of the fluid-solid interface near the evaporation/precipitation front. We present a series of experiments, including microfluidic, hele-shaw, and sandbox, along with pore-scale reactive transport modeling using the Lattice Boltzmann Method (LBM), providing fresh insights into brine evaporation and salt growth dynamics. Our research challenges the current understanding, revealing a common shortcoming in many experimental studies—failure to facilitate access and replicate in-situ continuous brine sources. This shortcoming significantly alters the dynamics of salt nucleation and growth in porous reservoir rocks, where the availability and continuity of solute through water film movement control geometric alterations. To address this issue, we also designed surface mineral precipitation tests and large-scale sandbox experiments to investigate salt precipitation and growth under two scales and regimes in porous geometries. The laboratory results indicated massive salt accumulation close to the injection port and underlined the effect of solute availability and continuity on the intensifying severity of salt accumulation. The research outcome highlights the interplay of complex processes (some of which are not yet fully characterized) crucial in investigating salt precipitation induced by million-tons-scale CO2 injection. The observed characteristics call for further in-depth investigation because, in the context of subsurface CO2 storage, we need to redefine how we see injectivity impairment due to salt precipitation.

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