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Unraveling Salt Precipitation Mechanisms: Insights into Dominant Driving Forces

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Salt precipitation during underground CO2 storage into saline aquifers poses a risk for injectivity impairment and presents a notable challenge for successful CO2 storage initiatives. Laboratory studies indicate that salt precipitation is sensitive to capillary forces, but extending this to field-scale is non-trivial due to radial flow conditions, gravitational effects (e.g. gravity override), and geologic heterogeneity. The goal of this study is to use detailed 3D numerical simulation of salt precipitation to gain further insight into the controlling physical mechanisms in realistic storage formations. First, axi-symmetric homogeneous simulations are used to characterize salt precipitation under controlled conditions using non-dimensional parameters, e.g. capillary (Ca), Gravity (Gr) and Bond (Bo) numbers. Results confirm that smaller Ca generally encourages more capillary backflow and increased salt precipitation as expected. However, increasing Gr is found to impact the localization of salt deposits, i.e. gravity override causes salt deposits to form deeper and further into the storage reservoir. In addition, flow of CO2 is redirected creating a feedback mechanism on local salt formation. These insights are used to understand salt precipitation observed in additional 3D simulations for heterogeneous systems. In layered systems, more salt is precipitated locally in higher permeability zones due to the lower Ca in those regions, causing flow to redirect into lower permeability zones that reduces the injectivity overall. For a random heterogeneity, the overall behavior holds with respect to Ca and Gr, but salt localization in a more complex permeability field exhibits an increased detrimental impact on injectivity than a simpler layered system. This study finds a strong coupling between salt precipitation and multiphase flow in 3D field-scale systems that can be characterized by capillary and gravity numbers. The ability to estimate salt precipitation from formation properties and anticipated injection rates is valuable for devising injection strategies for mitigating injectivity loss in industrial scale operations.

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References

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