Direct Experimental Quantification of Salt-Induced Permeability Reduction in Porous Media

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Salt crystallization is a known issue during subsurface gas injection, particularly in the context of supercritical CO_2 injection into saline aquifers. Field observations have confirmed that salt precipitation can significantly reduce permeability and injectivity. Experimental studies reproducing such conditions have reported permeability reductions ranging from 10% to 83% [1], highlighting the severity of pore clogging by salt. Similar phenomena have also been observed during gas production operations [2]. Most laboratory investigations rely on drying under reservoir temperature conditions, typically resulting in localized crystallization within the pore structure. However, other studies suggest that under certain subsurface conditions, particularly at high flow rates, a more uniform salt precipitation pattern can occur [3]. In this study, we aim to experimentally reproduce such homogeneous salt distribution using a controlled vacuum drying protocol. We use both model porous media (VitraPOR cylinders, 6 mm in diameter, with pore sizes of 40–100 µm, 100–160 µm and 160–250 µm) and natural rock samples (Bentheimer and Vosges sandstone, and Savonnières limestone). The protocol consists of repeated cycles of imbibition with a saturated KCl solution, followed by vacuum drying, leading to progressive salt accumulation. After every three cycles, X-ray tomography and mass measurements are performed to quantify in-pore salt deposition and salt distribution, and the sample's permeability is measured using a Hassler cell. This protocol allows for the establishment of a direct experimental relationship between permeability and salt mass, simultaneously assuring a homogeneous salt distribution. Our results show that vacuum drying enables uniform salt precipitation throughout the pore network, with salt consistently accumulating in the same regions. Such homogeneity was not achieved using conventional drying methods, which typically induce heterogeneous crystallization, mostly at sample edges, thereby making it difficult to derive an accurate permeability-salt relationship. First observations on the VitraPOR samples with 40–100 µm pores reveal an exponential permeability decline as salt mass increases. This experimental framework is highly relevant to subsurface injection scenarios and offers a rare direct quantification of permeability loss due to homogeneous salt precipitation at the REV scale, an effect that is usually estimated only through empirical models in the literature. As such, the experimental dataset can be used to validate or refine those models.

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References

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