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Insights into sandstone wettability alteration during cyclic scCO$_2$-brine injections

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Capillary trapping (also known as "residual trapping") of supercritical carbon dioxide ("scCO$_2$") is a key mechanism contributing to the safety and security of geologic sequestration operations for carbon capture and storage (CCS). Recent experimental studies have suggested that cycles of scCO$_2$ and brine injections alter surfaces of sandstone grains and increase capillary trapping. We present results from two supercritical-condition core-flooding experiments aimed at pinning down specifics of the alteration mechanism. Multiple cycles of scCO$_2$ and brine injections were performed in two Bentheimer sandstone samples; pore pressure was monitored during injections via transducers, and after cessation of flooding, fluid configuration and scCO$_2$ trapping were visualized via 3D X-ray microcomputed tomography at the Australain National University's CTLab. We confirm previous results that demonstrated shifts in injection pressure and scCO$_2$ trapping behavior over multiple injection cycles, and we conduct additional analyses to discern the fluid-fluid macroscopic contact angle, interface mean and Gaussian curvatures, scCO$_2$ interfacial area, and topology of trapped scCO$_2$ ganglia. Microstructural analysis of the scCO$_2$ phase indicates increasing presence of relatively high contact angle (i.e. less water-wetting) surfaces as the experiment progresses, indicating a transition to a "patchy" mixed-wet state. We observe that this wettability alteration renders scCO$_2$ more stable in the rock pore space, increasing capillary trapping over four injection cycles. However, the effect is only evident for homogenous region of the core; in regions where capillary heterogeneity dominates, wettability alteration effects are not evident. These results support previous work demonstrating progressive shifts in fluid flow and trapping due to scCO$_2$/brine cycling, and provide new clarification as to the conditions under which this phenomenon may occur. [1,2]

Participation

In-Person

References

[1] A.L. Herring, C. Sun, R.T. Armstrong, Z. Li, J.E. McClure, M. Saadatfar, Evolution of Bentheimer Sandstone Wettability During Cyclic scCO 2 -Brine Injections, Water Resour. Res. 57 (2021). https://doi.org/10.1029/2021WR030891.
[2] A.L. Herring, C. Sun, R.T. Armstrong, M. Saadatfar, Insights into wettability alteration during cyclic scCO2-brine injections in a layered Bentheimer sandstone, Int. J. Greenh. Gas Control. 122 (2023) 103803. https://doi.org/10.1016/J.IJGGC.2022.103803.

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