Sandstone Wettability in Supercritical CO_2-Brine-Rock Interactions Evaluated with ^{13}C and ^{1}H Magnetic Resonance/Magnetic Resonance Imaging

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Introduction: Carbon dioxide produced anthropogenically is thought to be a major contributor to global warming. Carbon capture and storage technologies play a pivotal role because they contribute to reducing emissions from hard-to-abate industries. The effectiveness of CO_2 containment underground hinges on the assumption that the sealing formation remains water wet in the presence of dense CO_2. In this work we employed MR/MRI techniques to determine if the pore space in a Berea sandstone core plug test sample was water wet, or CO_2 wet as illustrated in Fig. 1.

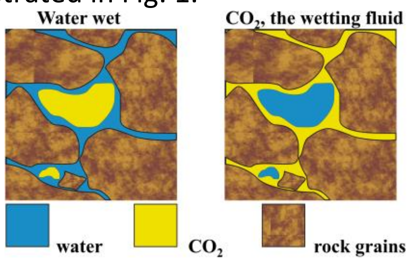

Fig.1: Pore wettability schematic: if water-wet (left), CO_2 occupies pore center; if CO_2-wet (right), water occupies pore center. Wettability describes the preference of two or more fluids to contact the pore surface. Wettability strongly affects fluid transport.

Methods: A novel variable field superconducting MR/MRI instrument was employed to undertake ^{1}H and ^{13}C measurements. The static field was switched from 0.79 T to 3.14 T as required to interrogate ^{1}H and ^{13}C at the common frequency of 33.7 MHz. A comprehensive suite of measurements was employed: ^{13}C and ^{1}H T_1, T_2, 2D T_1-T_2, 1D and/or 2D SPRITE images. Core plug saturations of brine and CO_2 were quantified from MR and MRI measurements. Measurements were undertaken at high pressure and temperature (4000 psi and 50 °C). The CO_2 phase was supercritical under these conditions. ^{13}C enriched CO_2 was employed to permit more rapid ^{13}C relaxation measurements and ^{13}C MRI measurements.

Results and discussion: Surface relaxation is well known in MR of porous media studies to be a good indicator of surface interactions and therefore wettability. T_2 is the most common parameter employed to examine surface relaxivity. In this work, the ^{13}C T_2 was not diagnostic since the high diffusivity of supercritical CO_2 resulted in a diffusion through internal magnetic field effect dominating the observed T_2. The ^{13}C T_1, particularly in T_1-T_2 relaxation correlation results showed that ^{13}C did not wet the pore surface. These results were confirmed by ^{1}H T_1-T_2 results of the brine phase. The ^{13}C enriched CO_2 phase was compressed in the core plug with a bolus of ^{12}C. ^{13}C MRI was employed to monitor mixing of the two species.

Conclusion: Supercritical ^{13}C and ^{1}H relaxation times indicate Berea sandstone remained strongly water-wet when exposed to CO_2. This multinuclear study showed the ability of MR/MRI to examine realistic processes under challenging experimental conditions.

Reference: Li, M., Kortunov, P., Lee, A., Marica, F., and Balcom, B.J. *"Sandstone Wettability in Supercritical CO_2-Brine-Rock Interactions Evaluated with ^{13}C and ^{1}H Magnetic Resonance",* Chemical Engineering Journal (2024) 500, 157100.