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Transport of CO_2 in heterogeneous porous media: Spatio-temporal variation of trapping mechanisms

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Geologic heterogeneity has a considerable effect on CO_2 trapping mechanisms in sequestration settings. This study is aimed to understand the two-phase flow (supercritical CO_2 and brine) as CO_2 replaces brine during the injection period, as well as when brine imbibes the CO_2 plume after the cessation of injection in a heterogeneous media. We here present the results of core-flooding experiments by assessing the impact of capillary heterogeneity on residual and dissolution CO_2 trapping. Two types of injection tests with different rates are conducted: single-phase (supercritical CO_2) injection and co-injection (equilibrated CO_2 and brine) cases are considered for drainage tests. In case of the single-phase injection, CO_2 builds up at a low capillary pressure (Pc) zone located upstream of a high Pc zone as CO_2 was hindered to transport across the barriers. The experiments were conducted under capillary-dominated condition, and as capillary number (Nc) was increased with greater injection rate, the increased viscous force led higher CO_2 saturation in fine matrix implying that high Pc zone was more sensitive to the injection rate than the low Pc zone. The co-injection, however, leads to greater CO_2 saturation at the high Pc zone. The observed disparity of CO_2 saturation patterns in these two experiments resulted from the induced pressure gradient across the core as well as the greater capillary forces in high Pc zone. The following imbibition test, which was designed to reproduce conditions for the post-injection period, characterized three regimes of spatio-temporal variation of trapping mechanisms as follows: (1) displacement of mobile CO_2 by the injected brine and concurrent CO_2 dissolution into the fresh brine; (2) preservation of immobile CO_2 as a residual trapping; and (3) gradual CO_2 dissolution into the fresh brine.