



Displacement and Mass Transfer Between Saturated and Unsaturated CO₂-Brine Systems in Sandstone

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The process of displacement and mass transfer between CO₂ and brine, which are relevant for the prediction of plume migration and pore-space utilization during CO₂ injection in saline aquifers, were studied by conducting unsteady-state core flood experiments in nearly homogeneous Berea sandstone rock. Mutually saturated and unsaturated CO₂ and brine phases were injected in the rock under realistic sequestration conditions.

Relative permeability and capillary pressure curves were extracted by history matching the unsteady state experiments conducted with mutually saturated CO₂ and brine. As a reference and for comparison, decane-brine primary drainage was conducted on the same sample. The CO₂-brine relative permeability was found to be different from the decane-brine relative permeability (which had been validated against steady-state experiments on twin-samples), reflecting the change in the wetting state from water-wet decane-brine/Berea to the rather intermediate-wet behavior of CO₂-brine/Berea, which is in agreement with literature data on contact-angles for the two cases. However, the CO₂ brine data are somewhat different from data on the same rock type as reported by Perrin and Benson (2010) which is likely a consequence of sample heterogeneity.

Aspects of the mass transfer between the CO₂ and the brine phase were studied by drainage and imbibition with unsaturated phases. When comparing saturated and unsaturated CO₂-brine primary drainage, the mass transfer due to mutual solubility leads to two effects: (1) evaporation in a 2-3 cm wide zone at the inlet due to water dissolving in CO₂ and (2) a diminished displacement of brine by CO₂ due to CO₂ dissolving in brine. In addition, an imbibition experiment was conducted where unsaturated brine was injected into rock filled with mutually saturated CO₂ and brine phase at near-residual CO₂ saturation. After the CO₂-saturated brine had been miscibly displaced by unsaturated brine, dissolution of the trapped CO₂ in the injected brine was subsequently observed. These experiments represent the transition from residual trapping to solubility trapping and indicate the time and length scales involved.