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Effect of capillary induced flow on CO2 residual trapping

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One of the main mechanisms to immobilize CO2 during geological carbon sequestration is residual trapping as a result of capillary forces at the pore-scale. It is often assumed that in the capillary dominated regime, capillary equilibrium within the system is reached instantaneously. This approximation is valid for homogeneous systems where the largest scale of heterogeneity is at the pore scale. However, for heterogeneous systems, there is, next to the capillary potential at the pore scale, a capillary potential at the scale of the heterogeneity which will result in capillary induced flow.

We investigate the impact of capillary induced flow on multiphase flow behavior and its implications for residual trapping of CO2 by performing experimental and numerical core-flood tests. The core-flood tests are carried out for a range of sandstone rock cores (including the Fontainebleau, Berea, Bentheimer, and Dundee) containing different heterogeneity features. Observations of the saturation distribution during drainage experiments, obtained with a medical X-ray CT scanner, are used to construct the sub-core scale permeability fields. With the use of the permeability fields and other experimentally obtained multiphase flow properties, the experiments are simulated numerically. The simulations allow us to calculate the capillary potential at the scale of the heterogeneity and to investigate the impact of capillary induced flow on residual trapping.

Our core-flood tests show that capillary equilibration is a function of time and that the time needed to reach equilibrium depends on the scale of the heterogeneity. The results confirm that for relatively homogeneous rocks capillary equilibration occurs almost instantly. For systems with a larger scale of heterogeneity, capillary disequilibrium can exist locally within a core even in the capillary dominated regime. Furthermore, the direction of the heterogeneity (parallel or perpendicular to flow), the scale of the heterogeneity, and the direction of the flow (from low to high permeability or high to low permeability) impact the local capillary forces and, therefore, the capillary pressure and saturation distribution. This can potentially control residual trapping as horizontal low permeability lenses could lead to bypass, while vertical layers could have a big impact on snap-off.

References

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Primary author: BOON, Maartje (Stanford University)

Co-authors: NI, Hailun (Stanford University); Dr GARING, Charlotte (Stanford University); Prof. BENSON, Sally (Stanford University)

Presenter: BOON, Maartje (Stanford University)

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