Metre scale gas-brine coreflood investigation of plume mobility and trapping

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Abstract. The carbon storage concept for the Petrel basin in Northern Australia involves injection of CO2 into a high permeability sand-rich fairway of the Sandpiper Formation with a likely permeability of around 1 Darcy or more. The plume trajectory is difficult to predict with models given the potential for unconstrained gas mobility. As no suitable cores were available from the basin, we conducted experiments on uniform cores of a good petrophysical analogue. Bentheimer sandstone has been widely used in rock properties research at core to pore scales, and we took advantage of that understanding in the design of large core flood experiments in tilted and vertical orientations to study 3D flow patterns, trapping efficiency and the relative importance of capillary, viscous and gravity forces at mm to metre scale. We used the nitrogen-brine system rather than CO2-brine, given that the system is mineralogically simple and strongly water wetting. The experiments were monitored by medical x-ray CT images. The first experiment, where gas was injected into the base of a ~1 metre long x 100 mm diameter core tilted at 17 degrees, showed the minor role of gravity forces compared with capillary-viscous flow instabilities. Once formed, gas channels bypassed the majority of the brine filled volume, leading to early breakthrough and inefficient trapping. Gas injection from the base of the vertically oriented core showed the same pattern. Gas formed a preferential path and minor gravity pooling at the top of the core, while subsequent brine sweep mainly followed the remaining brine zones, and hardly displaced any of the injected gas. The third experiment involved slow injection of gas from the top of the vertical core, forming a stable cap that achieved the maximum possible original gas saturation without gas breakthrough. Secondary brine imbibition forced the gas cap downwards, as well as creating a diffuse zone of residually trapped gas. A small zone of viscous brine fingering, where the maximum velocities are realised, was also seen the inlet region. The three dimensional x-ray imaging enables excellent visualization of the gas and brine channel patterns formed in the experiments as well as enabling the residual saturation to be assessed in a range of sub-regions of the core subjected to originally high and low gas saturations. The metre-scale experiments provide a wealth of information about flow instability that occurs even in highly homogeneous rocks, and provide a guide for further experiments on more realistic systems.