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Pore Geometry Controls on Residual Saturation Trapping Of CO_2: Applications for Commercial Scale Carbon Sequestration

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Abstract

Commercial deployment of Carbon Capture and Storage (CCS) will require selection of storage sites having sufficient storage capacity, adequate injectivity and viable containment to retain CO_2 produced from an industrial source. Initial studies of storage sites focused exclusively on structural, stratigraphic and hydrodynamic trapping, and sites with these "traditional" trapping mechanisms have been the primary objectives for most early assessments of storage projects. However, as the numbers of these "traditional" traps are limited and/or are at a commercially non-viable distance from CO_2 sources, exploration for migration associated trapping (MAT) will almost certainly be required for most 2nd generation storage sites. The principle MAT mechanisms are solution, mineral, and residual saturation trapping. Of these, the most prolific, and viable, at project-life time scales, is residual saturation. Residual saturation trapping of CO_2 comprises 2 stages: at injection the CO_2 displaces water in the pore system of the reservoir (referred to as the "drainage" phase). Because CO_2 is less dense than the formation brine, it migrates, via buoyancy, through the pore system of the rock (referred to as the "imbibition" phase). During imbibition, "snap-off" of the migrating CO_2 can occur resulting in permanent trapping of CO_2 within individual pores. The amount of snap-off, hence the amount of residual trapping, depends on the geometry of the pore system of the storage reservoir rock. Most significantly, it is the ratio of pore size relative to size of the pore throats connecting pores, and the number of pore throats relative to pores that control the volumes, rates and effectiveness of this trapping mechanism. Determining these properties requires a combination of petrographic and petrophysical (capillary pressure, relative permeability and wettability) analyses as part of the geological characterization procedure for identifying viable CO_2 storage sites. This study uses both pore-level modelling and results from several demonstration projects to discuss the viability of this trapping mechanism.