Engineered Geologic Heterogeneity for Understanding CO2 Saturation Flow Experiments

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Abstract

CO_2 sequestration aims at maximizing the subsurface storage efficiency and permanence. To achieve this, an engineered approach to storage is essential wherein the fate of the injected CO_2 and its saturation can be predicted with reasonable accuracy. This requires understanding of the dynamics of CO_2 migration and trapping processes in the subsurface. For typical field conditions (excluding produced fluids) and injection rates, pressure gradients weaken within hundreds of meters of the injection wells and buoyancy and capillary forces grow dominant over viscous forces. In such flow regimes, small scale (cm to m) heterogeneities due to depositional processes are known to affect migration and trapping of the non-wetting phase, a fact that has been emphasized by the Sleipner plume benchmark modelling and numerous numerical simulation studies. Most sand/bead-pack based lab scale experiments are conducted in macro-heterogeneous media constructed by arranging discrete homogeneous units. However, most natural sedimentary facies display heterogeneity at a hierarchy of scales, and heterogeneity at the mesoscale (mm to decimeter) goes unrepresented in laboratory experiments due to the difficulty in reproducibility. As a result, few experimental demonstrations of the effects of heterogeneity at these scales have been undertaken, the results of which can corroborate observations from numerical simulation studies. This work presents results from buoyancy driven fluid migration experiments conducted at the meter scale using glass beads packed in a quasi 2D glass cell (60 x 60 x 1 cm) and complementary reduced physics simulations. We demonstrate a novel, automated technique to build beadpacks that mimic natural outcrop/rock like features in a reproducible manner. The heterogeneous sedimentary structures are built by vertically depositing

glass beads of different sizes (ranging from 100 to 1000 microns) into the glass cell in an automated manner through a hopper mounted on a programmable dual axis (horizontal and vertical axes) linear actuator system. By programming the coordinated motion of the two axes the creation of crossbedding and ripple like sequences becomes possible. Fluid migration experiments are then conducted at ambient conditions using a surrogate fluid pair that mimics density and viscosity contrasts, and interfacial tension of in-situ reservoir brine and supercritical CO_2. Light transmission techniques are used for visualization, and to calibrate and quantify saturation of the trapped non-wetting fluid during the experiments. With the ability to generate different types of heterogeneous structures in a reproducible manner, a systematic investigation of the effect of heterogeneity on trapping and migration behavior becomes possible.