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Capillary heterogeneity in sandstones rocks during CO_2/water core-flooding experiments

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In the context of CO_2 sequestration, deep geological formations are often referred to as capillary systems, due to the important role played by capillary pressure in controlling fluid distribution in their porous structure. For instance, relative permeability and residual trapping curves depend on the character of the capillary pressure curve: the former controls fluid displacement, while the latter describes the amount of CO_2 that can be effectively immobilized in the pore space of the rock. Traditional techniques to measure capillary pressure curves on whole cores and with reservoir fluids are time consuming and as a result, the available experimental data set for the CO_2/water system is rather scarce. In addition, simulation studies clearly show the importance of capillary heterogeneity at the sub-score scale on CO_2 movement, but experimental techniques are needed for quantitative observation of these phenomena.

A novel technique has been developed to measure capillary pressure curves both at the core and sub-core (mm) scale using CO_2 and water at reservoir conditions. The method consists of carrying out 100% CO_2 flooding experiments at increasingly higher flow rates on a core that is initially saturated with water and requires that the wetting-phase pressure is continuous across the outlet face of the sample. The technique is faster than traditional methods that use porous plates and it can be applied in conjunction with steady-state relative permeability measurements.

Drainage capillary pressure curves of CO_2 and water are measured for two sandstones rock cores with different lithology and grain sorting.

Experiments are carried out at 25 and 50C and at 9 MPa pore pressure, while keeping the confining pressure on the core at 12 MPa. Measurements are in good agreement with results from the literature and data from mercury intrusion porosimetry; comparison with the latter allows for the estimation of the interfacial and wetting properties of the CO_2/water system. Additionally, during a core-flooding experiment, X-ray Computed Tomography (CT) scanning allows for precise imaging of fluid saturations at a resolution of about 1mm3. It is shown that a distribution of capillary pressure curves can be associated to the observed distribution of CO_2 saturation within the core, allowing for the quantification of capillary heterogeneity at the sub-core scale. This set of data is further exploited to investigate scaling laws that are based on the concept of similar media and that are used to describe the spatial variation of rock hydraulic properties. In particular, a set of scaling factors is obtained that relates the capillary pressure curve in each voxel to a representative mean, thus simplifying considerably the statistical description of capillary heterogeneity. Additionally, this proves the suitability of scaling laws such as the Leverett J Function to be applied at the sub-core scale, thus allowing the derivation of sub-core scale permeability distributions by combination with independent measurement of the corresponding porosity distribution.