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Experimental investigation of capillary entry pressure for caprock sealing capacity in Carbon Dioxide Sequestration

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The excessive emissions of carbon dioxide into the atmosphere lead to global climate change. Capture and Geological Storage of CO2, where CO2 is separated from industrial and other related emitters and injected into the underground for storage, has been universally acknowledged as a promising approach for reducing greenhouse gas concentrations in the atmosphere. The main mechanisms currently used for carbon dioxide storage are structural trapping and capillary trapping. The former uses the capping layer as a physical barrier to prevent the gas plume from moving upward, and the latter exploits forces within the pores of the rock to immobilize the gas. Therefore, in CCS formations, it is crucial to have sufficient capillary entry pressure to effectively prevent CO2 from escaping into the overlying formation and causing safety problems. The capillary entry pressure signifies the pressure exerted by a non-wetting fluid as it infiltrates the most extensive interconnected pore space, initiating the displacement of water.
This study focuses on carbonate samples as potential caprock and measures the capillary entry pressure of the caprock samples under different pressure conditions. The porosity and permeability of the samples before and after the breakthrough experiment were compared and analyzed. The calculated capillary entry pressure based on the Thomas et al. correlation for the carbonate caprock with a water permeability of 0.03 mD is 2.3 bar. By utilizing the Step-by-step method, in which the injected fluid pressure is gradually increased in a constant mode while monitoring the variations at the outlet, the flow rate starts to increase from 0 when the pressure is increased to 5.5–6 bar. Meanwhile, the volume at the outlet increases significantly, which means that the capillary entry pressure is reached. Therefore, the experiment results show that the practical capillary entry pressure is larger than the correlated one. The results of measuring permeability after the experiment were different from those before the experiment. During the experiment, slight variations in volume at the outlet due to changes in ambient temperature have implications for determining that the capillary entry pressure is reached. In particular, for future targeting of rocks with much lower permeability, a temperature regulation must be built into the core flooding setup.