Effects of pore-throat structure on reservoir blockage and wettability alteration during CO2 injection

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Injection of CO₂ into subsurface reservoirs occurs during Enhanced Oil Recovery (EOR) and also during Carbon Capture and Storage (CCS) operations. During CO₂ injection, the efficacy and distribution of fluid flow in sandstone reservoirs is controlled by the pore-throat microstructure of the rock. Furthermore, CO₂ injection promotes asphaltene precipitation on the pore surface and can also affect fluid flow in the pore throats, decreasing the permeability and altering reservoir wettability. In this work, miscible and immiscible CO₂ flooding experiments under reservoir conditions (up to 70°C, 18 MPa) have been carried out on four samples with very similar permeabilities but different pore-throat structures in order to study the effects of pore-throat microstructure on formation damage. The features of pore-throat structure were evaluated by fractal theory, based on pore size distributions and rate-controlled porosimetry (RCP) mercury intrusion curves. Reservoir rocks with smaller pore throat sizes and more heterogeneous and poorer pore-throat microstructures were found to be more sensitive to asphaltene precipitation, with corresponding 15-20% lower oil recovery and 4-7% greater decreases in permeability than that of rocks with homogeneous and better pore-throat microstructure. However, the water-wettability index of cores with larger and more connected pore-throat microstructures was found to drop by an extra 15-25% than heterogeneous core due to more asphaltene precipitation caused by the larger sweep volume of injected CO₂ they consequently experienced, which is a disadvantage for EOR. In addition, immiscible flooding exacerbates the differences from 4-7% to 8-15% in permeability decline of the rocks with different pore-throat structures. Miscible flooding leads to more asphaltenes being precipitated from the crude oil, triggering in average an extra 11% change in wettability in comparison to immiscible flooding.

Keywords: CO₂ flooding, asphaltene precipitation, pore size distribution, pore-throat microstructure, reservoir blockage, wettability alteration