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Microscopic Percolation Patterns in Multiphase Flow of CO2 Enhanced Oil Recovery and Mineralization

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The use of CO2 for secondary oil recovery has become a crucial means to achieve emission reduction. However, the microscopic transport mechanisms of water-oil-CO2 during this process, as well as the regulations governing CaCO3 precipitation in porous media leading to pore clogging and reduced permeability, remain unclear.

This experiment conducts a visualized study of CO2-oil-water percolation in homogeneous porous media, examining the impact of displacement factors such as flow rate and pressure on recovery. We quantify stable displacement, capillary fingering, viscous fingering, and other modes. Based on CO2-oil-water percolation experiments, a buffer solution is injected under different flow rates and pressure conditions to catalyze and accelerate CO2 mineralization reactions. The experiment observes the microscopic aggregation and distribution patterns of CO2 mineralization crystals in porous media, exploring the resulting changes in pore volume and their corresponding effects on permeability and fluid mobility.

This experiment employs a specialized pressure-resistant microfluidic chip with a CaCO3 coating, accurately simulating the geometric structure and surface properties of underground rocks. The chip initially exhibits an oil-wet surface, and upon injection of low-concentration desalinated seawater (referred to as desalination water), cations in the desalination water transform the wettability of the rock crystals, causing certain coatings to transition to water-wet characteristics. Before the breakthrough of desalination water, there is a positive correlation between the internal pressure of the chip and the injection flow rate, while it exhibits a negative correlation with pore size. The heterogeneity of pore shapes and sizes in heterogeneous media results in higher injection pressure compared to homogeneous media. After the injection of supercritical CO2 (ScCO2) into the chip, the remaining water dissolves some CO2, creating an acidic environment within the chip, and corroding the CaCO3 coating within the channels. However, the chip also contains ScCO2-encapsulated media, preventing corrosion and forming a protective phase. ScCO2 can similarly alter the crystal wettability, transforming it into CO2-wet. Injection of a buffering solution to adjust the internal environment of the chip to alkaline conditions results in the formation of CaCO3 crystals adsorbed on the surface of the porous media. Nevertheless, Some crystals tend to aggregate, indicating that CaCO3 might bridge at the pore entrance, potentially causing blockages.

This study focuses on the fundamental mechanism analysis of CO2 multiphase flow and sequestration, researching improvement measures for CO2 enhanced oil recovery and storage technologies. It lays a crucial research foundation for enhancing petroleum recovery, contributing to the achievement of carbon peaking and carbon neutrality goals.

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Primary authors: WANG, Qingxuan (China University of Petroleum (East China)); Mr WANG, Xiaopu (China University of Petroleum (East China))

Presenter: WANG, Qingxuan (China University of Petroleum (East China))

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