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Pore-scale Study of the Influence of Pore Heterogeneity on Non-miscible CO2 Displacing Oil

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CO2 Enhanced Oil Recovery (CO2-EOR) is a green and promising technology that not only improves crude oil recovery but also reduces carbon emissions. The micro-pore structure of porous reservoirs significantly influences the effectiveness of CO2-EOR, making research in this area crucial. This study aims at the influence of pore heterogeneity on the non-miscible CO2 displacement and employs a coupled approach utilizing the N-S equations and phase-field method to numerically simulate the microscale two-phase flow of CO2-oil displacement within porous media. The impact of pore heterogeneity on the shape and stability of the CO2-oil displacement front, residual oil types, and spatial distribution are investigated under different capillary numbers. The study elucidates the mechanisms through which heterogeneity affects the non-miscible displacement process of CO2. The results indicate that, under conditions of neutral wettability ($\theta=\pi/2$) and low capillary numbers (logCa=-6.253), the increased pore heterogeneity in porous media leads to a more unstable displacement front. The overall recovery increases with an increase in capillary numbers in the model with weak heterogeneity ($\sigma=0.004$). However, the presence of dominant channels leads to a decrease in the oil recovery with the increasing capillary numbers in the models with stronger heterogeneity ($\sigma=0.008$ and $\sigma=0.012$). With the pore heterogeneity increasing, the influence of capillary numbers on the displacement front, the quantity and spatial distribution of various residual oils, and breakthrough time become less pronounced. This research provides valuable insights into the mechanisms governing the impact of pore heterogeneity on the non-miscible displacement process of CO2-oil under different wettability and capillary number conditions for CO2-EOR.

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