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Multiphase flow in shale fracture networks applicable to hydrocarbon recovery processes: huff-and-puff, water displacement, and chemical additives using microfluidic experiments

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Current hydrocarbon recovery methods in hydraulically fractured shale have low recovery efficiency of about 10%. The objective of this work is to investigate several enhanced recovery methods to improve the production rates in shale. We examine the effectiveness of nitrogen and supercritical carbon dioxide in huff-and-puff methods for enhanced oil recovery to re-energize the reservoirs and improve recovery rates. In addition, we also present studies of water displacement in fracture networks as a baseline comparison as well as the effects of chemical additives (surfactants and friction reducer). We use direct visualization in microfluidic systems to reveal the mechanisms and to quantify the recovery rates of oil from fracture networks. We compared the effectiveness of water, nitrogen and supercritical carbon dioxide at reservoir conditions in a process mimicking huff-and-puff methods in both dead-end and connected fracture systems. Water and chemical additives were also used to study multiphase displacement mechanisms. The chips are made of glass and shale and placed in a confining pressure system pressurized to 10 MPa, 50 oC. The system was allowed to equilibrate, and then depressurized to determine oil recovery. Fluorescent microscope images were continuously taken to visualize and calculate residual oil saturation as a function of pressure draw-down. For huff-and-puff experiments, during depressurization from 10 MPa, gas exsolution from the oil liquid phase, including bubble nucleation and coalescence, appeared to be the main energy driver for mobilizing the oil from the fracture networks. Injection of supercritical CO_2 had the highest recovery rate and removed most of the initial oil in place; N_2 removes about 30% of oil; and injection of water had a negligible recovery rate. The connected fracture network allowed for more gas to dissolve into the oil and had better recovery rates than in the dead-end fracture network. For water displacement tests, we investigate the effects of flow rate and chemical additives in lowering the oil/water interracial tension, and rock surface wettability on hydrocarbon recovery rates. The mechanisms of oil mobilization, oil saturation, and water displacement patterns, and effectiveness of chemical additives observed in this study can be used to improve the recovery rates in shale through enhanced hydrocarbon recovery methods.

References

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