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Comparison between secondary and tertiary low salinity waterflooding in carbonates: pore-scale processes, wettability changes and recovery

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Improving oil recovery from existing fields is an essential element in the energy transition to help meet the world's energy demand in an efficient and sustainable manner while exploration for new fields is in decline. Many lab experiments and field trials have highlighted the potential of low salinity waterflooding (LSW) as a prominent enhanced oil recovery (EOR) technique. The main advantages of LSW over the other EOR techniques include its enhanced performance, and simple and environmentally friendly field implementation.

Previous experimental work investigating LSW was performed mainly at the core or atomic scales where there are limitations to understand the mechanisms responsible for the low salinity effect (LSE) on a natural rock at reservoir conditions. In this work, comprehensive experimental studies of both secondary and tertiary LSW were performed to shed light on the pore-scale processes and correlate them to wettability changes and oil recovery. To reach initial wetting conditions found in oil reservoirs, two limestone rock samples were continuously injected with crude oil at 1 μL/min at high pressure and temperature for three weeks. In the secondary mode, the oil-saturated sample was injected with low salinity brine at increasing flow rates. In the tertiary experiment, low salinity brine was injected after a sequence of high salinity floods. X-ray micro-computed tomography (micro-CT) was used to image in situ waterflooding. Pore-scale displacement processes, wettability alterations and oil recovery were captured and analysed using high-resolution micro-CT images.

Pore occupancy analysis showed oil redistribution during secondary LSW; oil was displaced from smaller to larger pores and eventually recovered as more pore volumes of brine were injected. In tertiary LSW, oil was observed in layers confined to pore walls and was trapped to pore corners after the high salinity floods. After switching to low salinity brine, oil was displaced by the growth of water micro-droplets (10s of μm in size) within oil, and the expansion of thin water films between the oil and rock surfaces. The water-in-oil droplets formed at the oil-brine and oil-rock interfaces. Water micro-dispersions were observed mainly in the tertiary mode, compared to secondary, as the high salinity brine is believed to have slowed down the osmosis process allowing the images to capture the development of these droplets. In comparison with tertiary mode, LSW resulted in higher oil recovery in the secondary mode. In both LSW modes, the changes in contact angle, curvature and capillary pressure values were observed mainly after low salinity brine injection indicating wettability alteration from oil-wet towards more water-wet conditions.

This comprehensive study provides insights into low salinity pore-scale displacement mechanisms previously observed only on micro-models. It highlights both fluid-fluid and fluid-rock mechanisms associated with the LSE. This study can, therefore, offer valuable input for the fluid selection criteria to design LSW-EOR.

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References

Time Block Preference

Time Block A (09:00-12:00 CET)

Participation

In person

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