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Wettability Alteration During Low Salinity Waterflooding: Effect Oil Composition and Divalent Cations

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Abstract

Laboratory and field tests have shown that reducing the overall salinity especially the concentration of divalent ions of the injected water can markedly improve the oil recovery. However, no mechanism have been widely accepted as the main reason for the enhanced oil recovery by low saline water. As wettability alteration toward be more water-wet has been observed in many promissing cases, desorption of polar oil components from the rock surfaces should occur during low salinity waterflooding. In this paper, the influence of solution cations (Ca^{2+} and Na^{+}) of initial water on initial wettability of sandstone cores and the reduction of salinity of imbibing water on wettability alteration was examined by spontaneous imbibition, and the adsorption/desorption of acidic polar compounds of crude oil onto clays were investigated by static adsorption experiments, thereby provide a better understanding of possible relations of microscopic desorption of acidic polar compounds from mineral surface to the macroscopic wettability alteration during low saline water flood and the relevance of divalent ions (Ca^{2+}) in this process. Spontaneous imbibition experiments showed that Ca^{2+} in initial water can largely bring about the retention of polar oil components onto mineral resulting in the initial wettability alteration of cores toward more oil-wet conditions in comparison to Na^{+}, and lowering salinity of imbibing brine can improve oil recovery of cores aged by Ca^{2+} solutions, whereas no obvious enhanced oil recovery (EOR) was observed for cores saturated with Na+ solutions. This indicated that oil components like carboxylate can retain on rock surface mainly by calcium-bridging to alter the wettability toward more oil-wet condition, and the reduction of salinity of imbibing brine can break the calcium bridges due to increased electric repulsive forces between oil and rock to change the wettability to be more water-wet, as a result, EOR occur. This is in accordance with the adsorption/desorption of acidic polar compounds experiments. The presence of background electrolyte Ca^{2+} can largely enhance the adsorption of acidic polar compounds (benzoic acid) onto clays (kaolinite and illite) in contrast with Na+, and reducing the salinity can lead to the desorption of acidic polar compounds pre-adsorbed onto clays. In conclusion, breaking calcium bridges between oil and rock due to increased repulsion forces can conbribute a lot to EOR during low-salinity waterflooding.