The role of heterogeneous wettability for hydrocarbon production from imbibition in a mixed multiporous carbonate reservoir rock investigated by magnetic resonance techniques

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Abstract. The intermediate and/or mixed wetness of carbonate rocks is often attributed to the adsorption of oil polar components onto the pore surface over time. Many carbonate rocks have multiple pore systems with large pore size distribution and irregular pore geometry which control the access of oil to the pore surface. The previously-developed correlations between the oil mobilization and mixed and/or intermediate wettability for sandstone and mono-pore carbonate rock, such as North Sea chalk, may not be valid due to the pore system differences. Furthermore, the clear pore scale identification of the initial and residual oil distributions in multiparous carbonate rocks is imperative to improve the EOR efficiency, which are the objectives of this study.

The NMR measurements are able to provide both oil saturation distributions at core scale from imaging and at pore scale from measurements such as T2 distributions. Three types of clean reservoir core plugs composed of macropore (M), micropore (m), and both macropore and micropore (M-m) are selected based on the T2 distributions of 100% water saturated. First, the oil is saturated at different levels using a centrifuge. The samples are aged at 75°C for various time periods to create different wettabilities monitored by T2 distribution shift. Then they are immersed in D2O for imbibition with two ends open (TEO) monitored by NMR for spatial oil saturation distributions and T2 distribution shifts. Finally, a small water head (1-2 inches) is applied for further changes in saturations within samples.

The results of the aging and imbibition experiments indicate the following relations and findings: the less the initial water saturation and the longer the aging duration, the larger the wettability alteration during aging. At the pore scale, the wettability of micropore appears to be less altered due partially to the lower oil saturation. In addition, no clear progressing water fronts are observed during imbibition from MRI saturation profiles. Additional oil production is observed for some samples after applying the water head. The increase of that from micropore is mainly caused by the better contact between water and micropore impeded by local capillary barrier. In summary, the current study provides insights on the wettability heterogeneity at both core and pore scales in this multiprorous reservoir rock. The observed phenomena of the wettability alteration and oil saturation in different pore systems is the key to understand the subsequent forced imbibition and to identify residual oil distribution as the target of EOR.