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Direct Pore-Scale Simulation of the Effect of Wettability Alteration by Low-Salinity on Oil Mobilization in 3D Natural Sandstone

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Wettability is an important factor controlling the pore-filling mechanism and displacement efficiency in the subsurface pore space. The trapped phase can be mobilized by wetting alteration, which is one of the main mechanisms of enhanced oil recovery technologies, such as surfactant flooding and low-salinity water flooding. Despite recent advances in the simulation of wetting alteration at the core scale or beyond, there are very few works that have modeled the wettability alteration at the pore scale, especially in three-dimensional (3D) micro-CT images, causing fluid displacement and retrapping mechanisms during wettability alteration are not well understood. With this objective, a wettability alteration model by low-salinity is developed and implemented in the open-source computational fluid dynamics software OpenFOAM (Open Source Field Operation and Manipulation), where both the Navier-Stokes equations for oil/water two-phase flow and the advection-diffusion equation for species transport are solved. The proposed model is validated against a published sinusoidal channel micromodel and then applied to 3D micro-CT images of sandstone to investigate the interplay between wettability alteration and pore structure. This study takes into account the effect of initial wettability, different degrees of wettability alteration, different time scales of wettability alteration, and different injection scenarios on oil trapping and the ultimate oil recovery factor. A larger degree of wettability alteration results in a higher oil recovery factor during tertiary low salinity water flooding. However, the oil recovery factor will first increase and then decrease with the increase of wettability alteration degree due to the snap-off effect during secondary low salinity waterflooding. In tertiary low salinity waterflooding, a lower wettability alteration time scale under the same degree of wetting alteration produces more oil. This study emphasizes the important interplay between wettability alteration, pore structure, and time scale during low salinity water flooding, and can explain some observations in recent micro CT experiments.

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