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The numerical simulation of two-phase flow in multi-mineral shale digital rock cores

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Shale oil and gas resources are widely distributed and have abundant reserves in China, with broad development prospects and potential. Due to the inherent characteristics of shale oil, such as the large number of nanometer-sized pores with complex pore structures, significant fluid-wall effects, complex mineral compositions, abundant organic matter, and complex and diverse wettability, the flow law of multiphase flow under shale reservoir conditions differs significantly from conventional reservoirs. Therefore, it is essential to characterize the flow of multiphase flow under shale pore scales, considering TOC content, complex wettability, and adsorption conditions. In this work, a new method for simulating the pore scale of shale oil-water two-phase flow based on mixed multi-mineral phase digital cores is proposed. This method is based on identifying the pore wall surfaces of each mineral and considering the corresponding adsorption and wettability conditions. Firstly, the multi-mineral phase shale digital core is reconstructed from the two-dimensional scanning electron microscope image of the shale sample, and the pore space of the corresponding minerals is divided by grids. Secondly, based on the Navier-Stokes equation, considering the TOC content, complex wettability conditions, and adsorption layer, the VOF method is used to simulate the shale oil-water two-phase flow process at the pore scale. Finally, the influence of TOC content, complex wettability, and adsorption on the shale oil-water two-phase flow is analyzed. The results have shown that the effects of TOC content, complex wettability, and adsorption on shale oil-water two-phase flow cannot be ignored. As the TOC content increases, the contact area between the organic pore walls and oil and water also expands. The flow of the water phase is hindered by the oil-wet organic pore walls, which significantly reduces the movable degree of oil. The movable degree of oil is also influenced by the organic matter distribution. In addition, the change in wettability of shale pore walls can also affect the flow of oil and water phases in shale. With the stronger oil-wetness of shale pore walls, especially organic pore walls, the movable degree of oil decreases. Due to the narrow pore radius and strong fluid-wall interaction, the adsorption phenomenon is significant, causing oil to remain on the pore surface, thus, greatly reducing the movable degree of oil. Our findings are critical for enhancing the efficiency of shale oil recovery, carbon dioxide geological sequestration, and other related areas.

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