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Microscopic damage rules of water flooding in ultra-low permeability reservoir: an experimental study based on the combination of microfluidic and low-field NMR technology

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Water flooding is one of the important ways of oilfield development in China. However, due to the poor-compatibility between injected water and reservoir rocks and fluids, free particles such as inorganic scale and rock clay often block the pores and throats under the carry-over effect of water seepage, which leads to engineering problems such as water injection pressure increasing, underinjection of injection-wells and decreased oil production capability of production-wells. Conventional core experiments and numerical simulations were used to study the damage induced by water injection. Since the black-box nature of the core, researchers cannot observe the fluid flow rules in porous media, nor can they know the specific location and degree of core damage. Although the numerical simulation method can simulate the scale formation and the occurrence of scale particles, it ignores the real situation of scale particles being carried and moved by fluid, and can not obtain the real rules of water flooding damage to the reservoir.
Considering the shortcomings of previous studies, we combined low-field NMR and microfluidic techniques to explore the damage rules of injected water to the core of an ultra-low permeability reservoir in northwest of China. Firstly, low-field NMR online displacement technology was used to detect the signal intensity changes of the core along the axial direction, as well as the pores of various sizes during the water flooding process, and we obtained the injury rules of the core at different locations during the water flooding process. Further, we used μ-CT to scan the core slice and obtain its pore distribution information, and etched it on the glass chip for displacement experiment, and observed the damage rules of the scale particles generated by the combination of injected water and formation water on the porous media in real time.
It is found that free particles are selective to reservoir damage. Due to the low-resistance flow characteristic of fluid, free particles will be carried by fluid to the micro-fractures and large pores, causing greater damage. This kind of damage has mobile characteristics, free particles will be carried to the center and tail end of the core, and increase the blockage these parts over time. The microfluidic experiment further confirmed the rules obtained by low-field NMR method, and the accumulation of scale particles in the middle and rear of the chip was also found in the microfluidic displacement experiment. The particles size of these areas continues to increase, which increases the damage to the middle and rear of the reservoir, blocks the flow channel of the production wells, and seriously reduces the swept efficiency of the displacement phase.

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