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The occurrence states of shale oil and its controlling factors in Yanchang Formation, Ordos Basin, China

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Oil mobility evaluation is the primary topic in shale oil development. The different occurrence states of shale oil, which closely relate to the pore structure and fluid properties tremendously affect the oil mobility in shale. As proved in previous studies, the higher the content of oil in free states, the better the oil mobility will be. In this study, the oil occurrence states and its influencing factors of the 7th member in Yanchang Formation (Chang7) in Ordos Basin, China were investigated by multiple experiments, including nuclear magnetic resonance (NMR), nitrogen gas adsorption (NGA), electronic scanning microscope (SEM), X-ray diffraction, and rock pyrolysis. The Chang7 samples were classified into four lithofacies based on mineralogy and TOC. With the increasing of the clay content, the four lithofacies are siliceous shale, OM-rich siliceous shale (TOC>5%), argillaceous shale, and OM-rich argillaceous shale (TOC>5%) (Figure 1). The NMR results indicate the fluids in Chang7 consist of structure water, free water, adsorbed oil, and free oil. The contents of adsorbed oil increase with TOC and clay percentages increase. However, the contents of free oil show negative relationships with TOC and clay percentages. Therefore, we speculate that the strong adsorbability in organic matter and clay minerals force the oil to be preserved as adsorbed oil in shale, which tremendously affect the oil occurrence states and mobility. Siliceous shale has the greatest content of free oil, and OM-rich siliceous shale has the greatest content of adsorbed oil. From the NGA results, mesopores have the domination in pore volume and specific surface area, especially in siliceous shale. The cumulative pore volumes decrease from siliceous shale to OM-rich argillaceous shale with the increase of clay contents. The NGA was also conducted on the samples after solvent extraction, which shows opposite changes of the volume in mesopores and macropores. Lots of mesopores were released by solvent extraction, particularly in siliceous shale which has the greatest increase in mesopores. Similarly, SEM images of the siliceous shale also show a large amount of mesopores in felsic grains. In the other three lithofacies, few pores were observed because of the tight compaction of clay and felsic minerals. Combing with the free oil content, the positive relationship between the free oil content and different percentage of mesopore volume indicates that the mesopores are the primary storage space of free oil (Figure 2). Compared with the lithofacies which have more clay content and TOC, the siliceous shale has more mesopores and low adsorbability in the pore system, which provides an optimum pore structure for the occurrence of free oil. To summarize, the free oil content shows an obvious preference in siliceous shale. The lithofacies defined by mineralogy compositions and TOC affect the oil occurrence states by pore structure. Parallelly, the pore structure was deeply affected by the grain size, spacial arrangement, and minerals (grain type). Therefore, the occurrence states of oil in shale were strongly affected by the pore structure through the lithofacies.

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