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Characterization of Fluid Mobility and Determination of Movable Pore Throat Lower Limit in Deep Tight Sandstone Reservoirs Based on Nuclear Magnetic Resonance

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Study on the Fluid Mobility Within Reservoir Microscopic Pore Throats Holds Significance for the Precise Evaluation of Reservoirs and the Efficient Development of Oil Fields. Nuclear magnetic resonance can rapidly and accurately determine common movable fluid parameters such as movable fluid saturation, movable fluid porosity, and bound fluid saturation. This enables effective fluid assessment and productivity prediction for various types of oil and gas reservoirs. In this research, different facies' sandstone fluid mobility and the lower limit of movable pore throats in lacustrine delta-turbidite systems were characterized via multi-gradient centrifugation nuclear magnetic resonance. This study, combined with experiments including particle size analysis, thin sections, X-ray diffraction, and high-pressure mercury tests, explicitly delineates the impacts of reservoir deposition, diagenesis, reservoir type, and microscopic pore structure on movable fluid saturation. The research findings reveal three types of lithofacies, three categories of pore throat structures, and three classes of pore throat spaces (micropores, sub-micropores, and nanopores) in the study area. Micropores and sub-micropores are prevalent in blocky and laminated fine sandstones of the delta front facies, with higher fluid migration rates in micropores than in sub-micropores, and nanopores exhibit the lowest rates. Turbidite facies mudstone fine sandstone and calcareous fine sandstone contain sub-micropores and nanopores, showing the highest fluid migration rates in sub-micropores. Fluid mobility is influenced by various factors such as rock physical properties, diagenetic minerals, pore-throat structures, and lithofacies. As pore-throat structures and petrophysical properties deteriorate, the fluid mobility in all three types of reservoirs decreases. The movable fluid content shows a significant correlation with feldspar content, highlighting the improved fluid mobility of feldspar dissolution pores. Conversely, carbonate minerals and clays (plastic minerals) exhibit a negative correlation with movable fluid percentage (MFP), resulting in reduced quality of reservoirs and pore structures. Additionally, the sand ratio (sandstone thickness/formation thickness), sandstone layer thickness, and distance from source-reservoir boundary affect the movable fluid saturation. Thicker sandstones with lower mud content and carbonate cement show higher movable fluid saturation. Conversely, thin sandstones often embedded in thick mudstones exhibit higher carbonate and clay content at source-reservoir interfaces, leading to decreased movable fluid saturation. Moreover, with increased centrifugal force, micro-nano-pore fluid production initially increases rapidly and then stabilizes. Under 2.75 MPa, nanopore fluids migrate towards micropores, calculating a movable pore throat radius of 18nm~30nm. The research outcomes contribute theoretical references for understanding and effectively developing deep tight sandstone reservoirs.

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