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Pore fluid identification with innovative non-electrical methodology for Ultradeep tight reservoirs

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The Tarim Basin is well known for its high-gas production as observed in the remarkable West-to-East Gas Transmission Project. The reservoirs are mainly located deep at approximately 8000-m vertically in different types of lithologies, with tight petrophysical properties. Fluid identification is a key tool used to locate the sweet spot with high producibility for further development. Resistivity is the most common and straightforward method for identifying the sweet spot. However, because of the mixed effects from pore structure, formation sedimentary dips, far-end fractures, and the influence of the surrounding rocks etc., hydrocarbon and water cannot be easily distinguished based on the resistivity difference. In tight carbonates, the Archie equation is not always a good solution while the reservoir shows strong heterogeneity in mineralogy and pore structure. There is no obvious cross-over effect for sonic based analysis as well. This paper presents how a novel methodology based on nonelectric openhole logs reveals the fluid types in the tight sandstone and carbonate reservoirs in this ultradeep environment.

The workflow presented in this paper is based on wireline logging techniques, including advanced spectroscopy and nuclear magnetic resonance (NMR) T1-T2 measurements. Advanced spectroscopy uses both capture and inelastic gamma ray spectroscopy measurements, providing precise dry weights for elements and minerals, together with total organic carbon (TOC). The spectroscopy measurements also provide the thermal neutron cross section (sigma) and chlorine concentration measurements, which are sensitive to different fluids while the formation is saline. T1-T2-based 2D NMR measurements provide porosity and permeability information for T2-based analysis. When used in conjunction with T1 -based measurements, the fluid identification through different T1-T2 response provides an advantage for distinguishing hydrocarbons and water. Relaxation due to diffusion only applies to T2 and never to T1. Given the typical magnetic field gradients of the logging tool, the oil and gas signal can be easily distinguished from the T1/ T2 ratio. The continuous measurement enables separation and quantitation of different fluids that exist in the pore system for the entire interval of the targeted reservoir.

This paper presents case studies from this ultradeep reservoir in China for both clastics and carbonates formations that solved the fluid identification issue when resistivity cannot directly distinguish fluid types. For hydrocarbon zones, borehole and formation chlorine concentration without obvious difference, and for T1/T2 ratio is normally over three summarized from different formation types. The results matched well with the test results, which provided a novel solution to f the sweet spot interval identification for the targeted reservoir. The results show the compatibility of this workflow in different formation types and reservoirs.

This paper presents a successful and novel integrated workflow that combines multiple wireline measurements for fluid identification in tight carbonate reservoirs when the uncertainty of the resistivity method is high due to multiple factors. Also, the nonelectrical methodology significantly lowers the uncertainty for water saturation estimation. This result has helped to enhance the methodology for fluid identification and earn considerable economic value by escaping the water zones in the further development of the reservoir.

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References

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