# A novel method for identifying pore fluids using nuclear magnetic resonance (NMR) logging in conglomerate reservoirs during oil-based mud (OBM) Drilling

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**Introduction:** Identifying pore fluids in conglomerate reservoirs during oil-based mud (OBM) drilling presented significant challenges. Traditional methods, such as crossplotting porosity and resistivity or overlapping multiple curves, often fallen short due to extremely low hydrocarbon saturation. The differences in log responses between oil-bearing formations and fully water-saturated layers were minimal. However, nuclear magnetic resonance (NMR) logging could play a crucial role in formations drilled with water-based mud (WBM), and various methodologies had been proposed. Unfortunately, in formations where OBM was used for drilling, existing methods were ineffective because they did not account for the impact of OBM filtrate on NMR $T_2$ spectra. **Methods:** This study aimed to enhance the applicability of NMR logging for pore fluid identification in formations drilled with OBM. We conducted NMR experiments on 10 representative core samples retrieved from the Permian Urhe Formation in the Shawan Depression, located on the southern margin of the Junggar Basin. The samples were analyzed under three saturation conditions: fully brine-saturated, OBM displacing brine, and crude oil-saturated states. We sought to clarify the NMR response mechanism under the OBM displacing condition. For the fully brine-saturated rocks, the NMR $T_2$ distribution demonstrated a shallow unimodal pattern, with relaxation times ranging from 0.03 to 10 ms. When large pore spaces were occupied by OBM filtrate, the resulting $T_2$ spectrum showed a bimodal distribution, spanning from 0.03 to 60 ms, with the second peak correlating to the bulk relaxation time of the OBM filtrate. Following the injection of crude oil into the pore spaces, the NMR $T_2$ distribution evolved into a trimodal pattern. The left peak represented the surface relaxation of bound water, while the second and third peaks corresponded to the bulk relaxation characteristics of the OBM filtrate and crude oil, respectively, with the maximum relaxation time exceeding 100 ms. We established two $T_2$ cutoff values—3 ms and 100 ms—to classify the NMR $T_2$ spectra into three segments. Three parameters, $S_1$, $S_2$, and $S_3$, were derived from the NMR $T_2$ spectra, representing the ratios of pore spaces occupied by small, medium-sized, and large pores to the total pore space of the rock. A new parameter, termed the pore fluid index (ifluid), was introduced to indicate the presence of different pore fluids, as expressed in Equation 1. Criteria were developed to identify hydrocarbon-bearing formations, water-saturated zones, and dry layers (**Fig. 1**). **Results and discussion**: Field applications demonstrated that the proposed method was effective for our target conglomerate reservoirs during OBM drilling. **Conclusion:** The accuracy of pore fluid identification using NMR logging had significantly improved. Once this technique was widely adopted, it would facilitate better evaluation of conglomerate reservoirs in OBM drilling, thereby greatly expanding the applicability of NMR logging.

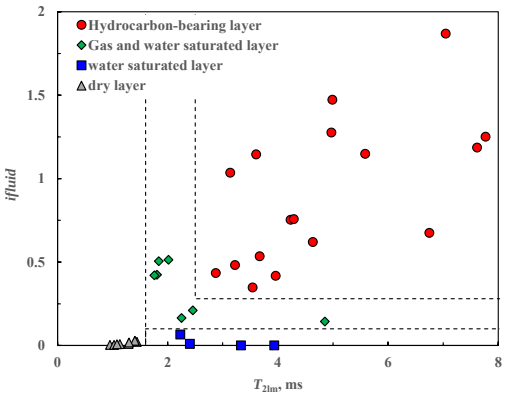


**Fig. 1**: Criteria for identifying pore fluids based on NMR logging in wells drilled with oil-based mud (OBM).

$$ifluid = \frac{S_2 \times S_3}{S_1^2} \times \varphi \qquad \text{Eq. 1}$$

Where, $S_1$, $S_2$, and $S_3$ represent the percentages of the total pore space of the rock occupied by small, medium-sized, and large pores, respectively. $\varphi$ is the NMR total porosity in %.

**References:**
[1] Coates G R, Xiao L Z, Primmer M G. Houston: Gulf Publishing Company, USA (2000). [2] Gao F M, Xiao L.SPE Journal (2024).