NMR characterization of critical boundary of pore fluid in shale

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Pore fluids are generally classified into movable fluid and irreducible fluid by one or two NMR *T2* cut-offs (*T2C*). Fluid movability in shale may not be accurately characterized by pore size-based classification methods solely because of the complex pore structure and heterogeneity in pore size. In this study, we propose a nine-grid dual *T2C* model to characterize critical boundary of fluid and calculate the percentages of free fluid (FF), capillary-bound fluid (CAF), and clay-bound fluid (CBF). The pore size distributions and capillarity boundaries are converted from *T2* and mercury injection capillary pressure (MICP). Three *T2* spectra (*TFF*, *TCAF*, and *TCBF*) under water saturation, centrifugation, and heat-treatments are measured to classify pore fluids as FF, CAF, and CBF according to the pore capillary force needed to displace them. *T2C1* and *T2C2* are calculated to classify pores into three size categories. Finally, the nine-grid dual *T2C* model that is composed of the three *T2* distributions and two *T2C* is applied to explain results of a N2 displacement test and evaluate fluid movability in shale samples. The results suggest that the conventional classification method based on fixed *T2C* results in the underestimation of CAF and overestimation of CBF. The macro-pores range in size of *T2* > *T2C1* and have lower pore capillary pressures. Micro-pores (*T2* < *T2C2*) are smaller, and have high capillary pressures. Compared with conventional methods, the introduced model interprets the pore capacity-related displacement process well, especially for the remarkable displacement ratio of medium pores. The co-effect of fluid types and pore sizes in gas-displacing-water tests indicates that the process is primarily governed by fluid-matrix interaction and the connections among pores, rather than a simple sequential displacement of larger-to-smaller pores.