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Effect of hydrocarbon to nuclear magnetic resonance (NMR) logging in tight sandstone reservoirs and method for hydrocarbon correction

Liang Xiao (1), Zhi-qiang Mao (2), and Xiu-hong Xie (3)

(1) China University of Geosciences, Beijing, PR China (xiaoliang@cugb.edu.cn), (2) China University of Petroleum, Beijing, PR China (13101103@qq.com), (3) Bright Stars Hi-Tech Development Co. Ltd., PR China (xiuhong.xie@bic-usa.com)

It is crucial to understand the behavior of the T2 distribution in the presence of hydrocarbon to properly interpret pore size distribution from NMR logging. The NMR T2 spectrum is associated with pore throat radius distribution under fully brine saturated. However, when the pore space occupied by hydrocarbon, the shape of NMR spectrum is changed due to the bulk relaxation of hydrocarbon. In this study, to understand the effect of hydrocarbon to NMR logging, the kerosene and transformer oil are used to simulate borehole crude oils with different viscosity. 20 core samples, which were separately drilled from conventional, medium porosity and permeability and tight sands are saturated with four conditions of irreducible water saturation, fully saturated with brine, hydrocarbon-bearing condition and residual oil saturation, and the corresponding NMR experiments are applied to acquire NMR measurements. The residual oil saturation is used to simulate field NMR logging due to the shallow investigation depth of NMR logging. The NMR spectra with these conditions are compared, the results illustrate that for core samples drilled from tight sandstone reservoirs, the shape of NMR spectra have much change once they pore space occupied by hydrocarbon. The T2 distributions are wide, and they are bimodal due to the effect of bulk relaxation of hydrocarbon, even though the NMR spectra are unimodal under fully brine saturated. The location of the first peaks are similar with those of the irreducible water, and the second peaks are close to the bulk relaxation of viscosity oils. While for core samples drilled from conventional formations, the shape of T2 spectra have little changes. The T2 distributions overlap with each other under these three conditions of fully brine saturated, hydrocarbon-bearing and residual oil. Hence, in tight sandstone reservoirs, the shape of NMR logging should be corrected. In this study, based on the lab experiments, seven T2 times of 1ms, 3ms, 10ms, 33ms, 100ms, 300ms and 1000ms are first used to separate the T2 distributions of the residual oil saturation as 8 parts, and 8 pore components percentage compositions are calculated, second, an optimal T2 cutoff is determined to cut the T2 spectra of fully brine saturated conditions into two parts, the left parts (with short T2 time) represent to the irreducible water, and they do not need to be corrected, only the shape for the right parts of the T2 spectra needed to be corrected. Third the relationships among the amplitudes corresponding to the T2 times large than the optimal T2 cut off and 8 pore components percentage compositions are established, and they are used to predict corrected T2 amplitudes from NMR logging under residual oil saturation. Finally, the amplitudes corresponding to the left parts and the estimated amplitudes are spliced as the corrected NMR amplitudes, and a corrected T2 spectrum can be obtained. The reliability of this method is verified by comparing the corrected results and the experimental measurements. This method is extended to field application, fully water saturated T2 distributions are extracted from field NMR logging, and they are used to precisely evaluate hydrocarbon-bearing formations pore structure.