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Determination Of Flow And Volumetric Properties Of Core Samples Using Laboratory NMR Relaxometry

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Abstract

The petroleum industry adopted the nuclear magnetic resonance (NMR) technology to be used for formation evaluation by the determination of the petrophysical formation properties. NMR can be used as an independent logging service that provides porosity and permeability indexes, as well as complete information on fluid type and saturation of the formation layers. In this work the possibilities of operative determination of the main volumetric-flow properties (porosity-permeality) of reservoir rocks by NMR relaxometry are shown. It was observed that NMR relaxometry provides information about the distribution of permeability-porosity properties of core samples both for the section as a whole and for each formation separately. The data obtained are compared with the results of lithological and stratigraphic analysis.

Keywords: *NMR, Porosity, Permeability, Petrophysical properties, Relaxometry.*

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INTRODUCTION

One of the primary tasks of all laboratory petrophysical core studies is to determine the reservoir properties of reservoir rocks[1 , 2]. Standard research methods often lead to partial or complete destruction of core samples, which makes them unsuitable for further research [3]. Moreover, this process is very laborious and takes a lot of time. That is why there is a need to search for alternative methods of core research. Pulsed NMR relaxometry relates to such methods [4 , 5]. This method allows obtaining qualitative and quantitative information about the structure of the pore space of the studied geological environment and the type of fluid saturating it. Measurements are performed on an MCT-05 NMR relaxometer. To date, extensive experience has been accumulated in obtaining petrophysical information from NMR data [6 , 7].

EXPERIMENTAL WORK

The object of this study was Mesozoic deposits presented in the section of a parametric well. The well penetrated the full section of the Cretaceous and Jurassic oil and gas complexes and the top to the Jurassic base.

The cores to varying degrees have characterized the section one (Lower Aptian, core sampling interval 1591–1608.3 m), section two (Lower Valanginian, interval 2220–2268.6 m), section three (Berriasian – Lower Valanginian, interval 2299–2309 m), section four (Callovian-Oxfordian , interval 2644–2673 m), section five (Bajos-Bathonian , intervals 2700–2717.7; 2760–2778.2; 2838–2872.7; 2970–3006 m), section six (lower Toar-Aalenian, interval 3050–3134 m), section seven (Lower Toarcian, interval 3136.5–3174.6 m), and section eight (Gettang-Plinsbach, interval 3174.6–3210.7 m). In this work, 107 water-saturated samples of predominantly silt-sandstone rocks that had undergone preliminary extraction with chloroform were studied.

The petrophysical properties of core samples are characterized by the following parameters[8];

The porosity (φ) and permeability (K) coefficients are determined both by classical methods using helium on the AP-608 facility (Coretest System, Inc.) and by NMR on the MST-05 relaxometer. The NMR porosity is defined as the initial amplitude of the NMR signal, and the permeability in the NMR method is determined by the Coates equation [9]:

$$K = C\varphi^4 \left(\frac{\varphi_{eff}}{\varphi_{bound}}\right)^2$$

where C is the calibration factor, $\phi_{eff.}$ - effective NMR porosity, φ_{bound} - NMR porosity, which characterizes the proportion of bound fluid.

RESULTS & DISCUSSION

The values of φ and K vary in the range of 3–25% with an average value of 12% and 10–2–103 mD with an average value of 70 mD. The average transverse relaxation time (T2av) varies in the range of 2–150 ms with an average value of 30 ms, the fraction of free fluid is 1–85% with an average value of 44%.In this case, most of the samples are characterized by porosity of 10-15%, permeability 1-10 mD, average transverse relaxation time 10-30 ms, and a free fluid fraction of 30-50% (Fig. 1).

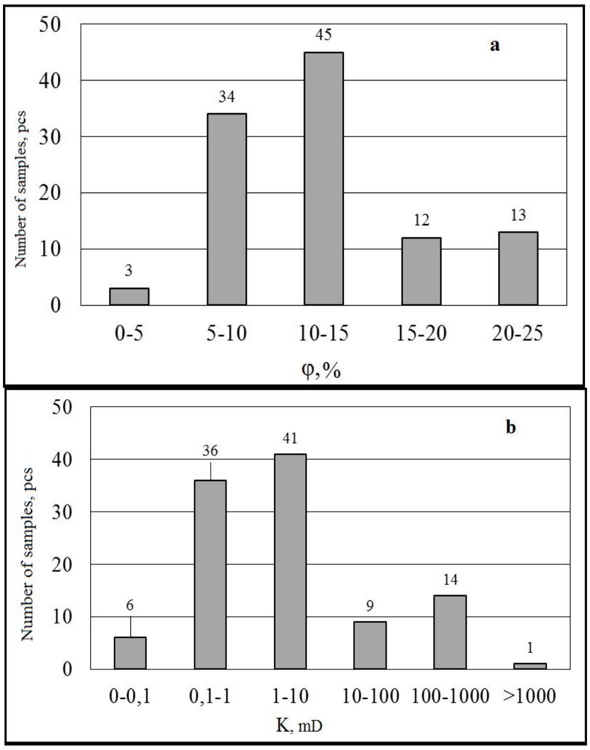

Fig. 1: *Distribution of porosity (a) and permeability (b) according to NMR data*

The data obtained make it possible to obtain reliable correlations between petrophysical parameters and NMR characteristics (Fig. 2, 3). It can be seen that the values of the porosity and permeability coefficients are closely related both to each other and to the main NMR parameter-the transverse relaxation time.

As is known [10, 11], the transverse relaxation time depends on the pore size, which explains the scatter of values in Fig. 2, a. The pore sizes depend, first of all, on the composition of the clastic part of the rocks, on the type and amount of cement. And also, with significant amounts of the clay component, the pore sizes depend on the mineralogical composition of this component [12 , 13].

To establish a more reliable correlation between the porosity coefficient and the transverse relaxation time, it is necessary to use the data of particle size and mineralogical petrographic analyses.

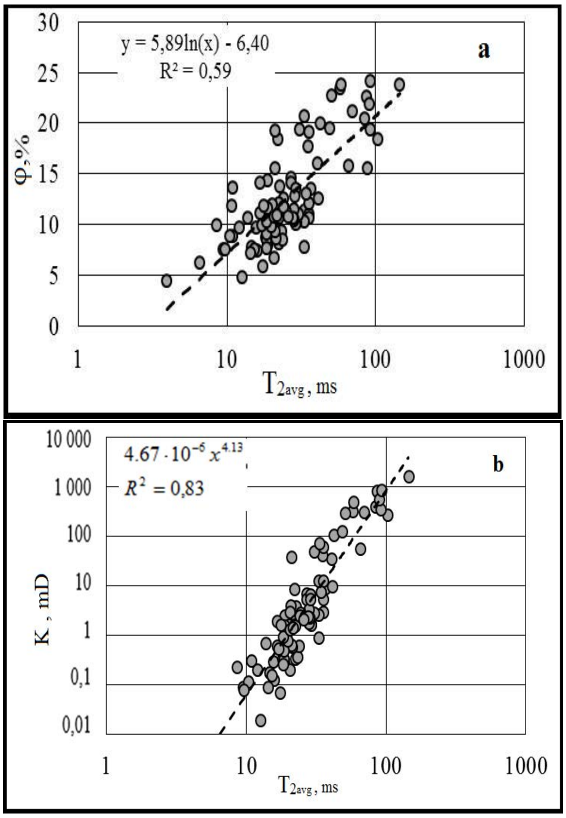

Fig. 2: *Correlation relationships of the coefficients of porosity (a) and permeability (b) with the time of transverse relaxation*

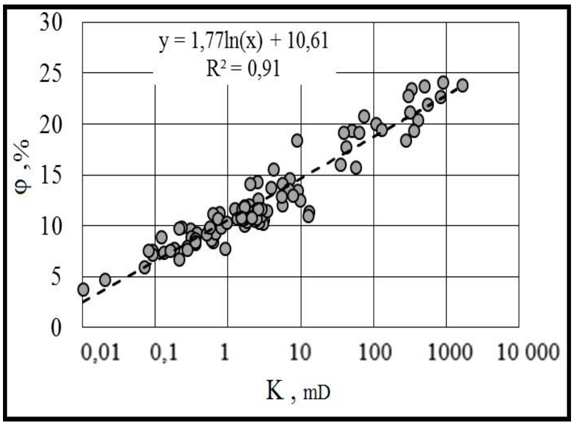

Fig. 3: *Correlation between porosity and permeability coefficients*

There is also a correlation between reservoir properties and the distribution of the studied core samples over the formations (Fig. 4), which reflects a decrease in the porosity coefficient of sand-siltstonerocks with depth due to compaction and catagenetic transformations [14 , 15].

This makes it possible to quickly compare the petrophysical data obtained by the NMR method with the results of lithological stratigraphic analysis and, with a certain degree of convention, predict information on the porosity and permeability properties of the core. Note that this example does not consider formations represented by less than 3 samples (section one-1 sample, section three - 1 sample, section eight - 1 sample, and section seven - 2 samples).

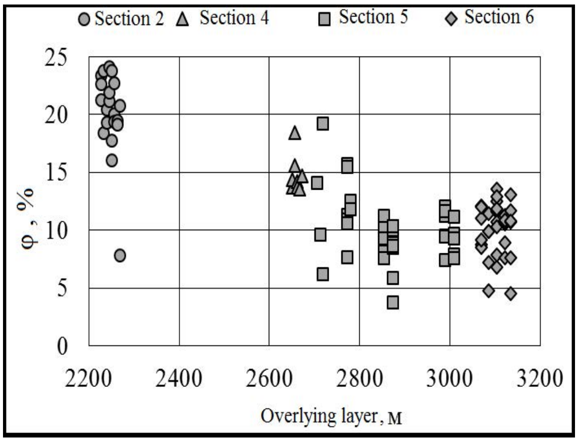

Fig. 4: *Distribution of the porosity coefficient in the formations depending on the overlying layer*

For the purpose of more rational and optimal access to data, all of them are stored in one file containing detailed information about each sample: measured porosity and permeability coefficients, transverse relaxation time, fraction of free and bound fluid, as well as a photo of the core, the original file of the recorded NMR signal, as well as a short report containing the main NMR characteristics in text form. This way of storing information makes it easy to access it for further work.

CONCLUSIONS

Thus, using the example of the parametric well Zapadno-Tym 1, it is shown that NMR relaxometry provides information about the distribution of permeability and porosity properties of core samples both for the section as a whole and for each formation separately.

It was observed that NMR relaxometry provides information about the distribution of permeability-porosity properties of core samples both for the section as a whole and for each formation separately. The main advantage of the NMR method is the possibility of its involvement in a complex of standard laboratory core studies.

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