EVALUATION OF FILTRATION AND CAPACITIVE PROPERTIES OF ROCKS BY NUCLEAR MAGNETIC RESONANCE IN TERRIGENOUS NON-CONSOLIDATED SECTION WITH SWELLING CLAY MINERALS

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This study investigates the use of NMR to evaluate net pay within a sequence of poorly cemented sandstones, argillaceous aleurolites, and thinly interbedded aleurolites and clays. Clay minerals in non-reservoir rocks are chiefly of montmorillonite-smectite composition, but have a kaolinite composition in poorly cemented sandstones (Fig.1). The rocks are of Albian to Cenomanian age, and are located in Western Siberia.

The porosity of non-reservoir rocks and producing formations are similar and range between 30–40%. In non-reservoir rocks, permeability for gas (dry samples) is from several mD to several hundred mD. In producing formations, permeability is 0.1–1.0D. High porosity in combination with high residual gas saturation in the near-well zone exerts an extremely detrimental effect on all logging methods, reducing their validity and causing errors in evaluation of the producing intervals.

To help evaluate properly the producing intervals, the authors examined core with the use of an NMR relaxometer that helped to clarify the "non-reservoir – reservoir" term.

A special low temperature technology of samples preparation without their destruction was used for sands and poorly cemented rocks. Core was frozen in liquid nitrogen, plugs were cut out by a diamond coring drill bit and shrink plastic enclosed.

The studies showed that the use of permeability data for gas in dry core samples does not give true permeability of rocks in a formation. Dry rock samples from aleurolite formations with up to 35% of porosity and swelling clay minerals in cement have up to hundreds of mD permeability for gas. The same samples were used to obtain "capillary pressure–saturation" curves in reservoir conditions. Residual water saturation is from 75% to 90%. By the results of NMR data processing for formations with clay minerals mainly represented by montmorillonite effective porosity is practically null. By capillarometry data 33 ms relaxation time cutoff turned out the most acceptable for S_{wirr} estimation.

Comparison of effective permeability for gas measured in samples put under confining pressure with permeability for gas under atmospheric pressure (Fig.2) shows that these values do not change much in producing formations. However, applying the same test to non-reservoir rocks shows permeability reduces by a factor of $10^3 – 10^4$.

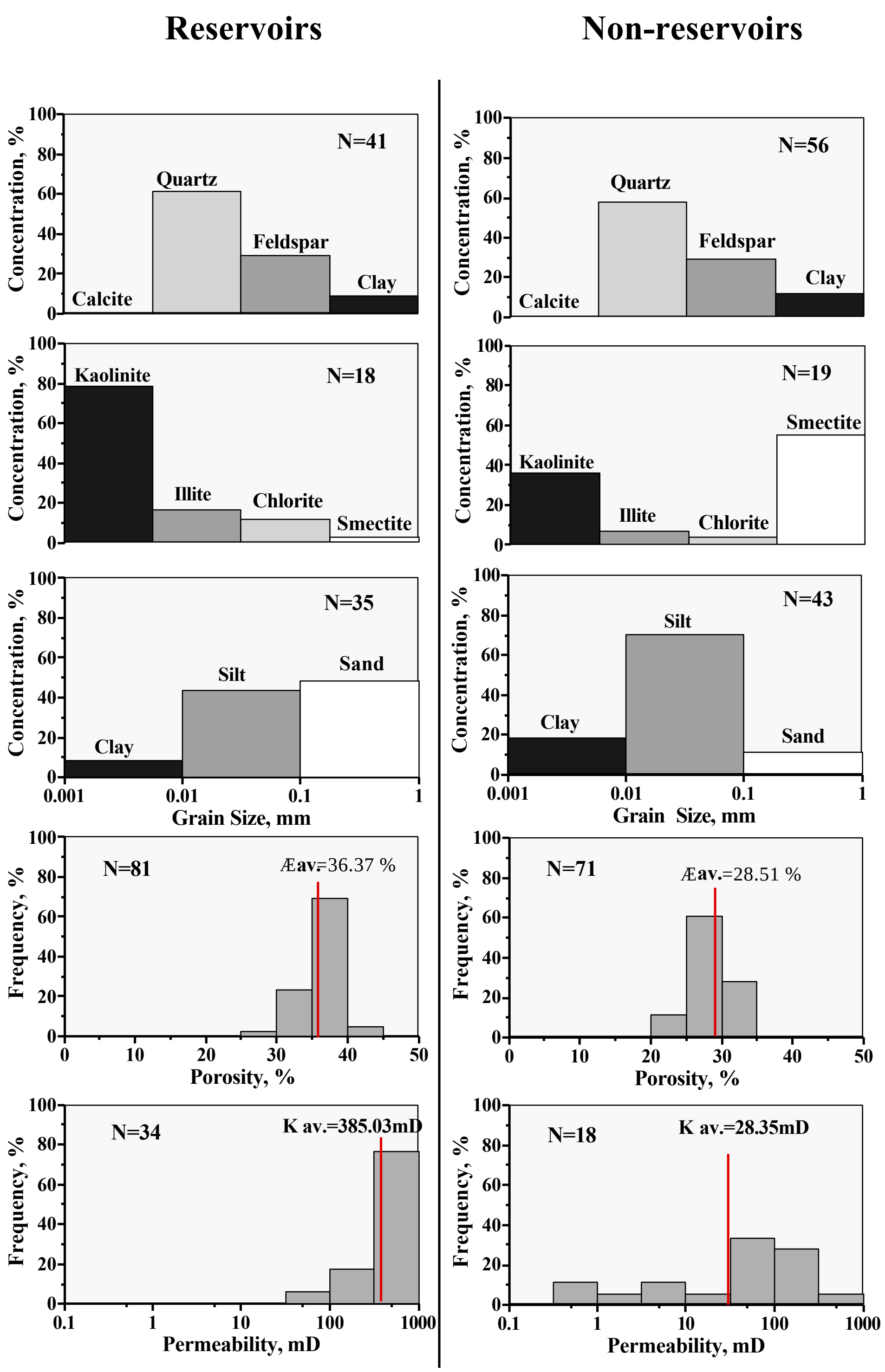

Fig. 1. Histograms of the Basic Petrophysical Parameters

For permeability calculation from NMR data there was used a new model of rock pore space in the form of 3-D cubic lattice of capillaries [1]. It differs from similar type models by the method of pore distribution by size. The method is based on the fact that porous medium seems to consist of a large number of similar cubic cells. Pore structure in all the cells is the same and pore size distribution r in cells is described by a f(r) function.

For such a model there was obtained an equation to determine permeability. The unknown function f(r) appearing in the equation was determined from transverse relaxation time spectra $?_2$. With this it was understood that relaxation time is proportional to pore size. Calculations revealed that permeability estimation by the proposed model better agrees with the results of its direct measurement by filtration method than estimation by the Timur-Coates permeability equation as well as the Kenyon equation [2].

However, the new NMR permeability estimate still overestimates permeability in non-reservoir rocks, and the authors believe that for a more reliable permeability estimation it is necessary to conduct NMR experimental research with rock putting under rock pressure. Estimation of porosity and residual water saturation by NMR method agrees with traditional methods. Hence we can conclude that NMR method will correctly estimate these parameters in-situ.

Clay bound water is clearly identified using a standard 3 ms relaxation time cutoff. The presence of large amount of clay bound water in rock unambiguously indicates that the rock belongs to non-reservoir rocks (Fig.2). It is probably the most convincing evidence for using NMR logs to identify non-reservoir intervals. Thus with the use of NMR data analysis results as a whole there are all prerequisites for producing formations and non-reservoir rocks division in the section.

As there is interbedding of aleurolite formations with sands and sandstones having the same porosity values and high content of residual gas in the section it is extremely difficult to divide them in the section by standard logging methods. By NMR it can be performed quite correctly. In view of this special NMR multiple echo spacing is to be used to eliminate this effect.

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2. Kenyon W.E. Petrophysical Principles of Applications of NMR Logging // The Log Analyst. 1997. Vol. 38, No.2, P.21-43.

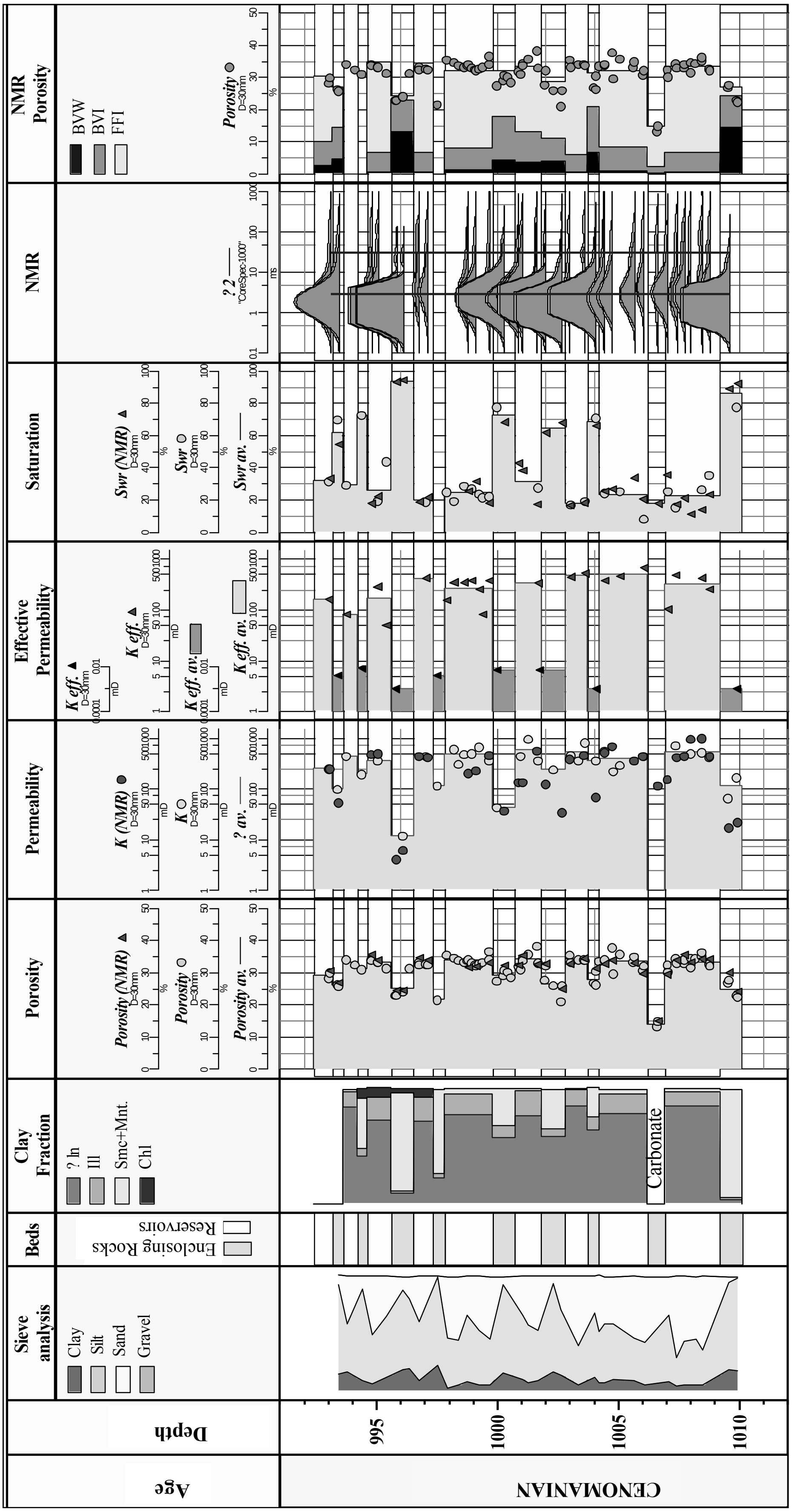

Fig. 2. Petrophysical Data By Depth together with NMR for Reservoirs and Enclosing Rocks

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