Evaluation of Logging Characteristics of the Yablunivske Oil and Gas Condensate Filed

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Abstract. A study of the reservoir characteristics of the Tournaisian formation in the Yablunivske oil and gas condensate filed shows that the pore structure of the reservoir in this area is complex and the pore permeability varies widely. Based on the reservoir logging response characteristics, core analysis data and logging curves GR, DT and normal resistivity curves, the reservoir mud content, porosity, permeability, bound water saturation and gas saturation parameters were calculated by statistical regression methods. The calculation accuracy of the established log interpretation models is high, which can meet the development needs of the oilfield and also lay the foundation for the subsequent study of the reservoir.

1 Introduction

The Yablunivske oil and gas condensate filed is located in the Poltava region of Ukraine and has been developed since 1977. Due to its complex structure, complicated pore-throat structure and strong non-homogeneity, its production and development are not perfect[1-2]. The sandstones and siltstones of the Tournaisian formation are currently the main reservoirs and the main object of hydrocarbon development in this oilfield. The lithology in this study area is mainly sandy mudstone, and sandy mudstone interbeds are widely developed. The reservoirs are characterized by high bound water saturation, complex gas-water relationships and difficult reservoir logging and evaluation, so it is of great importance to carry out relevant reservoir logging, interpretation and evaluation studies in the study area.

This paper uses conventional logging data and rock core analysis to establish logging calculation methods for parameters such as reservoir mud content, porosity, permeability and saturation, respectively, in order to improve the accuracy of reservoir logging interpretation and evaluation in the study area. On the basis of the reservoir log evaluation, a lateral distribution map is established and its lateral distribution pattern is analyzed by combining the lithology, physical properties and pore structure characteristics of the reservoir.

2 Study of reservoir characteristics

2.1 Lithological characteristics

The Tournaisian Formation is a well-developed and large sand body. Laterally, the sand bodies are structurally stable and the reservoir lithology consists mainly of quartz sandstones and quartz siltstones with quartz, feldspar, mica and quartz detritus as the main constituents.

2.2 Physical characteristics

Data from 298 rock samples from six logs in the Tournaisian formation of the Yablunivske condensate field were counted and histograms of porosity, permeability and mud content of the reservoir were plotted. The data analysis shows that the porosity of the Tournaisian formation in the study area ranges from 1.9% to 22%, with an average value of 11.5%, and the permeability ranges from 0.4 to 1629 mD, with an average value of 152 mD. Therefore, the porosity and permeability of the Tournaisian formation are highly variable, with porosity varying from low to medium porosity and permeability varying from ultra-low to high permeability. Due to the variety of lithologies in the Tournaisian Formation and the large physical disparity of the lithologies, the study area treats a porosity of 7.0% and a permeability of 0.8 mD as the lower limit to classify the reservoir in the study area.

2.3 Electrical properties

The reservoir in this area belongs to the gas zone, and the natural potential curve and the ordinary resistivity logging curve (potential electrode and gradient electrode) correlate well with the gas-bearing nature of the reservoir. In a gas-bearing reservoir, the natural potential curve shows significant negative anomalies, while the resistivity curve shows high values, and the natural potential curve can effectively distinguish permeable sandstone and mudstone layers.

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3 Methods for calculating reservoir parameters

3.1 Standardization of log curves

Standardization of logging information is the basis for log interpretation. Due to the early production of the Tournaisian production formation in the Yablunivske condensate field, the number of logs deployed in the study area in different eras, and the inconsistency of logging equipment, there are certain errors in the comparison between multiple logs [3-6]. In order to eliminate the errors caused by the above factors, it is, therefore, necessary to standardize the logging curves in the study area.

In this paper, six logs with complete data, good borehole conditions, relatively well-selected log series, complete stratigraphic positions and strong representativeness were selected as the standard logs in the study area; a large stable mudstone section at the top of the Tournaisian production layer was selected as the standard layer in Figure 1. The natural gamma value of the marker layer in the study area was unified to 226 API, and the acoustic time difference value was unified to 222.6 μs/m in Figure 2-3.

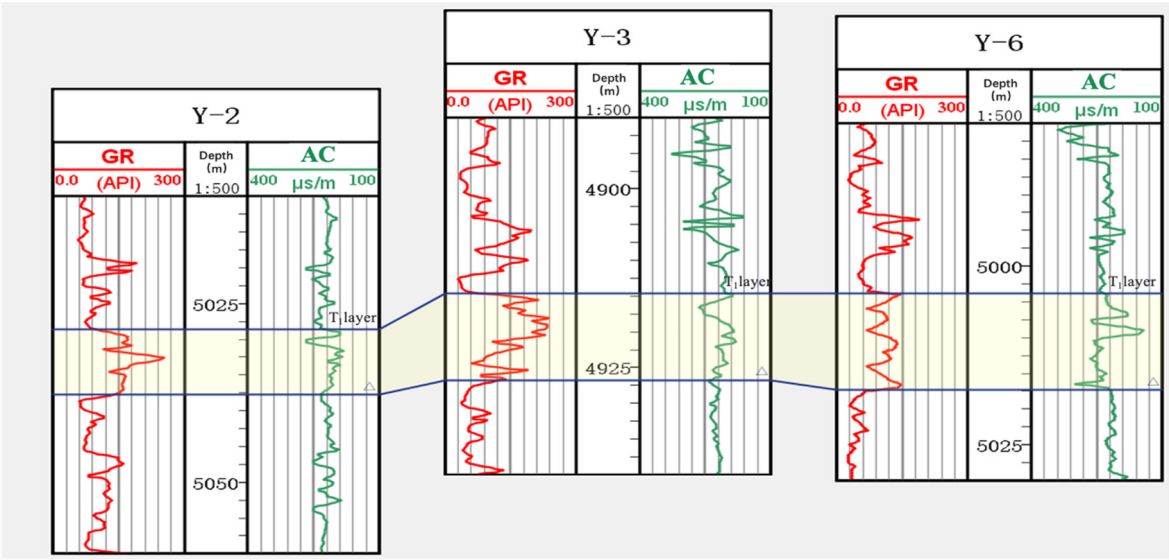

Figure 1. Log response characteristic map of standard formation in the study area

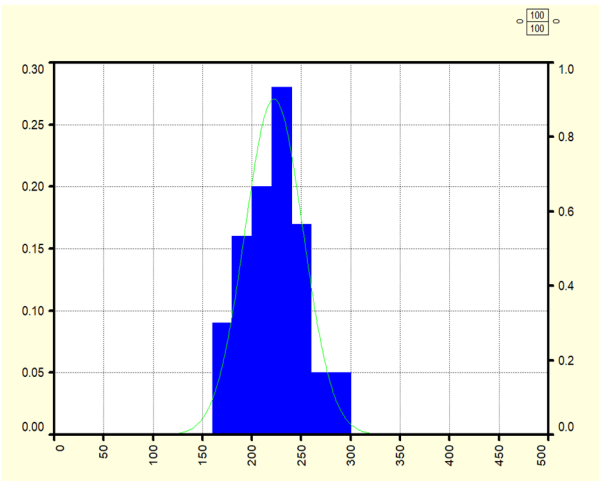

Figure 2. The histogram of the compensated sonic

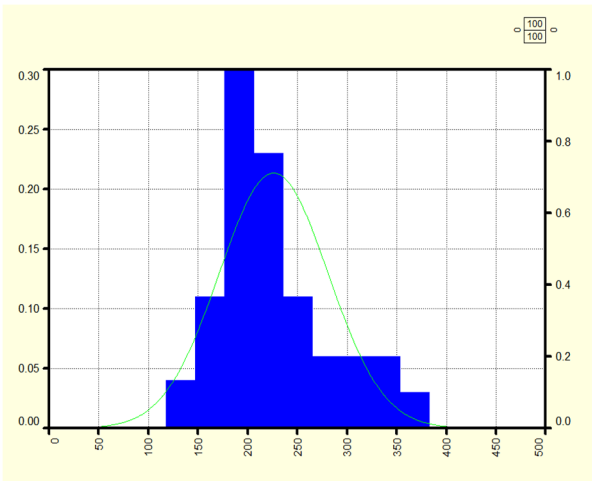

Figure 3. The histogram of Natural Gamma Ray

3.2 Mud content interpretation model

Mud content is an important basis for reservoir parameter calculations. Analysis of the response characteristics of the logs from the sandy mudstone reservoirs in the study area shows that there is a significant correlation between the natural gamma curve and the variation in mud content, and the following equation is obtained from the regression:

$$V_{sh} = 0.92\ \Delta GR^{1.42} \quad (1)$$

Where: V_{sh}- the mud content, %;

ΔGR - the relative value of natural gamma, API.

Comparison of the calculated mud content with the core analysis mud content values gave an average relative

error of 29% and an average absolute error of 1.93% for the mud content equation.

3.3 Porosity interpretation model

In this paper, the sonic time difference curve is regressed against the core analysis data, based on the porosity of the rock core. The porosity of the rock core analysis of a single log is accurately normalized on the logging curve before the sonic-porosity relationship is derived by intersection analysis in Figure 4 [5-6]. The relationships are as follows:

$$\phi=-32.501+0.1953*DT \quad (2)$$

Where: ϕ - porosity, %;DT- sonic time difference, μs/m.

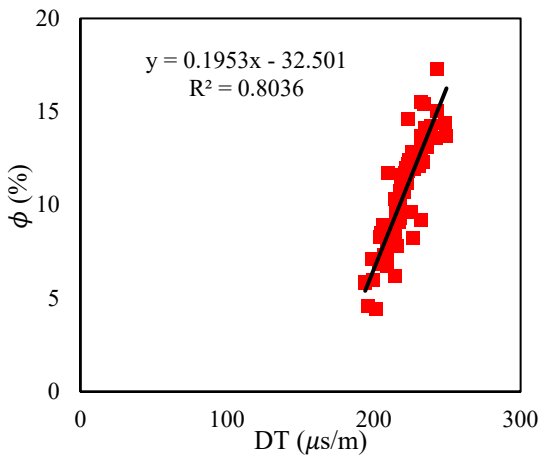

Figure 4. Rock core analysis porosity and sonic time difference intersection diagram

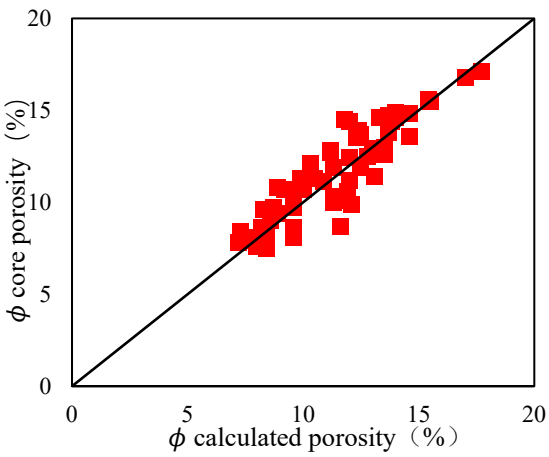

Figure 5. Comparison Chart of Calculated Porosity and Core Porosity

The calculated porosity was compared with the rock core analysis porosity values to obtain an average relative error of 10.8 % and an average absolute error of 3.38 % for the porosity calculation formula in Figure 5.

3.4 Permeability interpretation model

The reservoir permeability is mainly influenced by the lithology, physical properties and pore structure of the reservoir, and the reservoir permeability is obtained by the relationship between porosity, bound water saturation and permeability, respectively [7-9]. In this paper, the rock core data of 110 rock samples from the Tournaisian formation were counted, and after the core data were counted, the relationship between permeability and porosity and bound water saturation were established respectively based on the Timur formula in Figure 6-7, and the following relationship was established by regression analysis method:

$$K=1.1868\cdot\frac{\Phi^{3.7846}}{S_{wi}^{2.174}} \quad (3)$$

Where: K-permeability, mD; Φ- porosity, %;S_{wi} - bound water saturation, %.

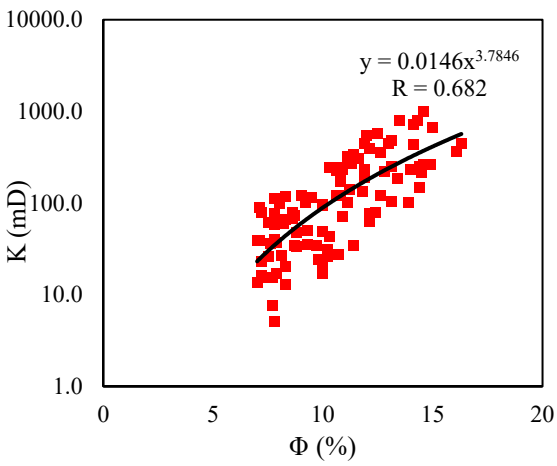

Figure 6. Relationship between porosity and permeabily

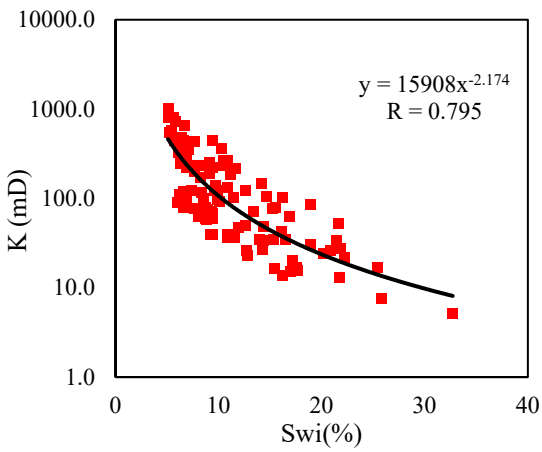

Figure7. Relationship between irreducible water saturation and permeability

The calculated permeability was compared with the rock core analysis permeability values to obtain an average relative error of 35.1% and an average absolute error of 29.03mD in the permeability calculation formula.

3.5 Gas saturation interpretation model

The gas saturation of a reservoir has always been an important parameter in the quantitative evaluation of reservoirs, and the evaluation of the gas nature of a reservoir mainly relies on the resistivity parameter[10]. As the Tournaisian formation in the study area is a pore-type reservoir, the commonly used Archie formula was used to calculate the saturation equation as follows:

$$S_g=100\cdot\left(1-\sqrt[n]{\frac{abR_w}{\Phi^m R_t}}\right) \tag{4}$$

Where: S_g -gas saturation, %;

R_w -formation water resistivity, Ω•m;

R_t - formation resistivity, Ω•m;

Φ-porosity, %;

m and n are the cementation index and saturation index respectively; a and b are lithology coefficients.

Based on the experimental analysis of the actual cores in this area, a is 0.2085, b is 1.05, m is 2.881, n is 1.338, and R_w is 0.014 Ω•m.

4 Application of logging interpretation models

Based on the information related to water analysis, the formation water resistivity in the area was determined to be 0.014 Ω•m. The established reservoir interpretation model was applied to the log interpretation of log Y-3 in the study area. The comparison results between the calculated reservoir parameters and the rock core analysis reservoir parameter values are given in Figure 8.

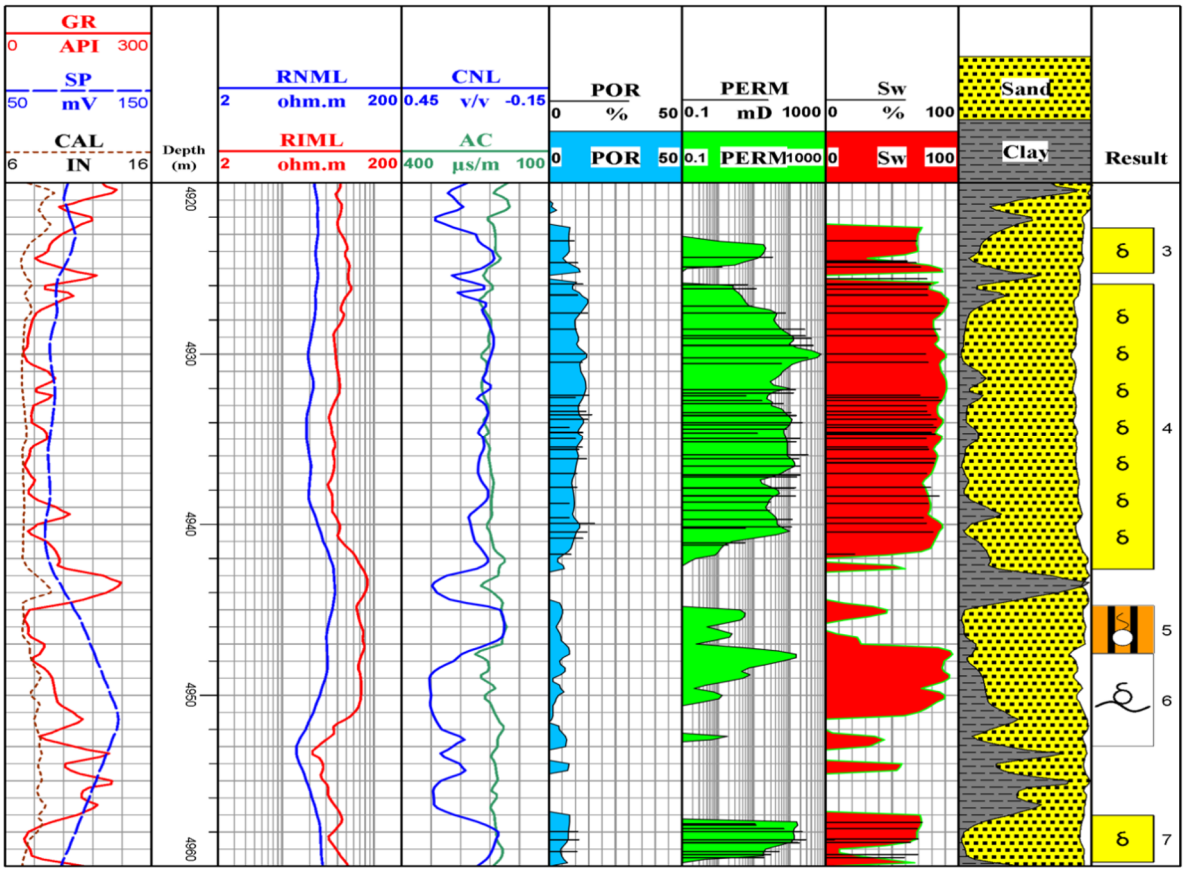

Figure 8. Integrated interpretation results from reservoir logging of Y-3

As can be seen from Figure 8, the calculated values of mud content, porosity, permeability and bound water saturation agree well with the rock core analysis values, indicating that the above parameters explain the high accuracy of the model calculation and can be used to better complete the reservoir evaluation in actual production.

5 Establishing a lateral distribution of reservoir parameters

Based on the variation pattern of the gamma curve and resistivity curve, the Tournaisian Formation is divided into 3 sand groups and 15 sublayers according to the sedimentary rotation from the largest to the smallest, after which the reservoir parameters of each sublayer are analyzed and interpreted to obtain the pattern of their

lateral distribution. Taking sub-layer 3 as an example, as can be seen in Figures 9-10, the porosity, thickness and gas saturation in the central and western parts of this sub-layer are high values. The reservoir is well developed with an average distribution of porosity between 11% and 16%. High permeability values are mainly represented by single logs 10 and 14, with an average thickness between 6m and 10m and an average distribution of gas-bearing saturation between 40% and 70%, while the values of each parameter in the eastern part of the area are smaller and the reservoir is less well developed.

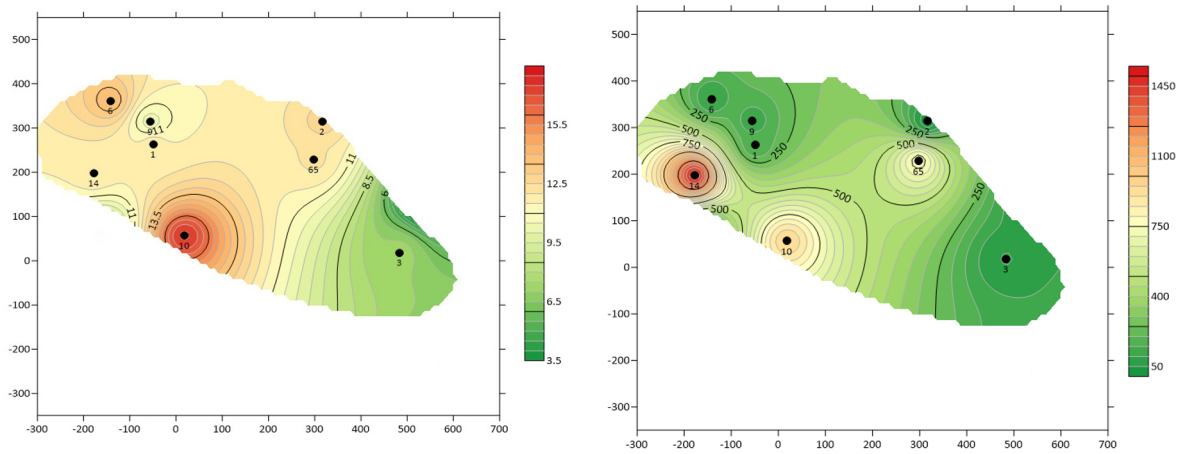

Figure 9. Study area Sub-layer 3 Porosity and permeability distribution

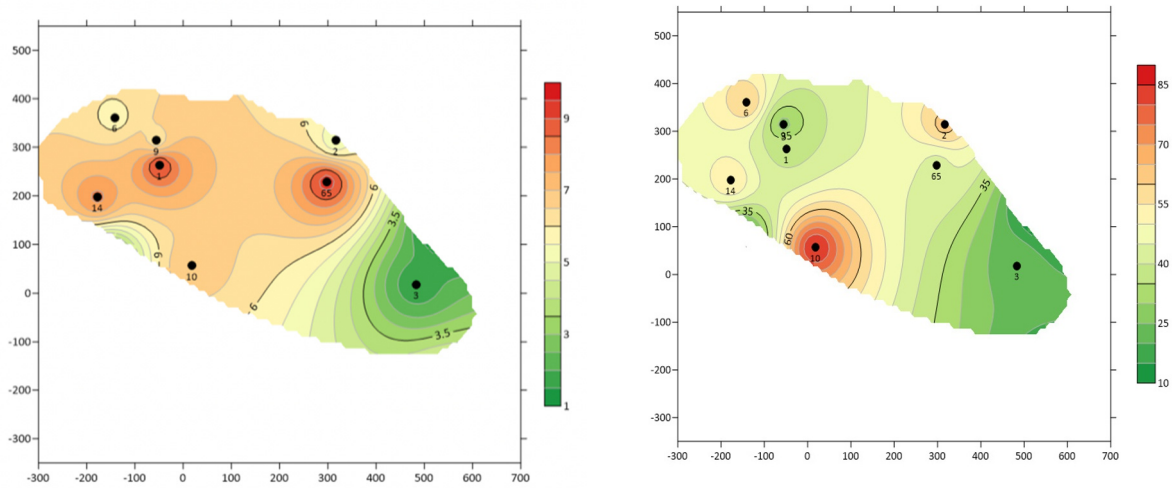

Figure 10. Study area Sub-layer 3 effective thickness and gas saturation of the third layer

6 Conclusion

The porosity of the Tournaisian formation in the study area ranges from 1.9 % to 22%, and the permeability ranges from 0.4 to 1629 mD, with an average value of 152 mD. Therefore, the porosity and permeability of the Tournaisian formation are highly variable, with porosity varying from low to medium pore and permeability varying from ultra-low to high permeability, and the lithology is dominated by sandy mudstone.

The results of the study of the Tournaisian formation in the Yablunivske condensate field show that the use of logging data interpretation to establish the model of reservoir physical parameters has a high accuracy of calculation results and is sufficient to meet the needs of oil field production and development. The results of the interpretation of reservoir physical parameters using the established model of mud content, porosity, permeability and oil-bearing saturation are of great significance in actual production and solve the problem of interpreting reservoir physical parameters from logging data in the old logs in the area.

By combining geological data and logging interpretation models, a lateral distribution map of each reservoir parameter can be established to analyze the lateral distribution pattern of reservoir parameters in the study area. This will enable the delineation of potential areas in the study area and open up new horizons for the production of new wells in the study area in the future.

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