Research on Geophysical Logging Lithology Interpretation Method Based on Computer Technology

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Abstract. The result of log lithology interpretation is the basis of reservoir parameter calculation and oil-gas evaluation, which provides the basis for geological research such as sedimentary facies division. However, there are different interpretation methods, involving different mathematical methods and calculation processing steps, and there are advantages and disadvantages in practical application. There are few previous discussions on this classification. Qualitative interpretation method of logging response characteristics based on computer technology, plate solution method based on logging response equation, equation group solution method based on logging response equation, statistical analysis method based on "core calibration logging", this paper will The application of the mathematical methods involved in statistical learning theory to the interpretation of logging lithology is the research trend of interpretation methods.

Keywords: Interpretation Method, Geophysical, Logging Lithology

1. Introduction

With the further development of oil and gas field exploration and development in China, the lithology of the reservoir becomes more complex, such as deep igneous rock reservoir, tight limestone reservoir, oil shale reservoir, shale gas reservoir, glutenite reservoir, etc. As one of the important sources of underground rock information, geophysical logging data is more and more important in the interpretation of formation lithology because of its advantages of high vertical resolution, good continuity and convenient collection. Lithologic interpretation based on well logging data is the basis of subsequent reservoir parameter calculation and oil-gas evaluation, and also provides the basis for geological research such as stratigraphic rhythm feature analysis, sedimentary facies division, sedimentary environment analysis, etc. The results of lithologic interpretation are of great significance not only for stratigraphic evaluation, geological analysis and other research, but also for reservoir fine description in exploration stage and development stage. It is also of great practical value in production practice. It is of great significance and value to study the interpretation method of logging lithology [1].

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According to the above investigation, there are some problems in the study of logging lithology interpretation methods as follows: different interpretation methods, various mathematical methods applied to logging interpretation and data processing, different calculation and processing steps of each interpretation method, differences in applicability and application effect of different interpretation methods in practical application, mathematical basis, calculation and processing steps and applicability of interpretation methods. Based on this, this paper first uses the general thinking of logging interpretation for reference to classify and sort out logging lithology interpretation methods, then sorts out and summarizes each kind of interpretation methods, finally compares and comments on the advantages and disadvantages of different interpretation methods, and carries out the development trend of logging lithology interpretation methods Outlook\textsuperscript{[2]}. 

2. Solution of equations based on well logging response equation

The solution method of equation group based on well logging response equation is a lithologic interpretation method, which is based on the well logging response equation of different well logging methods, constructs the equation group composed of multiple linear equations and a volume balance equation, and solves the numerical solution (porosity and percentage content of mineral composition) of the equation group variables by mathematical method. For example, when interpreting the lithology of rocks composed of three mineral components, four ternary first-order equations (formula 1) can be listed according to three kinds of "lithology porosity" logging data such as acoustic wave, density and neutron and volume balance equation:

\[
\begin{align*}
\phi \Delta t_f + V_{ma1} \Delta t_{ma1} + V_{ma2} \Delta t_{ma2} + V_{ma3} \Delta t_{ma3} &= \Delta t \\
\phi \rho_f + V_{ma1} \rho_{ma1} + V_{ma2} \rho_{ma2} + V_{ma3} \rho_{ma3} &= \rho_b \\
\phi \phi_f + V_{ma1} \phi_{ma1} + V_{ma2} \phi_{ma2} + V_{ma3} \phi_{ma3} &= \phi_{CNL} \\
\phi + V_{ma1} + V_{ma2} + V_{ma3} &= 1
\end{align*}
\]

Among:

\(\phi\) is Porosity;

\(V_{ma1}, V_{ma2}, V_{ma3}\) are Percentage of three minerals;

\(\Delta t\) is Acoustic logging results;

\(\rho_b\) is Density logging results;

\(\phi_{CNL}\) is Neutron logging results;

Influence of subscript \(f\) interstitial fluid on logging results;

The percentage content and porosity of these three mineral components can be obtained by solving the equations. From the mathematical point of view, the application of this method to lithology interpretation is the process of solving linear equations. Equations are usually expressed in matrix form to facilitate computer storage and operation. Therefore, the mathematical basis of this interpretation
method is matrix algebra solution theory.

The equation group solution method based on the well logging response equation can obtain the numerical solution of the unknown variable (percentage content of mineral composition) of the equation group in the balance, under determined, over determined and other equation system systems, especially the optimal well logging interpretation under the over determined equation system. It has been applied in the cross-section of sand shale formation and the complex lithology formation with many minerals and has achieved good results. This method is suitable for the interpretation of single mineral and dual mineral model, and more suitable for the interpretation of complex lithostratigraphic with three or more multi mineral components. Its application effect is affected by the number of logging curves and correction accuracy, the number of mineral types, the applicability of the selected mathematical model and mathematical method, the operation speed of the algorithm, the geological constraints of numerical solution, etc\[3\].

3. Observation of logging results

After correction of borehole environment and mud quality, the logging value of the interval to be interpreted is put on the interpretation chart, and the rock or mineral combination type is determined by comparing the location relationship between the intersection point and single mineral pure rock line and special mineral point. As for the solution method of the content of different mineral components, the compensation neutron density log intersection chart (below) is still taken as an example to briefly explain: if the rock skeleton is composed of a If the rock skeleton is composed of two kinds of minerals, then according to the location of the intersection point and the linear proportion algorithm, the formation porosity and the relative content of the two kinds of minerals can be calculated. Similarly, if the rock skeleton is composed of three minerals, it is necessary to find points with the same porosity value on three pure rock lines, establish a lithologic interpretation triangle on the line, and calculate the proportion of three minerals (percentage content of mineral composition) by measuring the proportion of line sections.

With the continuous update and development of logging tools, the lithologic interpretation plates matched with logging tools are diversified, such as lithologic porosity logging cross plot plate, M-N plate, mid plate, etc. Table 2 summarizes the applicable stratigraphic sections, interpretation advantages and disadvantages of several commonly used lithologic interpretation cross plot plates. In addition, when lithologic interpretation is carried out by using the plate solution method, it can be combined More petrophysical parameters (such as GR, th, K, etc.) or reconstructed parameter variables are used for cross mapping. For example, gr-pe or th-k crossplot plate has good applicability in distinguishing clay minerals from other minerals; ECS element capture log calculates SiO2 content and Na2O + K2O content through measured elements, and the TAS plate produced by the crossplot plate has good application value in identifying igneous rock lithology\[5\].
Figure 1. Logging results

The plates used in the plate solution method based on the log response equation are all made of pure rock formation with full water (fresh water or salt water), so the plate solution method is applicable to pure rock formation with water-based mud drilling[4]. Generally, there are no more than three kinds of skeleton minerals, and the logging data used need to be corrected by borehole environment, secondary pore, shale, oil and gas, etc. the effect of lithologic interpretation by this method is affected by the comprehensive influence of the factors such as the applicability of the selected plate, the accuracy of correction, the measurement error of the projection point, etc[6].

4. Summary

The calculation and processing steps of qualitative interpretation method and chart solution method are simple, but the interpretation results are greatly interfered by human factors and the data processing efficiency is low due to their manual processing and interpretation; the calculation and processing process of equation group solution method and statistical analysis method is easier to realize the automatic, rapid processing, high-efficiency and automation of data processing due to the use of computer technology such as software programming. The intelligent interpretation of lithology is one of the research trends of interpretation methods.

The application effect of interpretation method is affected by many factors, among which the selection and determination of interpretation chart, interpretation model, interpretation parameters and key characterization parameters in calculation processing have a significant impact on the result of lithologic interpretation. More and more perfect geological analysis tests are carried out to constrain the result of interpretation, optimize the interpretation model and parameters, so as to reduce the interference of influencing factors and improve the lithologic solution Interpretation accuracy is a trend in the study of log interpretation methods.
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