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Study on Logging Evaluation Method of Shale in Linxing Area

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Abstract

The eastern margin of Ordos Basin is mainly exploited by coalbed methane and tight gas. At present, there are relatively few systematic studies on the exploration potential of shale gas, and the understanding is not deep enough. If we want to understand the shale exploration potential in this area, we need to conduct more profound and systematic research on shale gas in this area. Based on the logging data of shale gas reservoir in Linxing area, this paper deeply excavates it to establish the comprehensive logging evaluation technology and system method suitable for shale gas reservoir in this area. The identification method of shale gas reservoir, fine interpretation and evaluation of reservoir logging and evaluation standard of shale gas reservoir in this area are deeply studied.

Keywords

Ordos Basin; Shale gas; The logging data of shale gas; Comprehensive logging evaluation technology.

1. INTRODUCTION

There is less in-depth understanding of the exploration potential of shale gas and CBM in the eastern margin of Ordos Basin[1-2]. In order to understand the exploration potential of shale in the eastern edge of Ordos Basin, it is necessary to conduct more in-depth and systematic research on shale gas in this area, so as to achieve reserves and productivity replacement, and better solve the problems that the current situation of tight gas exploration and development in the study area is not optimistic, the production decline is fast, the water breakthrough is fast, and the reserves are difficult to develop. There is less shale gas in pure shale in the eastern edge of Ordos Basin. It is difficult to study shale gas in this area by traditional methods. It is necessary to clarify the target interval of the study area and find thin sand layer, silty sand and mud wrapped sand layer of shale interlayer to expand shale gas exploration results.

This study conducts in-depth data mining of shale gas logging data in Linxing area, takes the establishment of comprehensive evaluation technology and system method suitable for shale gas reservoir logging in this area as the starting point, through effective shale gas reservoir identification method, fine interpretation and evaluation of reservoir logging Analysis and Research on the practical application of shale gas reservoir evaluation standard and shale gas reservoir logging comprehensive evaluation technology[3].

2. ANALYSIS OF SHALE RESERVOIR CHARACTERISTICS

According to the core observation and thin section identification of wells in Linxing block, the lithology of the dominant shale section is characterized by "complex fine-grained lithology, rapid lateral change of lithology interbedding, strong heterogeneity and thin interlayer thickness"[4]. The lithology involved includes mudstone, thin coal layer, silty mudstone, carbonaceous mudstone, limestone siltstone and argillaceous siltstone fine sandstone (Figure

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1). The whole rock minerals show that the shale skeleton clastic minerals are mainly quartz and feldspar (Figure 2).

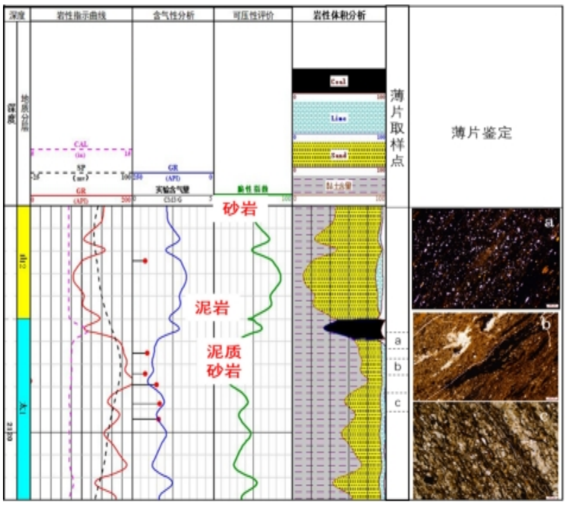

Figure 1. Logging curve and lithology identification diagram of dominant shale section

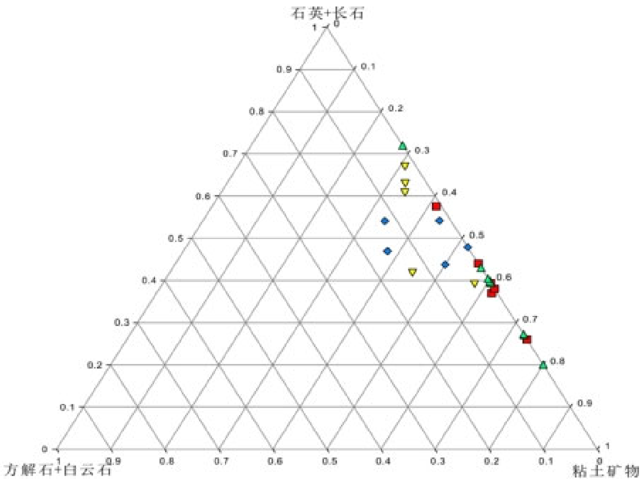

Figure 2. Characteristics of whole rock minerals in dominant shale section

3. ABNORMAL CURVE CAUSED BY LOGGING PROGRAM

Compared with conventional shale, the logging response of gas bearing shale is significantly different from that of conventional reservoir due to the influence of mineral composition, organic matter and gaseous hydrocarbon. Therefore, shale reservoirs can be identified qualitatively from the characteristics of logging curves[5]. There are many kinds of qualitative identification of dominant shale. In this study, acoustic resistivity overlap method, natural gamma ray spectroscopy method and cross plot method are applied.

3.1. Log Overlap Method

This method is a commonly used source rock identification method abroad, and the prototype of the method is passey's Calculation of total organic carbon content in formation by ΔlogR method. The superposition of acoustic time difference curve and resistivity curve is applied to lx3-74 well. There is an obvious envelope at the intersection of 1955-1969m section, which is judged as a source rock rich in organic matter. However, this method only qualitatively identifies the source rock, but does not give the lithology of the source rock. Therefore, to further identify the shale reservoir, it is necessary to make a comprehensive qualitative

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judgment in combination with other logging curves or logging data. Considering that the natural gamma curve can reflect the characteristics of argillaceous and organic matter rich formation, the natural gamma curve and resistivity curve are overlapped. In the consistent or almost overlapped formation, the shale section can be identified according to the variation amplitude of the natural gamma curve. Because in the interval where the natural gamma increases and the resistivity increases, it reflects the increase of organic matter and the increase of maturity level. When the content of organic matter increases and the maturity level of organic matter changes, the above curve change form can be used for reference to make a qualitative judgment on the formation of source rock. The advantage of this method is that it can identify source rocks. It is a deformed but real logging curve comparison method to identify shale reservoirs.

3.2. Natural Gamma Spectrometry

Under the condition that the mineral composition of the formation is basically unchanged, the shale reservoir is a favorable reducing formation formed in the low-energy environment with poor hydrodynamic force, clay minerals are developed, and the natural gamma logging curve shows high value; This environment is also conducive to the preservation of organic matter, and the existence of organic matter is a favorable environment for uranium accumulation and development. Therefore, the uranium curve in natural gamma ray spectrometry logging shows high value. Based on the above analysis, there will be obvious differences between uranium bearing gamma curve and uranium free gamma curve in shale reservoir.

From the actual logging curve of well LX-17 (Figure 3), the response difference between uranium containing gamma curve and uranium free gamma curve in the well section within the blue frame in the figure is 80 ~ 100api. In other well sections, there is little or no difference between the two gamma curves. Therefore, combined with the characteristics of other logging curves, this method can be used to qualitatively identify shale reservoirs.

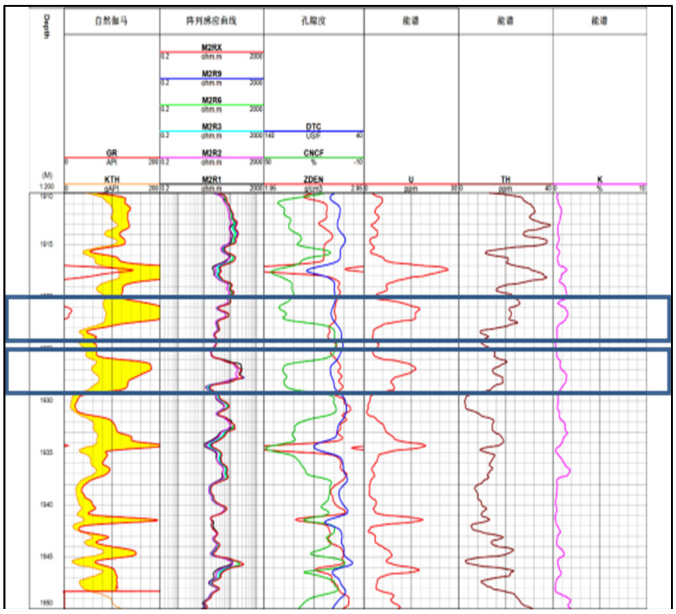

Figure 3. Logging curve of well LX-17

3.3. Crossplot Method

Conventional logging response is a single factor lithology identification method, but in practical work, different lithology often has the same single factor characteristics. The crossplot analysis technology is based on the response characteristics of different types of objects and the differences of data distribution areas. It is another common method to determine the lithology

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by using logging data. Combined with logging data, the formation lithology can be identified quickly and intuitively through logging response crossplot. Taking LX3-74 well as an example, according to the logging data, the cross plot of natural gamma and acoustic TDOA logging response is established, which can better identify and divide the formation lithology. As shown in Figure 4 and Figure 5, according to the well logging data, the intersection plates of density and natural gamma, acoustic moveout and natural gamma are made respectively. It can be seen that the dominant shale and other lithology (sandstone, limestone, coal rock, mudstone, etc.) are obviously distributed in different regions, and the dominant shale can be divided by the intersection diagram method. In the figure, yellow represents sandstone, light blue represents limestone, brown represents mudstone, black represents coal seam, and green represents dominant shale.

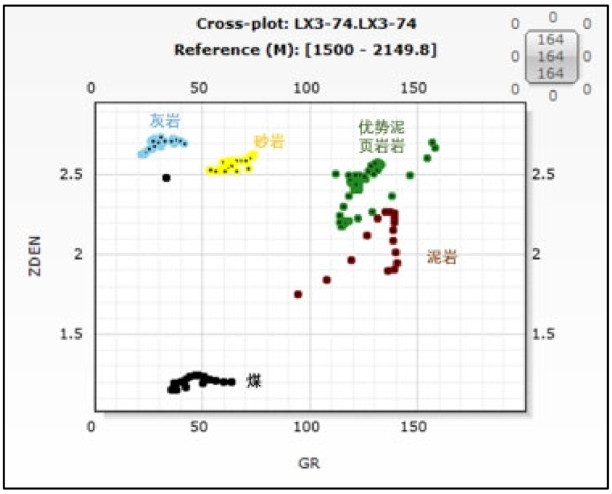

Figure 4. Density and natural gamma intersection chart

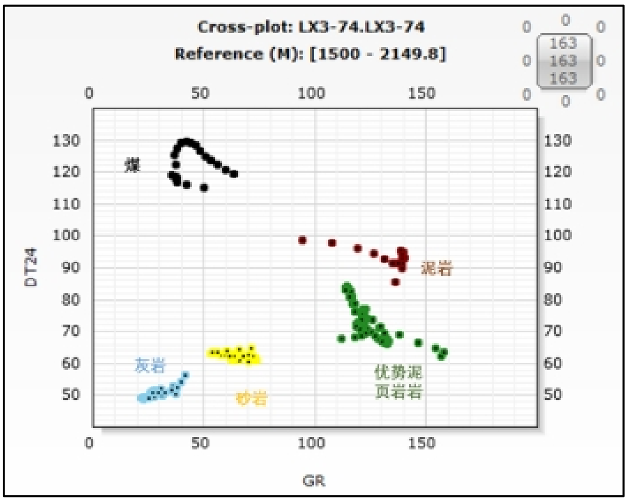

Figure 5. Acoustic time difference and natural gamma intersection chart

4. FINE INTERPRETATION MODEL OF SHALE GAS LOGGING IN THE STUDY AREA

By preprocessing logging data and calibrating logging based on core data, a quantitative interpretation model of shale gas is established. Specifically, it includes calculation models such as mineral composition and content, reservoir parameters, geochemical parameters, gas content and brittleness index. The established interpretation model is used to process and interpret the logging data of shale gas reservoir in Linxing area[6].

4.1. Shale Evaluation Volume Model

Considering the limited logging data collected in the shale gas reservoir and the actual mineral content in the formation, in order to facilitate the solution of the content of each component, the shale gas volume model is simplified into five parts based on the main minerals:

Clay minerals + siliceous minerals + calcareous minerals + organic matter + pores = 100%

When the simplified model is applied in the study area, the clay minerals are mainly illite, kaolinite and chlorite; Brittle minerals are mainly quartz, feldspar, calcite, dolomite and a small amount of pyrite and siderite; The organic matter is mainly kerogen, which is also the main place for the occurrence of shale adsorbed gas; Porosity is effective porosity, including free gas and water.

4.2. Reservoir Parameter Calculation

Logging evaluation of shale gas reservoir parameters mainly includes porosity, permeability and water saturation. The pore structure of shale gas reservoir is mainly nano pore roar, and the reservoir is characterized by low permeability - ultra-low permeability. The logging evaluation is mainly to calculate the permeability of bedrock; The water saturation of shale gas reservoir determines the accurate quantitative evaluation of free gas in the reservoir.

Compared with the core analysis results (see Figure 6), the calculated water saturation results are relatively reliable and can be applied to the calculation of shale saturation in the study area.

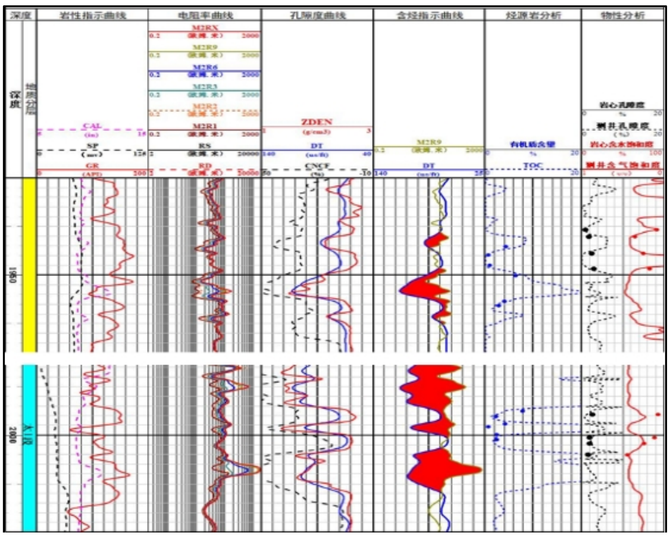

Figure 6. Comparison of water saturation of well LX2-48

4.3. Calculation of Organic Carbon Content in Shale

Organic matter is the key factor of shale reservoir formation, and the total organic carbon content (TOC) in shale is the indicator parameter of shale hydrocarbon generation potential. Organic carbon content (TOC) is an important index for source rock evaluation and oil and gas resource evaluation. It is generally expressed by the mass percentage of organic carbon in unit mass rock. Its quantitative calculation method is the focus of research and the key of evaluation. In this study, the core calibration technology is adopted, the response characteristics of logging curves are integrated, and the calculation models of each group are obtained by linear regression method.

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Compared with the core analysis results, the calculated TOC results are more reliable and can be applied to the TOC calculation of shale in the study area..

4.4. Calculation of Shale Gas Content

Gas content is one of the most important parameters for evaluating shale gas reservoir. There are many factors affecting the gas content of shale gas reservoir, including pore and fracture development degree, water saturation, formation pressure, formation temperature, total organic carbon content, kerogen type, clay type, etc. Shale gas is mainly composed of adsorbed gas and free gas. Therefore, the calculation model of total gas content of shale gas reservoir is as follows:

Qqv = HQL + QGY, where:

Qqv is the formation gas content, unit: m3 / T;

HQL is the gas content of formation adsorbed gas, unit: m3 / T;

QGY is the free gas content of formation, unit: m3 / T.

4.4.1 Free gas content

Free gas is the gas content in shale pore space. Free gas is less distributed in marine shale and mainly distributed in marine land transitional facies shale reservoir. It is the basic content of marine land transitional facies shale treatment. The content of free gas in shale formation is mainly affected by effective porosity and water saturation. In order to directly compare the content of free gas and adsorbed gas, it is necessary to convert the content of free gas into the same unit as that of adsorbed gas in the evaluation of gas bearing property of shale gas reservoir. Therefore, the content of free gas is also affected by gas specific gravity, formation pressure and temperature. In this study, the free gas content is treated with reference to the reserve calculation method in sandstone and calculated by volume model:

QGY=POR × (1-Sw)/(Bg × Zden), where:

Por: porosity (V / V);

Sw: water saturation calculated by conductive porosity model (V / V);

Zden: density of gas bearing shale (g / cm^3);

BG: gas volume coefficient; The value of the target layer in this area is 0.0047 ~ 0.0052.

4.4.2 Adsorbed gas content

According to statistics, the content of adsorbed gas in shale can reach 20 ~ 85%, which depends on the content of organic matter, porosity, mineral composition, diagenesis, rock structure, oil and gas reservoir pressure and temperature.

Through the regression between adsorbed gas content and TOC content, it is found that there is an obvious linear relationship between adsorbed gas content and organic carbon content. In this study, through the regression of adsorbed gas content and organic carbon content in this area, the following relationship is obtained:

Shanxi Formation: HQL=0.2527×ln(TOC)+1.1859 R^2 = 0.6664

Taiyuan Formation: HQL=0.6848×ln(TOC) + 1.3396 R^2 = 0.7129

Benxi Formation: HQL=0.2391×ln(TOC) + 1.11 R^2 = 0.4477

5. ABNORMALITIES CAUSED BY INSTRUMENT FAULTS

There is no unified standard for shale classification at home and abroad. This study mainly refers to the division standard of marine shale gas in Sinopec Fuling shale gas field and continental shale oil and gas in Yanchang oilfield, and establishes the division standard of shale

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reservoir in the study area in combination with the stratigraphic characteristics of the study area and the degree of exploration and development in this area. Table 1:

Class I reservoir porosity is greater than or equal to 4%, organic carbon content is greater than or equal to 4%, total gas content is greater than or equal to $2m^3$ / T, and brittle mineral content is greater than or equal to 40%. Class II reservoir porosity is greater than or equal to 2%, organic carbon content is greater than or equal to 2%, total gas content is greater than or equal to $1m^3$ / T, and brittle mineral content is greater than or equal to 30%. The porosity of class III reservoir is less than 2%, and the gas content is less than $1m^3$ / T.

Table 1. Classification standard of shale reservoir in Linxing area

parameter	high quality(I)	preferably (II)	difference (III)
Effective porosity(%)	≥4.0	≥2	<2
TOC(%)	≥4.0	≥2	
Total gas content(m3/t)	≥2.0	≥1	<1
Brittle material content(%)	≥40	≥30	

6. CONCLUSION

(1) The logging identification method of high-quality shale gas reservoir in the study area is established. Through the anatomical analysis of typical shale gas reservoir in the study area, the conventional logging data information is fully excavated, and the logging curves sensitive to the mineral composition, organic matter and gas bearing response of high-quality shale gas reservoir are optimized. The curve overlap method is adopted Natural gamma ray spectrum method and cross plot method have established the identification method of high-quality shale gas reservoir.

(2) The fine interpretation model of shale gas logging in the study area is established. Based on the core calibration logging data, the logging interpretation and calculation models of clay and brittle mineral content, reservoir parameters, organic carbon content, geochemical parameters, gas content and brittle parameters of shale gas reservoir in the study area are established. The innovation of technology and method in water saturation logging evaluation has been made, and the difficult problem of logging geological parameter evaluation of shale gas reservoir has been solved.

(3) The classification and evaluation criteria of shale gas reservoirs in the study area are established. Based on the analysis of the "seven properties" relationship of shale gas reservoirs in the study area, combined with the core analysis data and comparing the interpretation standards at home and abroad, porosity, TOC content, gas content and brittleness index are selected as the reservoir classification and evaluation parameters, and the classification and evaluation methods and evaluation criteria of shale gas reservoirs are preliminarily established.

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