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Determination of the Original Sedimentary Rhythm by Interpretation Unit Discrimination

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Abstract: - This paper represents that the sedimentary rhythm is a primary factor to control the distribution of water flooded zones in the thick-layer sand. The electrical properties of layers in the same well are comparable and the water flooded level discrimination has more practical significance only in the same sedimentary rhythm. The stable mudstone barrier bed is adopted as the separable symbol for different interpretation units that are identified from well logging curve so that only one sedimentary rhythm is contained in each interpretation unit. The average slope angle of resistivity curve and relative center of gravity of density curve are adopted as discriminant parameters for identifying the original sedimentary rhythm by computer in each interpretation unit.

Keywords: *original sedimentary rhythm; interpretation unit; level of water flooded; relative center of gravity; average slope angle; well logging*

I. INTRODUCTION

Interpretation and analysis of water flooded layer has the characteristics of large amount of work, high degree of professionalism, strong experience, and be not easy to promote[1].Therefore, it is necessary to establish a method for the identification of the water flooded level of the sand body's thick layer.However, at present, the main problem that the coincidence rate of the interpretation of water flooded interpretation is to determine the existence of multi solution with the log curve:The same flood level, and its electrical characteristics are often not the same;At the same time,the same typical characteristics often correspond to different water flooded levels.This phenomenon has brought great difficulties to the interpretation of water flooded.Even in the case of manual interpretation,the coincidence rate of the small layer water flooded level is also very difficult to exceed 80%.

Although there are many solutions to the level of water flooding in the use of log curves, the distribution of water in the thick sand bodies is a rule to follow. Many scholars studies show that the original sedimentary rhythm has a control effect on the water flooded level of thick sand bodies[2]. This is reflected in two aspects: different types of sedimentary rhythm, flooding intensity space distribution laws; and the same type of sedimentary rhythm in flooding intensity space distribution of roughly the same; in the same sedimentary rhythm, thick layer of sand body in the layers of intensity of flooding is not isolated from each others, but highly correlated and has a strong spatial regularity. As long as they can precisely divide the original sedimentary, rhythm types can give sedimentary rhythm of each layer in the rule of waterflooding, the thick layer of sand body internal rule of waterflooding is controlled by the sedimentary rhythm.

On the other hand, it is difficult to establish the standard of the water flooded level with the high, middle,and low water level. The reason, mainly is the interpreter only considering the different intensity of flooding, while ignoring the macro Geological Controlling Factors of different, the different types of sedimentary rhythm with the same level of submerged layer of electrical characteristics should be gotten together with inductive analysis. However different types of sedimentary rhythm of lithology, physical property, the salinity of formation water is different, resulting in the electrical characteristics of the same flooding level is different, so it is difficult to give

a unified electric standard. Even if the same type of sedimentary rhythm, the same water flooded level, because the type of sedimentary rhythm is different, the absolute power characteristics are not the same. And the same sedimentary rhythm has the same water dynamic variation law. Therefore, the electrical characteristics of each layer in the rhythm of the rhythm are relatively comparable. This shows that the same type of sedimentary rhythm is different, but the electrical characteristics of each layer of the inner layer are the same. Therefore, it is an important way to improve the rate of water flooded level by using the theory of sedimentary rhythm as the macro guidance, and the establishment of the standard of the relative electrical characteristics of the water flooded level within each small layer.

Through the above analysis, we will underground reservoir according to the different division of original sedimentary characteristics for positive rhythm, reverse rhythm, homogeneous rhythm, complex rhythm, multi section and rhyme, and other basic types and different sedimentary rhythms type mapping to the logging curve, forming unit of well log interpretation are in one-to-one correspondence with the sedimentary rhythm. The stability of mudstone interlayer as the boundaries between different interpretation unit signs on the resistivity logging curve to determine the top and bottom boundaries in the interpretation of unit. In the interpretation of element division on the basis, the resistivity curve combined with density logging curve, average resistivity curve slope inclination angle and density curve of the relative center of gravity as discriminate parameter, automatic classification and identification of each unit within the sedimentary rhythm.

II. INTERPRETATION UNIT DIVISION

The so-called interpretation unit is to geologic sedimentary units (sedimentary rhythm) ,the concept is mapped into the logging curve,and the logging curve is divided into one-to-one correspondence with the sedimentary geological unit of the overall interpretation layer. By the geological sedimentary theory, different sedimentary units have stable mudstone. Therefore, interpretation unit partition problem on logging curves is changed for stable mudstone in well logging curves of the problem. Select the resistivity curve as a division of the curve, when the resistivity curves appear flat straight shape and the resistivity value is less than a given threshold interval as a separator in different interpretation unit layer. For the thick sandstone (explain unit cumulative sandstone thickness is more than or equal to 1 m), mudstone interlayer thickness is not less than 0.5 m and the logging curve has obvious mudstone return as interpretation unit top (bottom) interface; for thin sand, logging curve is obvious to return as a unit to explain the top (bottom) interface.

III. DIVISION AND DESCRIPTION OF RHYTHM

In explaining the unit based on the division, to explain the unit internal lithology and physical property is good, electrical characteristics of high thick layer of sand. According to the different hydrodynamic conditions and sedimentary environment of deposition which is divided into several basic types, both before and after the flooding curve characteristic parameters change situation and see Table 1) homogeneous rhythm thick layer sand. It reflects the relative stability of the hydrodynamic conditions of the sedimentary environment, the lithology, the physical properties of the layers, and the fluid properties are relatively stable. Electrical curve is box shaped, and the surrounding rock is the mutation contact.

2) positive rhythm thick layer sand. It reflects the dynamic conditions of the sedimentary environment according to the strong to weak law: from the bottom to the upper lithology gradually become poor, grain size gradually becomes finer, the density gradually increases, the apparent resistivity decreases.

3) anti rhythm thick layer sand. It is the reflection of the sedimentary environment of hydrodynamic conditions in from weak to strong regularity: the highest penetration layer at the top of the sand body, by the lithology, physical property becomes poor, density increases gradually, apparent resistivity decreases.

4) complex rhythm thick layer sand. The sedimentary environment of the hydrodynamic conditions reflects to the weak variation in weak. In the longitudinal direction, the upper part is a positive rhythm, and the lower part is the counter - rhythm. In the middle part, the permeability is relatively high, and the upper and lower part of the gradient is often a low permeability layer. Composite rhythm sand body on the apparent resistivity curve of performance is small and one large and one small change characteristics; density curve showed one small and one large variation; microelectrode curve of amplitude, amplitude difference is small and one large and one small change characteristics, at both ends of the rhythm with tooth marked characteristics.

5) multi segment and multi rhythm thick layer sand. It is formed in a variety of channel sand bodies, for the multi - channel sand body of the cutting. The characteristics are that the thickness of sand body, the lithology and the material property of the layer are more than 2 in thickness. In the well log curves, the peak values of different thicknesses are shown to reflect the multi rhythm. The interlayer of a multi segment and multi rhythmic layer is usually a mudstone or a silty mudstone, or a dense calcareous layer. If interlayer condition is better, it will weaken the positive role of gravity in the rhythm, the lower interlayer oil displacement efficiency is reduced, then the channel, sand body is divided into single channel sand body. If the interlayer is not stable, it has the water power relation, and the water is injected into the water, the more unstable interlayer, the more complex the oil and water movement and the law of water flooding.

Table1 Comparison of different parameters of the curves of different sedimentary rhythms under water flooding

Before water flooding				
Sedimentary rhythm type	Apparent resistivity curve	The angle of the average slope of the apparent resistivity curve	Relative center of gravity of the apparent resistivity curve	Relative center of gravity of the density curve
Homogeneous rhythm	Box	（80°,100°）	About 0.5	About 0.5
Positive rhythm	Bell	（0°,60°]	>0.5	<0.5
Counter rhythm	Funnel	[120°,180°)	<0.5	>0.5
Compound rhythm	Upper bell and lower funnel	Upper(0°,60°] lower[120°,180°)	Upper>0.5, lower<0.5	Upper<0.5, lower>0.5
Multi segment and multi rhythm	Upper bell and lower bell	Upper(0°,60°] Lower(0°,60°]	Upper>0.5, Lower>0.5	Upper<0.5, Lower<0.5
After water flooding				
Sedimentary rhythm type	Apparent resistivity curve	The angle of the average slope of the apparent resistivity curve	Relative center of gravity of the apparent resistivity curve	Relative center of gravity of the density curve
Homogeneous rhythm	About bos or funnel	（80°,100°） [100°,180°]	≤0.5	About 0.5
Positive rhythm	Bell or funnel	（0°,80°] [100°,180°]	≥0.5	<0.5
Counter rhythm	Funnel or long funnel	[120°,180°) [100°,120°]	≤0.5	>0.5

Compound rhythm	About box	Upper(60°,80°] Lower[100°,120°)	Upper≥0.5, Lower≤0.5	Upper<0.5, Lower>0.5
Multi segment and multi rhythm	About box	Upper(60°,80°] Lower(60°,80°]	Upper≥0.5, Lower≥0.5	Upper<0.5, Lower<0.5

IV. CURVE CHARACTERISTIC PARAMETERS AND PROSODIC DISCRIMINATION

4.1 Discrimination method

On the geological, the use of log curve automatic division of sedimentary micro facies has been a relatively mature base, there are many authors who have done a corresponding research[3]. However, in the original water flooded reservoir sedimentary rhythm discrimination, it also has the particularity, which is reflected in: in the discriminant analysis on the sedimentary rhythm, logging curve is the most ideal resistivity curve, which can depict the rhythm with internal layers of lithology, physical properties, oil content and spatial variation of salinity changes; but sedimentary rhythm logging resistivity curve after flooding on performance, is not the original formation sedimentary rhythm, this is mainly because the local water flooded layer, especially the formation by water flooding, reduces the formation resistivity, the resistivity logging curve change greatly, the bell curve form of original (positive rhythm box type (deposition) into homogeneous rhythm) or even funnel (reverse rhythm). Therefore, the identification of the sedimentary rhythm based on the resistivity curve can often result in the false positives of the original sedimentary rhythm, and then the identification of the low level water flooded levels. The way how to explain that is combined with density logging curve and the resistivity curve of comprehensive judgment, although the flood will cause the change of reservoir physical properties, such as with the increase of the intensity of flooding, the porosity and permeability of reservoir will increase, the storage layer to improve, which makes original density curve shape has been further strengthened. Such as the original density curves for the bell shaped after the flood still is bell shaped without like resistivity curve ,that becomes the opposite. It can maintain the original sedimentary rhythm with the curve shape better, in addition, under water flooding situation, the density curve of amplitude changes will not like resistivity curve as a great changes, because density curve shape changes is relatively small.

4.2 Definition of feature parameters

In order to realize the automatic recognition of the type of the thick sand body, it is needed to describe the shape parameter of the log. In this study, the main parameters include the average slope angle and the relative weight of the log curve.

4.2.1 Mean slope angle(α)

Average slope of the curve is the identification of logging curve shape of an important parameter, it said a sand body internal electrical characteristics of continuous change trend, can be expressed as power curve increased, decreased or unchanged. For the density curve, the mean value of the negative slope indicates that the lithology changes and is positive, while the average slope is positive, and the average slope is positive, which is the normal rhythm (Figure 1). The average slope can be expressed as[3]:

$$\overline{K} = \frac{\sum_{i=1}^{n}(a_i - \overline{a})(d_i - \overline{d})}{\sum_{i=1}^{n}(a_i - \overline{a})^2} \quad (1)$$

Among them: $\bar{a} = \frac{1}{n}\sum_{i=1}^{n} a_i$; $\bar{d} = \frac{1}{n}\sum_{i=1}^{n} d_i$; a_i represents the magnitude of the first I log curve in thick sand body; n is the total number of sampling points for sand body; d_i is the depth sequence.

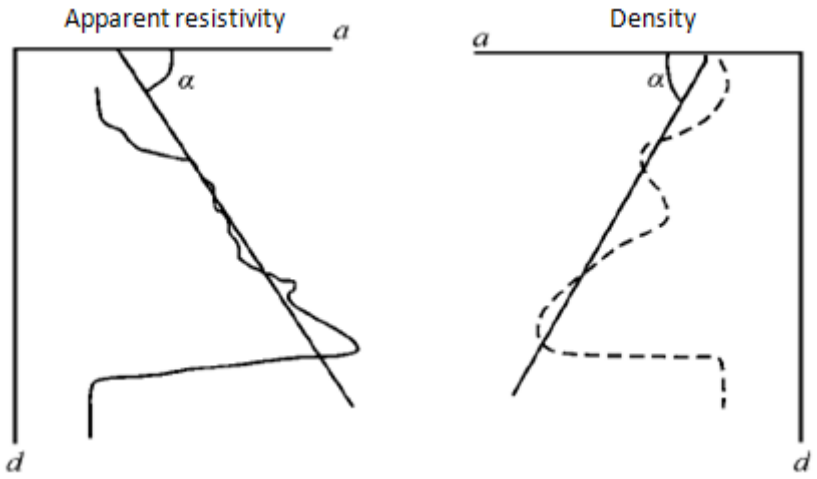

Fig. 1 the slope of the different log curves is indicated.

Because of the small change of the average slope, the distinction is not high, and it is not conducive to the automatic identification of the rhythm, so the average slope of the log curve is converted to an inclined angle:

$$\alpha = 57.2958^{o}\, arctg(\overline{K}) \tag{2}$$

When α≤80°, it is bell shaped curve. According to the interval (0°, 40°],(40°,60°], (60°,80°],accordingly can be divided into flat bell,long and normal bell. When α≥100°, curve shape is funnel-shaped. According to the range (180°, 140°], (140°, 120°], (120°, 100°] accordingly can be divided into flat funnel - shaped, normal funnel - shaped and long funnel shape. If α∈(80°,100°), and is a high amplitude, we will define the type as box.

4.2.2 Relative center of gravity(W)

Relative center of gravity(W) can be expressed in this way:

$$W = \frac{\sum_{i=1}^{n} i a_i}{n\sum_{i=1}^{n} a_i} \tag{3}$$

Relative to the size of the center of gravity expresses different logging curve amplitude distribution of the apparent resistivity curve, the morphology of the bell curve of relative gravity center offset, funnel shape is relative to the center of gravity on the side; for density curve, morphology of the bell curve is relative to the center of gravity on the side, funnel-shaped relative gravity center offset, box and the shape of the curve of the relative center of gravity center.

4.2.3 Discrimination method

Channel sand body in the deposition process will be at the top or bottom of the calcium dissection, it will change the shape of the resistivity curve, be easy to make the reservoir rhythms computer discriminant errors accurate recognition. According to the natural trend of cutting, interpolation, smoothing, in order to ensure that it does not affect the original sedimentary rhythm type discrimination accuracy; for the independent of the calcareous

layer, directly skip, not explained. In the process of removal of calcium, the most critical is the determination of the boundary of the calcareous interlayer. The boundary is too large, it will hurt the normal curve shape; the boundary is too small, the calcareous layer will have a residual. This study determined the boundary of calcareous interlayer by the activity of the log curve[4]. In order to improve the accuracy of activity layering, in the stratified, we set a threshold, when the activity of extreme value exceeds this value, it finds the effective interface.

Through the calculation of average slope and relative gravity center of some well known rhythmic types of thick sand body, summed up the after flooding in different rhythm types of sand body curve shape parameter variation (Table 1). According to the above rules, the original sedimentary rhythm of the single channel sand body can be identified by the average slope angle and the relative gravity method in the actual data processing.

The compound rhythm can be regarded as a combination of positive and anti - rhythm. Therefore, in the actual calculation, the midpoint of the layer thickness is bounded, the average slope of the provisions as the starting point of this layer to the midpoint of the curve continuous is in the decreasing or increasing trend, which is not limited to changes between the two points, but they are a reflection of the trend curve. In the same way, the average slope is continuously decreasing or increasing from the point to the last 1 point. Recording the up average slope and the down slope of the average as $\overline{K}_{上}$ and $\overline{K}_{下}$, the corresponding tilt angles are recorded as $a_{上}$ and $a_{下}$. Then we should calculate the relative gravity of the density curves of the upper and lower segments respectively, and record them $W_{上}$ and $W_{下}$, and according to the angle of the slope and the change of relative center of gravity, the original sedimentary rhythm of the sand body is determined. While the multi segment and multi rhythm are often used for the multi phase channel sand body cutting, it can be divided into the single phase channel sand body according to the stability of the rhythm. For multi rhythm of single channel sand body calculated separately. Then the resistivity curve of the average rate of brake and density curve of the relative center of gravity, according to the criterion of single channel sand body sedimentary rhythm of each channel sandbody sedimentary rhythm type recognition.

V. CONCLUSION

1) the waterflooding rules of the thick layer of the internal sand body is mainly controlled by the sedimentary rhythm, different sedimentary rhythms have their unique rule of waterflooding, and in the same sedimentary rhythm of each layer in the space of water flooded level distribution has their own regularity. Therefore, based on the accurate interpretation of the unit, it is an important way to improve the water flooding of thick sand bodies.

2) the absolute electrical characteristics of the small layer that the sedimentary rhythms are different are not comparable, and the electrical characteristics of each layer are relatively comparable only in the same sedimentary rhythm. So, it should be on the basis of correctly dividing the original sedimentary rhythm, according to the small layer in prosodic position of the internal space of the well logging curves, the relative change in trend, lithology, physical difference and its combination of fine judgment will water out the water flooded degree.

3) in the channel, multi section and sedimentary rhythm, which each channel has different rhythm types, between the single channel , they are separated by a stable interlayer, and make the single period river channel form independent oil-water movement unit , which has its own rule of waterflooding. Therefore, in the thick layer of water flooded levels should be treated separately.

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