Study on the Four- property Relationship of Reservoirs in YK Area of Ganguyi Oilfield

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Abstract

The "four- property" relationship refers to the interrelationship and internal law between the lithology, physical properties, electrical properties and oil-bearing properties of the reservoir. Through the statistics and analysis of the core, logging and oil testing data in the YK area of Ganguyi Oilfield, the four- property relationship of the reservoirs in this area can be clarified. Based on this, an interpretation model of reservoir porosity, permeability and oil saturation is established, and the effective thickness of the reservoir is determined and divided, which can provide an important basis for reservoir development in this area.

Keywords

Four- property relationship, Lithologic, electrical, Physical property, Oily, Interpretation model.

1. Introduction

The bottom of Chang 4+5 and Chang 6 reservoirs in the YK area of Ganguyi Oilfield have the characteristics of low porosity, low permeability and low oil saturation, thus reducing the ability of the logging curve to reflect the oil and gas reserves of the reservoir. At the same time, due to the strong diagenesis of the reservoir, the control factors of reservoir physical properties are more complicated. The difference between the low-porosity oil layer with oil production ability and the non-oil layer in the logging response is sometimes small, which makes some routinely effective methods often fail. Therefore, in the evaluation of low-permeability reservoirs, the study of the relationship between "four property" is particularly important. Only by understanding the changing laws between the "four property", based on the well logging data to reflect the overall physical properties of the reservoir, it is possible to make an analysis of the many phenomena in the electric measurement curve of low-permeability reservoirs from the surface to the inside and the other, to achieve the purpose of evaluating the oiliness[1].

2. Reservoir four- property relationship research

2.1 Relationship between lithology and electrical properties.

The lithology of the bottom of Chang 4+5 and Chang 6 formations is mainly sandstone and mudstone, and the difference in lithology and mineral composition in the longitudinal direction makes the geophysical properties often different.

Both mudstone and silty mudstone are characterized by high natural gamma, natural potential baseline, micro-electrode no difference or small difference, relatively low resistivity and high acoustic time difference. The mudstone layer often has a well diameter expansion phenomenon. Siltstone and argillaceous sandstone are characterized by medium or high natural gamma and medium-low negative anomaly amplitude natural potential and small or no difference in microelectrode difference. The acoustic wave time difference is about 240 μs/m, and the apparent resistivity is relatively low (Rt ≈ 30 to 40 Ωm). Since the lithological particles are fine (average particle size is less than 0.1 mm), the absolute porosity is high, but the effective porosity is low, the permeability is poor, and generally no oil and gas. The fine sandstone is the main oil-bearing reservoir of the Chang 4+5 and Chang 6 strata, characterized by a significant negative anomaly of the natural potential, a low natural gamma value and a large difference in the microelectrode. The oil-bearing fine sandstone has a high electrical resistivity and the oil layer resistivity is generally greater than 35Ωm.

2.2 Reservoir physical property and electrical relationship.

The reflection of the electrical measurement curve on the reservoir performance is mainly reflected in the natural potential and the acoustic time difference. Reservoirs with relatively good pores and permeability show a relatively negative anomaly on the natural potential curve and a relatively high acoustic time difference. The sound time difference of the better reservoir in the study area is generally 230~245μs/m, the acoustic wave time difference of most oil layers is 225-235μs/m, and the acoustic wave time difference of the dense layer with relatively high calcium content is generally less than 220μs/m. At the same time, the resistivity is also relatively high. The acoustic wave time difference of the reservoir in this area has a good correspondence with the porosity.

2.3 Oil bearing and electrical relationship.

The Chang 6 reservoir in the YK area of Ganguyi Oilfield is divided into four sub-groups of Chang 61, Chang 62, Chang 63 and Chang 64 according to sedimentary characteristics. The Chang 61, Chang 62 and Chang 63 are the main oil-bearing target intervals, and the oil content is higher. Well, the Chang 64 is only partially oily, and the oil content is very poor. The permeation layer is characterized by a typical low-resistance water layer on the log curve.

The resistivity curve is the most important curve for identifying the oil and water layer. In theory, the induction logging curve has a circular distribution in the formation due to its current line. The equivalent resistance of the original formation, the transition zone and the flushing zone are parallel, so it can identify relatively low-resistance formations more than ordinary apparent resistivity curves and lateral logging. Therefore, the induction log should be used to identify the oil and water layer. The area uses deep induction, medium induction, and eight lateral combinations to detect the resistivity of the original formation, transition zone and flushing zone. For pale cement slurry, the typical oil layer is characterized by drag reduction, that is, the deep detection resistivity is greater than the shallow detection resistivity; the typical water layer is the resistance increase intrusion, and the shallow detection resistivity is greater than the deep detection resistivity.

The density of the lithology of the Chang 6 reservoir in this area is different, and the permeability is very different. In the reservoir section with better permeability, the oil content is generally good. The curve characteristics of the oil-bearing layer of the Chang 6 oil layer group are obvious, and the characteristics of the oil and water layers are easy to identify. The resistivity of the oil layer is large, the reservoir resistivity of the oil-bearing section is 1.5 to 4 times that of the water layer, the deep sensing resistivity of the oil-bearing layer is approximately 40～150Ωm, and the average value of 4.0m apparent resistivity is generally 40～200Ωm. The water layer has a low induced resistivity value and a sound time difference of more than 220 μs/m. The oil saturation calculation formula is obtained by the rock power experiment, and the oil saturation of the reservoir can be calculated by the acoustic wave time difference and the oil layer deep sensing resistivity value.

3. Log interpretation model

The reservoir is a unity formed between the rock and the contained fluid, linked to each other's physical and chemical roles, it has two characteristics: one is the skeleton characteristics of the rock itself, such as porosity, permeability, particle size and pore distribution, etc.; the second is the comprehensive characteristics between fluid and rock, such as capillary force, wettability and relative permeability. These characteristics directly determine the distribution and flow characteristics of oil, gas and water in the reservoir, and the evaluation of oil and gas layers is mainly based on them. In order to improve the calculation accuracy of these parameters, in the study of regional logging reservoir parameter interpretation model, we use the core analysis of the target interval and logging data to carry out the basic data collation, and establish the interpretation and prediction model of the parameters required for the reserve calculation[2,3].

3.1 Porosity interpretation model

Porosity is an important parameter reflecting the physical properties of reservoirs. It is also one of the indispensable parameters for oilfield reserves, capacity calculation and log interpretation. It requires high calculation accuracy. According to the actual data status of the area, the acoustic time difference is usually used to calculate, and after the stratified value processing, the statistical interpretation model and volume model of the porosity analysis are established.

Through the core analysis data, the response relationship between the acoustic time difference of the target interval and the core analysis porosity is established. Through regression analysis, the relationship between core analysis of porosity and acoustic time difference is established. Its the bottom of Chang 4+5 and chang 6 are:

$$\phi = 0.1291\,\Delta t - 20.754 \tag{1}$$

$$\phi = 0.1314\,\Delta t - 21.327 \tag{2}$$

Among them: ϕ-core analysis porosity, %; Δt - acoustic time difference, μs / m.

3.2 Permeability interpretation model

Through the analysis of core physical property data, the main reason for affecting the permeability is porosity. According to the porosity and permeability of the core analysis data, the intersection map is used, and then the correlation is used for the interpretation of the well permeability. The response relationship between the bottom of Chang 4+5 and the chang6 to establish porosity and permeability is:

$$K=0.0477e^{0.1275\phi} \tag{3}$$

$$K=0.0097e^{0.3635\phi} \tag{4}$$

Where: ϕ-core analysis porosity, %; *K*- core analysis of permeability, $\times10^{-3}\mu m^2$.

3.3 Water saturation interpretation model

Formation water saturation is a basic parameter for evaluating the oil content of a reservoir,it represents the relative proportion of water in the pore volume of the rock. $1\text{-}S_w$ is the hydrocarbon saturation of the reservoir, which represents the relative volume of oil and gas in the pores of the rock. The basic method for determining saturation using well logging data is usually based on the relationship between rock and electricity to establish the relationship between resistivity, saturation and porosity. The main research of the rock and electricity experiment is two aspects: the relationship between the formation factor and the porosity, and the relationship between the resistivity increase coefficient and the saturation.

3.3.1 Formation factors and porosity

The resistivity of the formation is not only related to its oil-bearing properties, but also related to the porosity, pore structure and formation water mineralization of the formation. Therefore, in order to eliminate the influence of formation water salinity, the concept of formation factor (F) is cited to illustrate the effect of formation properties such as porosity on electrical resistivity.

$$F = \frac{R_o}{R_w} \tag{5}$$

Where: R_o—100% water-containing rock resistivity;R_w—the formation water resistivity.

According to Archie's experiments, the relationship between formation factors and porosity is:

$$F = \frac{a}{\phi^m} \tag{6}$$

“a”is the lithology coefficient associated with the characteristics of the regional strata, and “m” is the cementation index, which is related to the degree of cementation of the rock. For a certain stratum, “a”and “m” reflect the formation characteristics, and the accurate determination of this parameter becomes the core problem to determine the relationship between formation factors and porosity. Take the logarithm of the two ends of the above formula:

$$\log F = \log a - m \log \phi \tag{7}$$

From this formula, in the double logarithmic coordinate system, the formation factor and the porosity are linear, the slope of the straight line is “m”, and the intercept is loga. Based on this idea, the relationship of formation factor and porosity was established for the bottom of Chang 4+5 lower oil layer subgroup and the Chang 6 oil layer group, respectively. The samples of 45 Chang 6 oil layers in Tang 82 well area and Tang 81 and Tang 89 of YK area of Ganguyi oilfield were collected, and the relationship between formation factors and porosity was analyzed,made the following conclusion:

$$F = \frac{6.42}{\phi^{1.04}} \tag{8}$$

The correlation coefficient R is equal to 0.74, which reflects the good correlation between sample parameters, strong regularity and high credibility.

3.3.2 Resistance increase rate and water saturation

Since the resistivity is affected by factors such as pore size, formation water salinity, saturation, etc., in order to determine the relationship between resistivity and oil saturation, the concept of resistivity increase factor (I) is introduced, that is, the ratio of the resistivity of an oil-bearing rock to the resistivity of the rock when it is saturated with water.

$$I = \frac{R_t}{R_o} \tag{9}$$

Where : “I” is the coefficient of increase in resistivity, dimensionless;

Rt -resistivity of the rock formation, Ω•m;

Ro - 100% water-bearing formation resistivity, Ω•m.

Through experiments, the following relationship exists between the resistance increase rate “I” and the water saturation (S_W):

$$I = \frac{b}{S_w^n} \tag{10}$$

Where “n”,“b” are regional parameters related to lithology. Therefore, the correct determination of “n”,“b” is the basis for evaluating saturation.

Based on this idea, the relationship between the resistivity increase coefficient and the water saturation is established for the bottom of Chang 4+5 lower oil layer subgroup and the Chang 6 oil layer group. According to the statistical analysis of the resistivity increase coefficient and water saturation of the 110 group of the Chang 4+5 oil layer in the Tang82 and YK areas of the Ganguyi Oilfield, “I” and “Sw” have a linear relationship in the double logarithmic coordinates, the correlation coefficient of the both is 0.84, which accurately marks the relationship between water saturation and resistivity. The relationship is as follows:

$$I = \frac{0.97}{S_w^{1.31}} \tag{11}$$

3.3.3 Determination of formation water resistivity

The conductivity of the rock skeleton is usually poor, and the oil and gas in the pores of the reservoir is almost non-conductive, so the conductivity of the formation depends mainly on the nature of the formation water in the porosity. The resistivity of formation water is related to the level of formation water salinity, ion type and temperature. According to the results of formation water analysis in the reservoir of Ganguyi Oilfield, the formation water resistivity of the area is determined. First, the total salinity is converted into the salinity of the equivalent NaCl solution, the formation water resistivity at the formation temperature is then determined from the temperature of the water sample horizon. (ground temperature gradient is 3o/100m).

The resistivity of the formation water in the YK area of Ganguyi is determined by the analysis of the salinity of the water samples to determine the resistivity at the formation temperature of each well. The resistivity of the formation water is usually 0.12 Ω•m.

3.3.4 Interpretation model of water (oil) saturation

According to the relationship between the above-mentioned formation factors-porosity and resistivity increase coefficient-water saturation, and the formation water resistivity determined by water sample analysis, the water saturation can be calculated by using induction logging and sonic logging curves:

$$Sw = \left(\frac{abRw}{\phi^m Rt}\right)^{1/n} \tag{12}$$

The parameters in the formula are:a = 6.42, b = 0.97, m = 1.04, n = 1.31, R_w = 0.12 Ω • m.

4. Determination and division of effective thickness of oil layer

The effective thickness of the oil layer refers to the thickness of the reservoir that has certain porosity, permeability and oil saturation, which can be produced under current economic and technical conditions and has industrial oil and gas value. Obviously, the effective thickness must have two conditions: first, the oil layer has a certain oil storage capacity, that is, it has a certain degree of porosity and saturation; secondly, it can provide industrial oil flow under the prior art economic conditions, that is, it has certain penetration ability. An oil layer that can be divided into effective thickness does not necessarily have a separate economic exploitation capacity, and as long as its production has a certain contribution to the achievement of the industrial oil flow standard in the whole well, that is, as long as the movable oil flows out, it can be used as an effective thickness. Conversely, in wells that meet industrial oil flow standards, reservoirs that do not contribute to production cannot be classified as effective thickness. Due to the extremely low natural productivity of the Chang 4+5 and the Chang 6 oil layers in the Ganguyi YK area, it is generally necessary to obtain industrial oil flow through fracturing transformation, so this factor must be taken into consideration when dividing the effective thickness.

Table 1 List of effective thickness lower limit of Chang 4+5 and Chang 6 oil layer groups in YK area

Layer	Core analysis				Logging parameters		
	Lithology	Oil level	K ($10^{-3}\mu m^2$)	Φ (%)	AC (us/m)	Rt (Ω.m)	Sw (%)
Chang4+5bottom	Fine sandstone and above	Oil spots and above	≥0.14	≥8.0	≥223	≥35	≤65
Chang 6			≥0.20	≥7.5	≥219	≥35	≤65
Chang 61			≥0.65	≥7.5	≥220	≥35	≤65
Chang 62			≥0.68	≥7.5	≥219	≥35	≤65
Chang 63			≥0.75	≥7.0	≥216	≥35	≤65
Chang 64			≥0.19	≥7.4	≥217	≥27	≤65

According to the above requirements and standards, the determination of the effective thickness lower limit is based on the test oil data, based on the core analysis data, combined with the current mining process, comprehensive research on geological, mud logging, geophysical logging and other data, comprehensive the physical and electrical characteristics of the bottom of Chang 4+5 and Chang 6 reservoirs, the lithology, physical properties, oil content of the oil layer in the Ganguyi YK area and the effective thickness lower limit of logging parameters are shown in Table 1.

The lower limit of the effective thickness of the reservoir determined by this reserve research work is closer to the calculation of the previous reserves of the Ganguyu Oilfield and the adjacent Chang 4+5 and Chang 6 reservoirs, which is in line with the actual geological and production conditions of the reserves calculation in the area.

5. Conclusion

Among the reservoir lithology, physical properties, oil bearing and electrical properties, oiliness is the ultimate goal and core of reservoir evaluation. Lithology are the basis of reservoir evaluation. Physical properties are parameters that represent reservoir performance and oil and gas production capacity. Electricality is the means of research. It is not only the comprehensive performance of the first three, but in turn it is used to determine the first three, which is the main content of our research.

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