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Study On Thin Differential Interpretation Method Of 0.2 m High Resolution Logging Series in Sabei Development Zone

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Abstract. Sabei development zone has entered a stage of development for determining remaining oil distribution of plane scattered, longitudinal mainly concentrated on the thin layer and thick thin poor parts of the reservoir, the existing in DLS logging series layered rate will not form a complete set, and the problem of insufficient depth lead to form a complete set of logging interpretation of water-out reservoirs technology, on the untabulated reservoir and thin poor reservoirs under 0.4 meters can't realize the quantitative explanation, become the bottleneck of poor thin reservoir interpretation in the future. The development of the new series of 0.2m can effectively solve the problem of thin differential zone interpretation by improving the vertical resolution and horizontal detection depth, and establishing the logging interpretation technology matching this technology, so as to meet the need of fine tapping remaining oil in the development stage of extra-high water-cut development in sabei development zone and better guide the dynamic development and adjustment of oilfield.

1. Introduction

Since 2014, on the basis of the DLS logging series, a total of 12 Wells in the 0.2 m high resolution logging series have been measured in the Sabei development zone, including 2 sealed coring Wells (north 2-6-inspection 533 and north 2-312-inspection 054). In this study, the core calibration logging method was adopted to re-calibrate the petroelectric correspondence, establish the interpretation model of porosity, permeability and saturation, and extract the logging response characteristics of water-flooded layer on the logging curve in combination with the development of dynamic production data, and establish the qualitative and quantitative identification standard of water-flooded layer. By applying the 0.2-meter logging interpretation model in the field, the better effect is seen in the actual production of oilfield.

2. Layering Method of Logging Curve

With DLS logging series, currently in focus, in addition to the microspheres microelectrode, acoustic time stratification capacity can reach 0.2 meters, 3 lateral stratification ability in 0.3 meters deep, other logging projects, such as natural potential, natural gamma, density and other major curve hierarchical ability only can reach 0.6 meters, the logging resolution differences between project is large, there are serious mismatch problem. 0.2 meters high resolution logging series is averaging 0.2 meters, the logging projects better matching between sex every curve, the heterogeneity of the reservoir on the log response is more sensitive, studies have shown that in 0.2 meters of logging series directly to use the layered with accessor methods of DLS logging series, will be led to the decrease of the precision of log interpretation model, so you need to 0.2 meters high resolution logging series various logging curve of layered and accessor methods to study.

2.1. Logging Curve Stratification Method

Current core inoue explain water level include strong washing, washing, weak washing and not washed, according to the washing section on the top and bottom in the 0.2 m new series of logging response characteristics, summed up the method of four layers: half of a third point method, root method, the active law, commercial law, including the thickness of the internal development of the poor thin lithology location displayed on the well logging curve as a turning point, using active layered method, its principle is by calculating log curve slope value to identify a turning point, extreme value interval so as to improve on this part of the reservoir water flooded layer interface recognition rate.

The activity function is defined as:

$$E(d) = \int_{d-\frac{width}{2}}^{d+\frac{width}{2}} \left[f(x) - \overline{f(d)}\right]^2 dx$$

where: f(x) -- the amplitude of the curve when the depth is x;f(d) -- the amplitude of the curve when the depth is d;E(d) -- the activity value at depth d;Width - filter window length

2.2. Logging Curve Stratification Principle

h resolution deep lateral 3, micro potential as the layered roof and bottom datum curve, the curve of other layered interface will be subject to benchmark curve layered interface, half range point and a third root layered method used to determine the layered interface, active method and curve of a turning point in the commercial law is used to determine layer and the steps, thickness of layered interpretation under the limit of 0.2 meters, near layer benchmark curve peak return for less than 10% for alloy layer interpretation. The self-potential curve was used as the condition for identifying mudstone points. The three curves of high resolution depth, three lateral curves, micro-potential and microsphere focusing curves reached the lowest limit for dividing the reservoir. The self-potential was more than 2 meters thick, and the self-potential baseline was divided according to the mudstone points. The sand body is thin, stable and distributed over a large area for the thin differential oil layer below 0.4 m, which can be layered as a layer. For the thin interlayer with an effective thickness of 0.5 m H < 2 m, it can be layered according to the changes of deep resistivity curve, lithology and water flooding.

3. Logging Curve Valuation Method

3.1. Research on the Value Method of Logging Curve

There are three commonly used logging curve value methods: morphological value, average area value and geometric weighted average thickness value. Among them, multiple peaks and valleys will appear in the form of logging curve for the oil layer deposited in thin interbeds, and the target layer is susceptible to the influence of surrounding rocks. At this time, the logging curve cannot truly reflect the resistivity value of this layer. Layer in order to minimize the attached to the objective layer, the influence of the geometric thickness weighted average value according to the size of the peak valley value and contribution to the overall thickness size, endowed with different weighting factor, coring well water to wash the statistical results show that this method can significantly improve the thin interbed of sedimentary reservoir reservoir parameter interpretation accuracy.

$$x = \frac{\sum_{i=1}^{i=n} x_i * h_i^m}{\sum_{i=1}^{i=n} h_i^m}$$

Where: m-geometric weighting factor; hi - corresponds to the thickness of the i-layer peak or valley; xi - The value of the peak or valley at the corresponding layer I.

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3.2. Value Principle of Logging Curve

The morphological value of the reference curve, the geometric weighted average value of the thickness of the high-resolution sp curve, the area average value of the high-resolution acoustic wave curve, the geometric weighted average value of the thickness of the high-resolution density and high-resolution gamma ray curve were adopted, and the relative value of the natural layer from the middle to the shale baseline was read from the sp curve.

4. Establishment of Interpretation Model for Thin Differential Logging

4.1. Determination of Standard Layer

The selection principle of this standard layer is: in the whole Sabei Development Zone, the thickness is large, the buried depth is not changed much, the lithology is basically stable, and the response of logging curve is obvious. A black mudstone of 16 ~ 18 meters is developed between the Sa_0 and Sa_1 groups in the Sabei Development Zone. The resistivity curve of R2.5 shows three distinct gentle bulges, and the whole area has a drilling rate of 100, which is a first-grade standard layer. The second protuberance (i.e. Sa 02) is taken as the standard layer and the average value of each curve is selected.

4.2. Standardization of Logging Curves

Select 10 key wells, take Sa 02 as the standard layer value of high resolution sonic time difference and high resolution density curve, and correct the curve.

Table 1. Standard layer correction table

Logging project	Standard layer range value	adjusted value
High resolution acoustic moveout	410~425μs/m	≤410μs/m, adjusted to 410μs/m ≥425μs/m, adjusted to 425μs/m
High resolution density	2.1~2.2g/cm^3	≤2.1g/cm^3, adjusted to 2.1g/cm^3 ≥2.2g/cm^3, adjusted to 2.2g/cm^3

4.3. Establishment of Reservoir Parameter Interpretation Model

In order to accurately describe the five star parameters of reservoir and improve the interpretation accuracy, according to the sedimentary characteristics of strata and the lithology and physical characteristics of reservoir in Sabei Development Zone, the effective thickness and the out-of-table thickness in the interpretation of reservoir physical properties are divided into three types: Saertu, Gaotaizi and Putaohua, and the logging interpretation models are established respectively.

4.3.1. Establishment of Porosity Interpretation Model. According to the principle of logging, sonic moveout can be used to measure the velocity of longitudinal wave, the porosity of the main reaction formation, the volume density of the reaction formation of density logging, so the porosity of core interpretation and the time difference of acoustic wave can also be used to calculate the porosity. The porosity interpretation model was established by correlation analysis of density curve. The porosity calculation method, 345 cores, adopted multivariate regression, correlation coefficient 0.83, statistical average relative error ±5.5, formula: POR=71.093 +0.527 *HAC-28.65* HDEN.

4.3.2. Establishment of Bound Water Interpretation Model. By analyzing the irreducible water saturation and median size, clay content, porosity and so on the relevance of the geological factors, shows that this area related to porosity and irreducible water saturation and sandstone type, has the greatest effect in the median size and porosity, clay content and the wettability of the rock has a certain influence, bound water saturation decreases with increasing of the median size of median size increases with the increase of porosity and. Calculation method of bound water, 296 cores, multiple regression, correlation coefficient 0.91, statistical average relative error ±16.8%, formula:

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$$S_{wi}=EXP(0.526-0.188*POR+0.01318*HRLLD-0.0118*RLLS-2.643*HDEN+0.0165*RMN+2.8273*\log(POR)-0.5194*\log(HRLLD)+0.2668*\log(HRLLS)+7.99*\log(HDEN)-0.5345*\log(RMN)).$$

4.3.3. Interpretation Model of Water Saturation. In the calculation of water saturation, the most popular model is the Archie model, the double formation water resistivity model, the Vicksman-Smith model, the dispersed clay model and so on. By comparing these water saturation interpretation models with those of coring wells, the dispersed clay model, 107 cores and the statistical average absolute error of 9.3% are selected.

$$S_W = \left[\frac{aR_w}{\phi^m}\left(\frac{1}{R_t} - \frac{V_{c1}^2}{R_{c1}}\right)\right]^{\frac{1}{n}}$$

In the formula: Rw- formation water resistivity; Rt- formation resistivity; ϕ -porosity; m- porosity index, n- saturation index; a- saturation coefficient; Vcl- clay content; Rcl- clay resistivity.

After analyzing the parameters of the model, determining whether the resistivity value of formation water can be calculated accurately will directly affect the accuracy of the water saturation interpretation model. The determination of formation water resistivity (called apparent formation water resistivity) and the selection of Rxo, normalized natural potential SPx, which is closely related to the resistivity of the flushing zone mixture, is used to estimate the formation water resistivity Rw, due to the limited accuracy of the Rw estimation. The accuracy of saturation Sw calculation is improved by calibrating the calculation results of different water flooding levels. The Rw, method for estimating the resistivity of formation water is obtained by using the theoretical formula of natural potential and so on. The following R_w estimation method is obtained.

$$SP=SP_{da}+SP_k$$

$$SP_{da}=K_{da}\log(R_{mf}/R_w)$$

$$R_w=R_{mf}\times 10^{-(SP-SPk)/Kda}$$

4.3.4. Establishment of Permeability Interpretation Model. The main influencing factors of permeability are pore radius and porosity, the factors determining porosity are distribution mode, connectivity degree, pore type and burial depth, and different pore structures have great influence on permeability. In particular, the contribution of macropores to permeability is very obvious. The factors determining the pore radius are grain diameter, sorting coefficient, filling mode and content of cemented matter in pores. Under certain geological and sedimentary conditions, the factors that determine permeability are particle size median, porosity, muddy content, bound water, sorting coefficient and so on.

5. Study on the Discriminant Technique of Water Flooding Interpretation in Thin and Differential Layer

At present, in the late stage of oil field development, the reservoir is in full view of water, and it is of great significance to distinguish the water-flooded degree of the reservoir. The conventional series resolution is low, the matching between the curves is not good, and it is difficult to extract the response characteristics to the thin and differential layers. The correspondence between the 0.2m new series curves is very good, which can reflect the difference of physical property and oil content between thin and differential oil layers, which provides favorable geological information for the study of interpretation technology.

5.1. The Changes of Reservoir Lithology and Physical Properties on Water Flooded Layer

5.1.1. Clay Mineral. The experimental data of water flooding show that the content of clay minerals decreases and the composition of clay minerals changes greatly after water flooding. The change is mainly due to the transformation of reservoir by injection fluid. There are two kinds of revamping, one is hydration expansion (water sensitivity of reservoir), the other is migration and accumulation (velocity sensitivity of reservoir). Usually, in the weak water washing area, clay is swelled by the immersion of injected water, and the pore diameter is blocked. In the strong water washing area, the clay is washed by water, the mud content is reduced, and the pore throat is increased.

5.1.2. Change of Reservoir Rock Wettability. A great deal of data have proved that the original wettability of reservoir rocks in Daqing Oilfield belongs to the non-uniform wettability that is partial to oil. When the reservoir is flooded, the wettability of the rocks is not static, but with the increase of the degree of water washing. Transformation from oil to hydrophilic.

5.1.3. Changes in Porosity and Permeability. Laboratory water flooding experiments show that during the process of oil field water injection, different reservoir types show different pore structure changes after long-term injection, such as high porosity, permeability reservoir increases with permeability, and pore radius of rock increases, the pore structure coefficient becomes smaller, but the porosity change is not obvious. When the ratio of air permeability to porosity is small, the reservoir permeability, pore radius, pore structure coefficient and porosity do not change obviously.

5.2. Changes of Logging Curves in Flooded Layer

Deep detection resistivity curve, after reservoir flooding, the nature of the fluid in the formation has changed, the oil in the pores of the rock is displacement by the injected water, the amplitude of resistivity curve of deep detection is obviously reduced, the shape of the curve tends to be more smooth, and the gradient resistivity curve of 2.5 meters may show the feature of raising the maximum value at the bottom when flooding is serious.

The microelectrode curve, in the process of water injection, the character of fluid in the formation changes from oil-bearing to oil-water coexistence or water-cut, which leads to the obvious decrease of the value of microelectrode curve, and the stronger the degree of water flooding, the greater the amplitude of the curve, the more smooth it is.

The natural potential curve, after the development of stratified water injection for a long time, the change of natural potential is mainly in two aspects: (1) the salinity of mixed fluid decreases with the increasing of water cut. The dominant position of diffusion adsorption potential in natural potential is destroyed, which leads to the obvious decrease of diffusion adsorption potential in natural potential curve, the occurrence of mudstone baseline migration, and the deterioration of curve shape. (2) due to the heterogeneity of the reservoir, the pressure difference between the layers increases, which results in the increase of the range of filtration potential and the anomaly of the natural potential.

High resolution acoustic move out curve, because the underground reservoir is developed by water injection for a long time, the mud structure in the pore changes and the mud is washed away resulting in the increase of the porosity, which is reflected in the increase of the acoustic time difference on the acoustic logging curve. Under the condition of excluding borehole influence, the increase of sonic time difference is the characteristic of water flooding.

5.3. Establishment of Criteria for Distinguishing Flooded Layers

Based on the data of 360 layers in 6 newly drilled coring wells in recent years, the relationship between water flooding level, water saturation difference and oil displacement efficiency is analyzed, and the following fine dividing lines are obtained.

Table 2. Subdivision limits of five-level water logging in Sabei development zone

Leval of water logging	saturation difference	oil displacement efficiency
No water logging	$\Delta Sw<12\%$	$\eta<16\%$
Low water logging	$12\%\leq\Delta Sw <25\%$	$16\%<\eta<35\%$
Middle water logging	$25\%\leq\Delta Sw<40\%$	$35\%\leq\eta<50\%$
High water logging	$40\%\leq\Delta Sw<53\%$	$50\%\leq\eta<65\%$
Extra-high water logging	$\Delta Sw\geq53\%$	$\eta>65\%$

6. Analysis of Application Effect

6.1. Evaluation of Application Effect of Reservoir Parameters

The interpretation accuracy of reservoir parameters is tested by using North 2-Ding-2-Geng 38 well wall, the average absolute error of effective layer porosity is 1.4%, the relative error of air permeability calculation is 77.8%, and the average absolute error of outer layer porosity is 1.8%. The relative error of air permeability calculation is 121.5%. The interpretation accuracy of reservoir parameters is verified by using Bei2-6-Jian 533 closed core well. The mean absolute error of irreducible water saturation is ±6.4 % and the mean absolute error of water saturation is ±9.3%. Can meet the production well interpretation needs.

6.2. Evaluation of Interpretation Methods for Water Logging

The interpretation conclusion of waterflooded zone by using Bei2-6-Jian533 closed core well is that the effective thickness is ≥ 1m, the interpretation coincidence is 87.6%, the effective thickness is < 1m, and the interpretation coincidence is 72%. Out-of-sheet thickness interpretation coincidence rate is 67%, can meet the production well interpretation needs.

7. Conclusion

In this paper, four layering methods and three value methods of 0.2m logging series are established by using closed coring wells, and water flooding in different parts of oil layers is described in detail.

The logging interpretation model of reservoir parameters is established for different reservoir groups by using core calibration logging method. By comparing with coring wells, the average absolute error of porosity and the relative error of air permeability are 1.4% and 77.8%, respectively. The average absolute error of porosity is 1.8%, the relative error of air permeability is 121.5%, the mean absolute error of irreducible water saturation is 6.4%, the mean absolute error of water saturation is 9.3%. Can meet the production well interpretation needs.

In this paper, a method is established to distinguish the water flooding between the thin and differential layers and the off-surface reservoirs in the high resolution logging series of 0.2 m, which fills up the blank in the interpretation of the off-table reservoirs and forms a new set of interpretation techniques for the 0.2 m series.

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