Analysis of Reservoir Four-Properties Relationship and Reservoir Fluid Identification in Daqing X Block

Bailong Wan

ABSTRACT

The Fuyu oil layer in Daqing area belongs to the low-porosity and low-permeability reservoir, which is characterized by complex lithology, fast phase transition and thin interbred-sandstone. Taking the Fuyu oil layer in Daqing X area as an example, this paper comprehensively applies the drilling, logging and oil testing data, and through the geologic statistics, data fitting and pattern method, and so on, the four-sex relationship of the reservoir is clarified. The reservoir physical property interpretation model and reservoir fluid identification standard are established to provide strong technical support for the remaining oil potential in the study area.

KEYWORDS

Four-Properties Relationship, Reservoir Boundary, Logging Interpretation Model, Oil-Water Layer.

INTRODUCTION

The Daqing X block is located on the Daqing Changyu in the central depression of the Songliao Basin, which is the Qijia-Gulong sag in the west and the Sanzhao sag in the east. During the sedimentary period of the Fuyu oil layer, its tectonic form is a large south-northwest direction anticline, which is divided into two wings, the west wings is a steep slope zone, and the east is a gentle slope zone. The work area in this study is 83.8km², and there are 23 evaluation wells.

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With the deepening of exploration and development, Daqing Oilfield has entered the middle and late stages of development. High water cut, strong water out and low harvesting degree are common problems [1]. The second interpretation of logging is an important part of this period. In recent years, many domestic scholars [2~14] conducted the lithology identification and oil-water identification for different lithologic reservoirs by various methods, and various logging interpretation models and reservoir fluid identification standards were established which has promoted the development of logging interpretation technology. Taking the X block as an example, this paper comprehensively applies logging data, core analysis data, well testing and production test data and mining data, and establish the well logging interpretation model and oil-water Identification Standards suitable for this area.

ANALYSIS OF RESERVOIT FOUR-PROPERTIES RELATIONSHIP

The “four-properties” relationship refers to the interrelationship between reservoir lithology, physical properties, hydrocarbon-bearig properties, and electrical properties. The lithology of the "four-properties" is the foundation, the physical property is the key, the electrical is the means, and the oil and gas is the core.

(1) Relationship between physical properties and lithology

By core analysis data analysis, we can know the effective porosity of most sandstone and fine sandstone reservoirs is mainly distributed between 6.0%~18.0%, with an average of 11.8%. The air permeability is mainly distributed at 0.05~5mD, whose average is 0.79mD (Figure1, Figure 2).

![Figure 1. Histogram of effective porosity distribution.](image)

![Figure 2. Histogram of air permeability distribution.](image)
The reservoir lithology has great influence on physical properties. When the lithology is calcium-bearing siltstone, argillaceous siltstone, the reservoir has low porosity and permeability value. The porosity is more than 10%, the permeability is less than 0.2mD, and the porosity has little correlation with the permeability. However, when the lithology is fine sandstone, the core sample points with porosity greater than 10% increase significantly, and the permeability values increase correspondingly, and they have better co-directional trends (Figure 3).

(2) Relationship between physical properties and oiliness

According to core physical and oily data, the porosity-permeability intersection map was established. It can be seen from Figure 4 that there is a good positive correlation between the oiliness and physical properties.

(3) Relationship between lithology and electrical properties

From the comparison of logging curve and lithology, it can be seen that the log response characteristics of mudstone formations show high GR, low RT and SP near the baseline; the log response characteristics of sandstone layer show low GR, high RT and SP Curve negative-abnormality.

(4) Relationship between physical properties and electrical properties

From the comparative analysis of physical properties and electrical properties, it is known that as the physical properties of sandstone reservoirs become better, the AC curve is larger, the amplitude difference between the micro-electrode curves tends to increase, and SP also shows a significant negative-abnormality. With the deterioration of physical properties, the above various curves show opposite trends.

(5) Relationship between electrical properties and oiliness

The electrical properties of the reservoirs in the study area are well correlated with the hydrocarbon-bearing properties. The oil test results show that good oiliness layers have the characteristics of low GR, low DEN, high AC, medium-high SP and high RT.
RESERVOIR INTERPRETATION STANDARDS

In the fluid identification of sandstone reservoirs, the calculation of reservoir parameters is an important part. The main reservoir parameters are porosity, permeability and hydrocarbon saturation. Therefore, it is especially important to establish a reasonable interpretation model.

**Interpretation Model Parameter Analysis**

(1) Porosity model parameters

The porosity is mainly reflected by AC, DEN or CNL curve data. In this study, the Den-Por model was established by density analysis and core analysis porosity regression analysis whose correlation coefficient is above 0.99 (Figure5) which indicates a good correspondence between DEN and porosity.

(2) Permeability model parameters

Permeability is usually affected by many factors such as rock pore structure, pore size, shale content and distribution. The Por-Perm interpretation model was established by the correlation regression analysis method between permeability (Perm) and porosity (Por), whose correlation coefficient is above 0.8983, which shows a good correspondence with porosity and permeability (Figure6).

![Figure 5. DEN-φCross plot.](image1)

![Figure 6. Φ-logkCross plot.](image2)
(3) Saturation model parameters

In this study, the Archie formula is selected as an effective saturation interpretation model, which is mainly to determine the water saturation $S_w$ by the combination of porosity and formation resistivity, and then calculate the oil saturation. (Where the regional empirical parameter $a = b = 1, m = n = 2; Rw \approx 0.9$)

$$S_w = \sqrt[3]{a b R_w \phi^m}$$

$$S_o = 1 - S_w

(1)

Reservoir Fluid Criteria

Based on the above data analysis and logging interpretation model, DEN-RT cross plot, AC-RT cross plot and POR-RT cross plot (Figure 7 ~ Figure 8) were established to determine reservoir fluid criteria (table 1).

![Figure 7. RD-POR Cross plot.](image1)

![Figure 8. RD-AC Cross plot.](image2)

<table>
<thead>
<tr>
<th>Layer section</th>
<th>SP</th>
<th>DEN</th>
<th>AC</th>
<th>RD</th>
<th>POR</th>
<th>SW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-reservoir</td>
<td>Baseline value</td>
<td>&gt;2.55</td>
<td>&lt;220</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry layer</td>
<td>Slight negative anomaly</td>
<td>[2.40, 2.55]</td>
<td>[220, 255]</td>
<td>Difference by the compact degree</td>
<td>≤9</td>
<td>100</td>
</tr>
<tr>
<td>Oil layer</td>
<td>obviously negative anomaly</td>
<td>≤2.3</td>
<td>≥255</td>
<td>≥30</td>
<td>≥12</td>
<td>&lt;55</td>
</tr>
<tr>
<td>Reservoir Poor-reservoir</td>
<td>low amplitude negative anomaly</td>
<td>(2.32, 2.45)</td>
<td>(250, 255)</td>
<td>Difference by the compact degree</td>
<td>[9,12]</td>
<td>[55,85]</td>
</tr>
<tr>
<td>Oil-water layer</td>
<td>obviously negative anomaly</td>
<td>≤2.3</td>
<td>≥255</td>
<td>25</td>
<td>≥12</td>
<td>[55,85]</td>
</tr>
<tr>
<td>Water layer</td>
<td>obviously negative anomaly</td>
<td>≤2.3</td>
<td>≥255</td>
<td>&lt;20</td>
<td>≥12</td>
<td>&gt;85</td>
</tr>
</tbody>
</table>
CONCLUSIONS

Through the above analysis and research, the understanding and conclusions are as follows:

(1) There is a good correspondence between lithology, electrical properties, physical properties and oil-bearing properties of effective sandstone reservoirs in the study area. Among them, fine sandstone has the best physical and oil-bearing properties.

(2) Based on the analysis of the four-properties relationship, a log interpretation model of porosity, permeability and water saturation is established, whose accuracy of the fitting is greater than 90%.

(3) Established the reservoir fluid identification standard and determined the lower limit of electrical and physical properties of the Fuyu oil reservoir.

REFERENCES
