Study on the relationship between internal heterogeneity of single sand body and remaining oil distribution in Pubei Oil Field

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Abstract. According to the distribution characteristics of remaining oil in narrow thin sandstone reservoir of Pubei oilfield, the influence parameters such as sedimentary microfacies, structural morphology, effective thickness, rhythm, superposition relation, permeability and variation coefficient are selected, the relationship between Heterogeneous Composite Index and remaining oil distribution is studied by using analytic hierarchy process (AHP). The results show that the area where the heterogeneity index is larger is the main enrichment area of remaining oil. Based on the characteristics of injection and production of single sand body, the cause of remaining oil and the distribution of remaining oil potential, 6 sets of typical well groups and 19 kinds of single sand body injection and production potential countermeasures are optimized to provide a strong basis for fine injection and production of single sand body.

Key words: Single Sand Body; Heterogeneity; Comprehensive Index; Remaining Oil.

1. Study on the principle of Heterogeneous Composite Index

The basic idea of quantitatively characterizing reservoir heterogeneity with heterogeneous composite index is to use modulus and mathematics method, through the Modulus and operation of various parameters, to obtain a heterogeneous composite index to quantitatively characterize the strength or weakness of heterogeneity, the key of comprehensive index calculation is the establishment of single factor evaluation Matrix and the determination of weight coefficient [1]. The heterogeneity comprehensive index is obtained by using the eight parameters of reservoir sand body thickness, rhythm, sedimentary microfacies, lithologic structure, permeability, superimposed relation, interlayer characteristics and coefficient of variation [2]. In the actual calculation, because the unit of eight kinds of parameters is not uniform and the size is very different, first of all, the eight parameters are normalized, that is, the unified calibration is between 0 ~ 1. The Heterogeneous Composite Index can be obtained by averaging the weighted values of each parameter at each well point. In the process of comprehensive evaluation of reservoir heterogeneity, the weights of parameters are determined by analytic hierarchy process [3]. Firstly, the target layer structure is established, which includes 8 indexes such as net variation coefficient, rhythm characteristic, permeability, interlayer characteristic, sandstone thickness, superimposed relation, sedimentary microfacies and reservoir structure. The Judgment Matrix is constructed by comparing the indexes according to the scaling principle [4].
For Formula (1), its equivalent matrix can be obtained by the square root method, and the weight of each factor can be obtained by the square root method according to the equivalent Matrix, coefficient of variation, prosody characteristics permeability, intercalation feature, sandstone thickness, superimposed relation, sedimentary microfacies and reservoir structure are 0.37, 0.236, 0.155, 0.097, 0.061, 0.041, 0.024 and 0.015.

\[
P = \begin{bmatrix}
r_{11} & r_{12} & r_{13} & r_{14} & r_{15} & r_{16} & r_{17} & r_{18} \\
r_{21} & r_{22} & r_{23} & r_{24} & r_{25} & r_{26} & r_{27} & r_{28} \\
r_{31} & r_{32} & r_{33} & r_{34} & r_{35} & r_{36} & r_{37} & r_{38} \\
r_{41} & r_{42} & r_{43} & r_{44} & r_{45} & r_{46} & r_{47} & r_{48} \\
r_{51} & r_{52} & r_{53} & r_{54} & r_{55} & r_{56} & r_{57} & r_{58} \\
r_{61} & r_{62} & r_{63} & r_{64} & r_{65} & r_{66} & r_{67} & r_{68} \\
r_{71} & r_{72} & r_{73} & r_{74} & r_{75} & r_{76} & r_{77} & r_{78} \\
r_{81} & r_{82} & r_{83} & r_{84} & r_{85} & r_{86} & r_{87} & r_{88}
\end{bmatrix}
= \begin{bmatrix}
1 & 1 & 1 & 1 \\
3 & 3 & 3 & 3 \\
4 & 4 & 4 & 4 \\
5 & 5 & 5 & 5 \\
6 & 6 & 6 & 6 \\
7 & 7 & 7 & 7 \\
8 & 8 & 8 & 8 \\
9 & 9 & 9 & 9
\end{bmatrix}
(1)

2. Relationship Between Heterogeneous Composite Index and remaining oil distribution

In Pubei Oilfield, I single sand body is selected, the heterogeneous comprehensive index of every well point of every structural unit of I single sand body is calculated according to the calculation principle, and the heterogeneous comprehensive index is superimposed on the remaining oil saturation diagram of every structural unit, to form an overlay (Figure 1).

![Superposition diagram of heterogeneous comprehensive index and residual oil saturation of single sand body structural unit](image)

It can be seen from the superposition diagram that the larger the heterogeneous composite index of the oil well, the larger the remaining oil saturation value, so the larger the heterogeneous composite index of the oil well is the area where the remaining oil is mainly enriched, although the remaining oil saturation in the thin sand layer between the underwater distributary channels is also high, its geological reserves and remaining recoverable reserves account for a small proportion [5].

3. Study on tapping potential of remaining oil

3.1. Tapping the potential of remaining oil in single sand body

According to the results of numerical simulation, the cumulative injection-production ratio and recovery degree of single sand body are counted [6]. The ratio of 1.3 is divided into high injection-production ratio and low injection-production ratio The average recovery degree of single sand body is 29.1%, which is divided into high recovery factor and low recovery factor [7]. Based on the analysis of scatter diagram of Cumulative injection-production ratio and recovery degree, the cumulative injection-production ratio and recovery degree of single sand body can be divided into four cases: first, Low injection-production, cumulative injection-production ratio \( \leq 1.3 \), stage recovery ratio \( \leq \)
29.1% ; second, high injection and low production, Cumulative injection production ratio > 1.3, stage recovery ratio ≤ 29.1% ; third, low injection-production, Cumulative injection production ratio ≤ 1.3, stage recovery ratio > 29.1% ; fourth, high injection and high production, Cumulative injection production ratio > 1.3, stage recovery ratio > 29.1% . (Figure 2).

**Figure 2.** Scatter plot of Cumulative injection-production ratio and recovery degree of single sand body

According to the distribution of remaining oil in single sand body, six typical well groups are selected according to the characteristics of injection and production, the origin of remaining oil and the potential position of remaining oil (Figure 3).

**Figure 3.** Typical potential well group for remaining oil exploration of single sand body

3.2. **Study on injection-production model of single sand body**

According to the distribution characteristics of each single sand body in Pubei, the injection-production model of single sand body is determined by combining the superimposed relation, prosody characteristics and the development of interbed[8]. According to the potential distribution of potential sand bodies, the distribution of remaining oil in potential sand bodies and the characteristics of
remaining oil in potential sand bodies should be taken different optimization measures. According to the different potential positions of different types of single sand bodies, 19 kinds of single sand bodies are put forward for potential tapping by injection and production [9].

There are 9 kinds of potential-tapping measures in the river course superimposition, including 3 kinds of potential-tapping measures in the lump-like superimposition, 4 kinds of potential-tapping measures in the crisscross superimposition and 2 kinds of potential-tapping measures in the interlaced mudstone interval [10].

There are 5 kinds of injection-mining potential countermeasures in the single sand body of branching channel, among which there are 3 kinds of injection-mining potential countermeasures at the entrance of branch channel, 1 kind of injection-mining potential countermeasures at the narrow channel and 1 kind of injection-mining potential countermeasures at the variation of channel.

There are 4 kinds of main body and main body variation parts, and 1 kind of sheet thin difference parts.

4. Conclusion
(I) The concept of macroscopic Heterogeneous Composite Index is introduced, which considers the sedimentary microfacies, structural morphology, effective thickness, rhythm, superposition relation, permeability and coefficient of variation, and eight parameters such as reservoir sand body thickness, rhythm feature, sedimentary microfacies, structure, permeability, superimposed relation, interlayer characteristics and coefficient of variation are used to reflect and obtain heterogeneous comprehensive index.

(II) By calculating the heterogeneity comprehensive index of single sand body, the comprehensive evaluation result of the Heterogeneity of single sand body is given, and the relationship between the heterogeneity comprehensive index and the distribution of remaining oil is pointed out, the results show that the remaining oil is mainly enriched in the part with large heterogeneous comprehensive index.

(III) According to the distribution of remaining oil in single sand body, considering with the injection production characteristics, the origin of remaining oil and the potential position of remaining oil, a typical well group is selected. The injection-production model of single sand body is determined according to the distribution characteristics of single sand body, the superposition relation, prosody characteristics and the development of interbed. According to the potential distribution of potential sand bodies, the distribution of remaining oil in potential sand bodies and the characteristics of remaining oil in potential sand bodies, different optimization measures are adopted, it is helpful to improve the development effect in the later period of high water cut.

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