Research on Control Factors of Remaining Oil Distribution

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Abstract. Aiming at the characteristics of the overall dispersion and local enrichment of residual oil in the high water cut period of the continental water flooding reservoir, the Fuyang oil layer in the V block of Xinli Oilfield is taken as the research object, the remaining oil enrichment law is the main line, and the comprehensive application of earthquake, logging, based on drilling, logging, closed coring, testing and production dynamic data, we conducted research on the effects of various geological factors and development factors on the remaining oil distribution. Preliminary research indicates that the remaining recoverable reserves with a certain scale are mainly controlled by the heterogeneity of reservoirs such as low-order faults, interlayers and physical properties, and the differences in hydrodynamic conditions.

1. Introduction
The traditional concept is that the remaining oil distribution in the ultra-high water-bearing reservoir is highly scattered. The fine research and practice of Xinli Oilfield in recent years prove that the distribution characteristics of remaining oil in the extra high water cut period are overall dispersion and local concentration, and there are still many remaining oil enrichment areas. The remaining oil with a high degree of dispersion can only tap the potential through enhanced water injection and tertiary oil recovery. The locally concentrated residual oil enrichment area can be tapped by conventional water injection methods, which is more economical and feasible. Therefore, in the analysis of the remaining oil formation control factors, we should focus on the factors that lead to the relative concentration and concentration of the remaining oil.

2. Geological factors
2.1. Sedimentary microfacies
It is the main factor controlling the horizontal movement of oil and water, and also the main factor controlling the distribution of remaining oil. Studies have shown that in large-scale sandstone-deposited reservoirs, the remaining oil is mainly distributed in areas where sand bodies are partially destroyed. In the subaqueous distributary channel sedimentary reservoir, the remaining oil is mainly distributed in the thin layer sand in the sandstone layer between the river channels, the edge of the river body partially damaged by the physical body of the sand body, and the small lenticular sand body. In the process of water injection development, under the same conditions, the water absorption
capacity of the river micro-phase is relatively strong, while the water absorption capacity of the leading edge sand is poor. In addition, the flow velocity of water in different phase bands is different, and the relative interface tends to have a blocking effect on the water cross-phase flow. The sedimentary microfacies affect the remaining oil distribution in the following aspects: sedimentary facies control the movement law of the injected water; sedimentary facies determine the type of water washing; sedimentary facies control the flooding law.

2.2. Sedimentary rhythm
The sedimentary rhythm mainly controls the distribution of the remaining oil in the vertical direction. For example, the remaining oil enrichment is formed at the top of the rhythm oil layer, and the remaining oil enrichment is formed at the bottom of the anti-rhythm oil layer. The composite rhythm oil layer has multiple permeability segments in the longitudinal direction, and the relatively low permeability. The rate of water washing is weak, forming the remaining oil enrichment.

2.3. Difference in permeability in sedimentary units
It controls the vertical and horizontal distribution of the remaining oil in the reservoir. Injected water is driven by a high permeability layer. It is difficult for the injected water to reach the low-permeability area, resulting in the enrichment of residual oil in the low-permeability area.

2.4. Interlayer distribution
The distribution of the interlayer controls the distribution within the remaining reservoir. The interlayer has different degrees of influence and control on the oil-water seepage of the oil layer, and its influence degree is related to the thickness, extension scale and position of the interlayer.

The research indicates that the sedimentary rhythm, interlayer, monolithic rhythm and sedimentary structure, sedimentary facies change in the reservoir lead to the change of the vertical reservoir properties and the development characteristics of the interlayer. This is an important factor in controlling the vertical wave of water injection into the sand layer and the formation and distribution of residual oil in the layer.

3. Development factors
The development factor is the external control factor of the remaining oil distribution, ie the external cause. The most important factor in the development factor is the degree of perfection of the injection and production system and the relationship with the geological factors. For oil layers with unstable sand body distribution or small scale, the existing well pattern control is low, resulting in imperfect injection and production, thus forming residual oil. The injection-production relationship is also one of the main factors affecting the distribution of remaining oil. The oil layer in the mainstream line has a high degree of flooding, while the non-mainstream oil layer has a relatively low level of flooding.

In summary, in the high water-bearing development stage of terrestrial heterogeneous water flooding reservoirs, the remaining oil-rich areas with a certain scale are mainly controlled by the geological factors such as faults, interlayers and physical properties, as well as the development factors such as injection and mining conditions. Revealing the mechanism of residual oil enrichment is to clarify the control effect of these four factors on the remaining oil enrichment zone. The reservoir physical property differences and development factors are often transformed into reservoir superior seepage channels in the later stage of development. Therefore, the focus of residual oil enrichment theory is to explore the control of residual oil distribution by geological factors. For the river-delta reservoir, the main factors controlling the distribution and enrichment of the remaining oil are geological factors such as sedimentary facies, sedimentary rhythms and interlayers.

4. Main types and distribution patterns of remaining oil

4.1 Interlayer type residual oil
4.1.1. Microphase differential residual oil in the layer
The main sedimentary microfacies in the area include underwater (water) diversion channels, underwater (onshore) natural dikes, estuary sand dams, crevasse fans, side beaches, abandoned rivers, flooded thin sands between rivers, flood plains, River floodplain, bay, etc. The difference in physical properties between various microphases and the influence of heterogeneity within the layer lead to differences in the development effect of water flooding, which affects the difference in the distribution of remaining oil. Specifically, for each micro-phase, the underwater (water) diversion channel, the side beach, the estuary sand dam, and the micro-phase of the ventilating fan are better in physical properties, the seepage capacity is stronger, the water injection range is wider, and the oil saturation decreases rapidly. Therefore, it is not a favorable zone for the remaining oil enrichment. The micro-phases of underwater (onshore) natural dikes, flooded thin sands and abandoned rivers are relatively poor, generally in areas where water injection is not possible, so the remaining oil will be relatively rich. Micro-phases such as floodplains, floodplains, and bays are extremely poor in physical properties, and the original oil saturation is very low, so the remaining oil is not enriched.

4.1.2. Microphase internal differential residual oil
Due to the influence of reservoir heterogeneity, the seepage capacity of various parts inside the microphase will also be different. In the process of water injection development, the water body will always move along a place with good physical properties and strong seepage capacity, while some water bodies with poor physical properties and weak seepage ability will not reach, which will cause the difference of residual oil distribution inside the microphase. In the case of underwater distributary channel microfacies, the physical properties of the central part of the river are better than those of the river. Therefore, after the water injection is developed, the central part of the river will be flooded. The remaining oil is sporadically distributed in the edge of the river where the physical properties are poor and the water cannot reach the water.

4.2 Interlayer type residual oil

4.2.1. Residual oil in the interlayer
An interlayer is an interlayer between two single layers of sand within the same small layer. It is an important factor hindering the interconnection between sand bodies in the layer. In general, the more developed the interlayer, the more concentrated the remaining oil will be.

4.2.2. Yangdachengzi meandering river side accumulation type residual oil
The Yangdachengzi oil layer is the deposition of the meandering river facies, and the sand body is mainly formed by the side product. The developing interlayer is also called the lateral layer. The lateral accumulation interlayer controls the remaining oil mainly in the vertical direction. The one side of the side product divided by the side layer is connected to the bottom, and the upper part is not connected. Therefore, after the water injection is developed, the remaining oil is mostly concentrated in the upper portion.

4.3 Rhythm type remaining oil
This is the distribution pattern of the prosody-type residual oil we studied without considering the influence of the interlayer factor.

4.3.1. Positive Prosody Upper Enrichment Mode
The positive rhythm oil layer is getting worse from bottom to top, and the seepage ability is getting weaker. Therefore, in the water injection development process, the injected water generally drives the oil along the bottom, and the upper oil layer displacement is difficult, thereby forming an enriched area of the remaining oil.
4.3.2. Anti-rhythm lower enrichment mode
The anti-rhythm oil layer is getting better from bottom to top. Therefore, in the process of water injection development, the injected water first drives the oil along the upper part of the physical property, while the lower oil is difficult to drive, thus forming an enriched area of the remaining oil.

5. Remaining oil level distribution law and prediction

5.1. Prosody Control
From the plan of the prosody type and the plane distribution of the remaining oil, it can be seen that on the plane, the range of the prosody type controls the plane distribution of the remaining oil, and the remaining oil content is more in the plane distribution of the positive rhythm (figure 1).

5.2. Microphase control type
It can be seen from the superposition of sedimentary microfacies and permeability that the physical properties at the edge of the channel are poor and the seepage capacity is weak, resulting in a low value of permeability at the edge of the channel. An enriched area of remaining oil was formed in the middle and late stages of development (figure 2).

![Figure 1. Prosody-controlled residual oil](image-url)
5.3 **Mezzanine control type**

It can be seen from the superposition of permeability and interlayer frequency and saturation that the permeability value will be relatively reduced where the interlayer frequency is large, resulting in local enrichment of the remaining oil in the region. (figure 3)
6. Conclusion
Through the above research, we have summarized a set of remaining oil distribution patterns and their main control factors, namely the residual type of residual oil, the micro-phase difference type residual oil, the prosody type residual oil, and their combination. At the same time, the influence of various factors on the remaining oil was deeply analyzed, and the distribution law and influencing factors of the remaining oil in the plane and longitudinal direction were studied, which provided a basis for the preparation of the later fine water injection development plan.

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References
[1] Chuanling Lei, Quanfeng Li, etc. Characterization of Internal Structure and Residual Oil Distribution of Sandy River Delta [J]. Mud Logging Engineering, 2019, 2(3): 122～127.
[2] Xiaoxia Xin, Yonghe Liu, etc. Fluorine facies reservoir configuration and remaining oil distribution in Yangzhuang Oilfield [J]. Mud Logging Engineering, 2018, 5(3): 101～106.
[3] Bo Yang, Zhanli Ren, etc. Analysis on Main Control Factors of Remaining Oil Distribution in Chang 4+5 Section of YanChang Formation in Zhidanzheng 359 Well Area [J]. Unconventional Oil & Gas, 2017, 6(5): 76～82
[4] Haidong Li, Daojie Liu, etc. Study on Distribution Law of Remaining Oil in Extra High Water-cut Period of Complex Small Fault Block Reservoir in High and Light Southern Area [J]. Petroleum Geology and Engineering, 2014, 6(4): 74～78
[5] Liang Zhang, Bo Zhang, etc. Study on Distribution Law of Remaining Oil in Horizontal Wells of Layered Edge Water Reservoirs [J]. Journal of Yangtze University (Natural Science Edition), 2014, 49(16): 74～79.
[6] Congjun Feng, Zhidong Bao, etc. Residual oil prediction based on single factor analysis and multi-factor coupling in Fuyu Oilfield [J]. Acta Petrolei Sinica, 2012, 15(3): 465～471.