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The Rapid Quantitative Description of the Remaining Oil

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Abstract

At the late development stage of an oilfield, the distribution and potential evaluation of remaining oil is the key to comprehensive adjustment. Only if the location and quantity of the remaining oil is clear, can the targeted adjustment measures be made. Therefore, the quantitative description of remaining oil has become a significant issue to be solved in the middle-late period of oilfield development. In this paper, based on the concept of remaining oil, a new calculation principle of remaining geological reserves is determined - the difference between geological reserves and the cumulative oil production. The quantitative description of remaining geological reserves is refined into the single sand body. Moreover, based on the development condition of the study area, the remaining geological reserves distribution is described in phases. The new method is practically applied in a study area, of which the result is compared with the numerical simulation, and the precision is high. This method has good accuracy, can quickly quantitatively describe remaining oil distribution, and also has high practical value.

Key words: Geological reserves; Remaining geological reserves; Single sand body; Infilling adjustment

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INTRODUCTION

At present, most of the major oilfields in China have entered into the high water-cut period. The water percentage is increasing continuously, the output has obvious digression trend, and the distribution of subsurface fluid is more and more complex. Consequently, the oil development becomes more and more difficult. Therefore, it's important to accurately grasp the distribution, potential and producing condition of remaining oil. Moreover, it has guiding significance for the old oilfield to adjust the development plan, and make measures of excavating remaining oil potential. As reservoir description has been developed from macroscopic to microcosmic, from qualitative to quantitative and from description to forecast, the research on remaining oil began to transform the comprehensive qualitative explanation which is based on geological and well logging method into the quantitative forecast based on fine numerical simulation, logging interpretation of water-out reservoirs and the parameter calculation of reservoir engineering[1-4].

Numerical reservoir simulation is an important way to massively quantitatively describe remaining oil. According to the numerical simulation, we can calculate the indicators of the different small layers such as remaining oil saturation, movable oil saturation, remaining reserves abundance recoverable remaining reserves abundance and recovery percent of reserves. However, the numerical simulation is mainly finished on the workstation, the data files which need to establish is more complex, and the workload is huge. Therefore, the numerical simulation method is often required for a long time, which is unable to satisfy the emergency requirement to formulate adjustment plan. Aiming at these problems above, a simple and quick method is presented to quantitative forecast remaining oil. It is used as practical application in the experimental area of Xiyuanerqu, and checked by the dynamic data, which find out that the result is consistent with the field data[5].

1. FUNDAMENTAL

The remaining oil refers to the oil and gas in the developed reservoir (or oil layer) which has not yet produced. It includes both the remaining recoverable reserves and unrecoverable reserves (quite a part of these reserves will be the main goal in the research of enhancing oil recovery)[6]. Its essence is the oil and gas which is left in layers after the oilfield development. Based on the essence of the remaining oil, it can be concluded that remaining geological reserves are equal to the difference between geological reserves and the cumulative oil production. This article is based on this idea to quantitatively study remaining oil distribution.

First of all, use volume method to calculate geological reserves. Reserve coefficient which is gained from coring well data is adopted as a parameter and triangulation network method is used to calculate the oil-bearing area which single well controlled. Based on all this, geological reserves of single sand bodies in each well is obtained.

$$N = A_o \cdot H \cdot \phi \cdot S_o \cdot \rho_o / B_{oi} = A_o \cdot H \cdot \omega.$$

N—geological reserves, 10^4 t;
S_o—oil saturation, decimal;
A_o—oil-bearing area, km^2;
ρ_o—ground oil density, t/m^3;
H—effective thickness, m;
B_{oi}—crude oil volume factor, dimensionless;
ϕ—effective porosity, decimal;
ω—reserve coefficient, 10^4 t/(km^2·m).

Then, according to the different stages of oilfield development, calculate cumulative oil production step by step. However, as the obtained output data includes the whole oil production of single well, cumulative oil production is split by formation coefficient, when the calculation of single sand body cumulative oil production of each well needs formation coefficient to split of oil production.

2. APPLICATION EXAMPLE

2.1 General Geology of the Experimental Area of Xiyuanerqu

Experimental area of Xiyuanerqu locates in the west of Sazhong development area, was put into development in 1960. During more than 50 years' oilfield development, it has experienced the basic well pattern development, infilling adjustment development, and polymer flooding development, which make the well density in experimental area gradually increase. At present, the oilfield development is faced with high water cut, high recovery degree, and high decline rates situation. Now, the general water cut in the oil field is more than 90%.

The oilfield development in experimental area of Xiyuanerqu has experienced three stages, including basic well pattern, infilling adjustment, and polymer flooding. The well pattern in study area has different development time. According to the development situation in study area, calculate and analyze single well geological reserves, remaining geological reserves in infilling adjustment stage, and remaining geological reserves before and after polymer flooding, combined with interpretation of water flooded layer. Then, determine enriched area of remaining oil[10].

2.1.1 Remaining Geological Reserves in Infilling Adjustment Stage

According to the developing history of the study area, the wells dug in the basic well pattern stage, have already lost part of reserves which is extracted, when the oilfield stepped into infilling adjustment stage. So the first mission is to calculate remaining geological reserves right before infilling adjustment stage.

First of all, calculate the recovery percent of basic well pattern, right before infilling adjustment. Divide the difference between initial oil saturation and current oil saturation by initial oil saturation, and then recovery percent is obtained.

$$R = \frac{S_{oi} - S_{os}}{S_{oi}} \times 100\% .$$

R —recovery percent, %,
S_{oi}—initial oil saturation, %,
S_{os}—current oil saturation, %.

Using recovery percent, the cumulative recovery volume of the wells dug in basic well pattern stage is easily to get. Subtract the cumulative recovery volume from geological reserves, and we can get remaining geological reserves in infilling adjustment stage.

2.1.2 Remaining Geological Reserves Before Polymer Flooding

Remaining geological reserves before polymer flooding = Remaining geological reserves in infilling adjustment stage − Cumulative oil production

According to the formula above, getting the remaining geological reserves before polymer injection should firstly calculate the single well cumulative oil production before the polymer injection. During the calculation, cumulative oil production of the whole well is split by formation coefficient to get cumulative oil production of each single sand body. It needs to subtract cumulative oil production of each single sand body from remaining geological reserves in infilling adjustment stage, to get remaining geological reserves of each single sand body before polymer flooding.

2.1.3 Remaining Geological Reserves After Polymer Flooding

According to the calculation method of remaining geological reserves before polymer flooding, by the way of analogy, it's easy to get remaining geological reserves after polymer flooding.

Remaining geological reserves after polymer flooding= Remaining geological reserves before polymer flooding－Cumulative oil production in polymer flooding stage

Using the method above, after calculation it's easy to get remaining geological reserves after polymer flooding of 12 wells in study area (Figure 1). From the Figure 1, it's obvious that remaining geological reserves are higher in the wells of CD6-P3, C6-P3, C6-P1, CD7-P3, C7-P3, and ZD7-CZ1. According to the calculation results, it can get single well contour map of remaining geological reserves after polymer flooding. Figure 2 is contour map of cumulative remaining geological reserves distribution in PⅠ group 1 to 4 layers.

Compared single well geological reserves, remaining geological reserves in infilling adjustment stage, remaining geological reserves before polymer flooding, and remaining geological reserves after polymer flooding (Figure 3), it's obvious that the effect of polymer flooding is better in the wells of C5-P1, C6-P1, C6-P3, C6-P5, C7-P3, CD7-P1, CD7-SP5, CD6-P1 and CD7-P3, while the effect of polymer flooding is worse in the wells of ZD7-CZ1, C8-P5 and CD7-SP5.

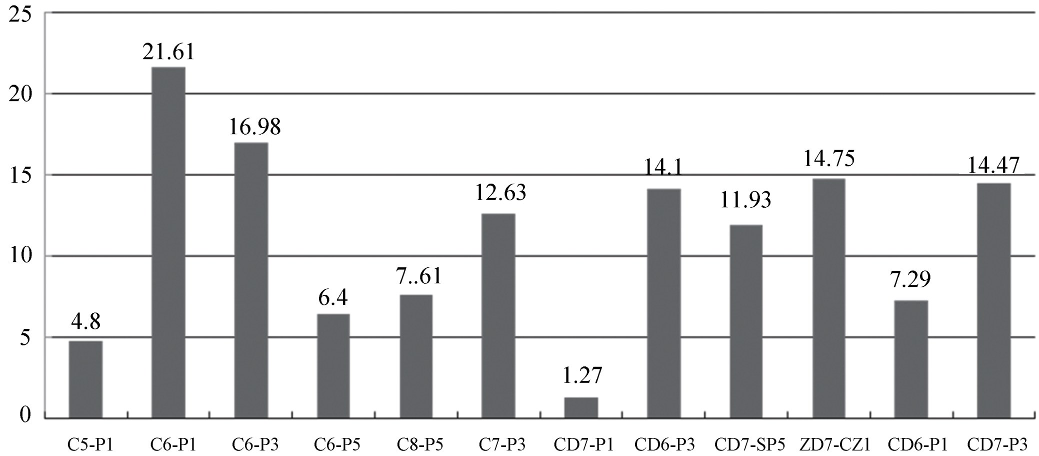

Figure 1
Remaining Geological Reserves After Polymer Flooding of 12 Wells in Study Area

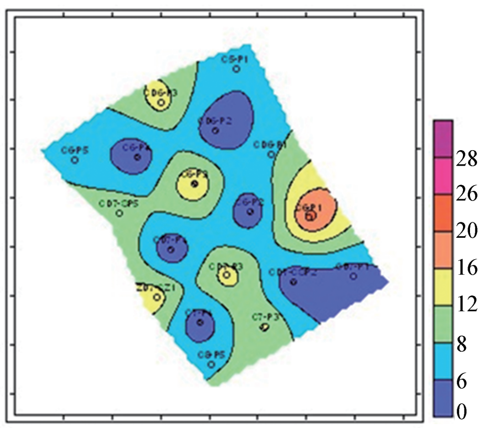

Figure 2
Contour Map of Cumulative Remaining Geological Reserves Distribution in PⅠ Group 1 to 4 Layers

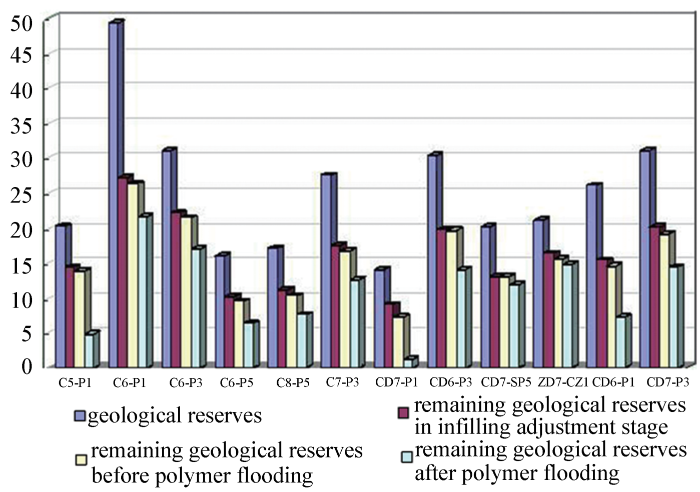

Figure 3
Remaining Geological Reserves of 12 Wells in Study Area in Different Stages

2.2 Comparison With the Results of Numerical Simulation

In study area, the calculation result of remaining geological reserves of 12 wells in different stages is compared with the results of numerical simulation. Seen from the Figure 4, the average error of two methods is 0.88% in infilling adjustment stage, the average error is 8.44% before polymer flooding and the average error is 11.53% after polymer flooding. Single well dynamic analysis data also matches the calculation results. This method has high maneuverability and good accuracy as well as it can quickly quantitatively describe remaining oil distribution. Moreover, it can provide basis for adjustment plan of old oilfield development, and measures of excavating remaining oil potential. Furthermore, it can be well applied to the oilfields or blocks without numerical simulation. Therefore, it is worth expanding and application.

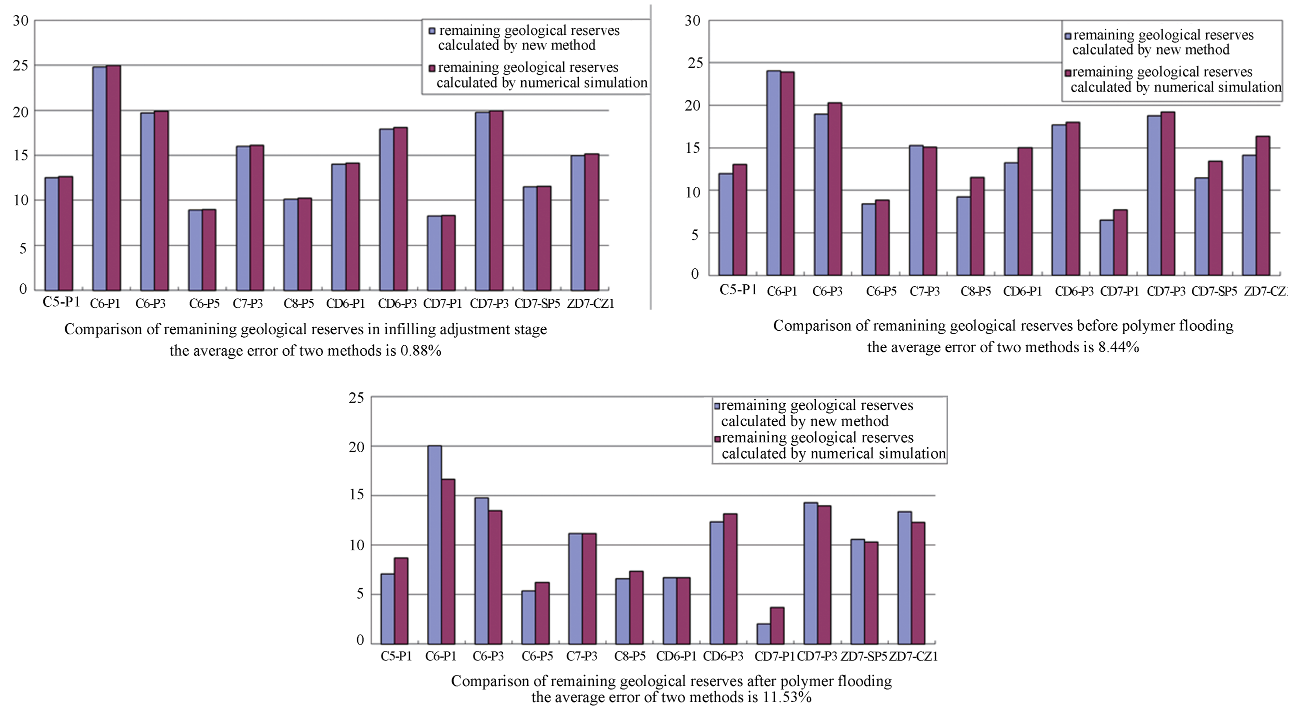

Figure 4
Comparison With the Results of Two Methods

CONCLUSION

In this article, based on the concept of remaining oil, a new calculation principle of remaining geological reserves is determined—the difference between geological reserves and the cumulative oil production. According to the development condition of the study area, remaining geological reserves distribution is described in phases. With high maneuverability and good accuracy, this method can quickly quantitatively describe remaining oil distribution. It can provide the basis for the adjustment plan of old oilfield development and measures of excavating remaining oil potential. Therefore, such method is worth expanding and applying.

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