Study on layer system complementarity technology in Block N

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Abstract—In view of the low permeability of oil reservoir, poor physical properties of crude oil, narrow strip development of channel sand, scattered development of plane sand body and serious heterogeneity in block n, there are some problems in water drive development, such as low well pattern control, low oil production rate, fast water cut rise rate and large production decline, the ideal stimulation effect can not be achieved by conventional measures, which restricts the potential of the block. In block n, 9 water injection wells and 16 production wells are selected to carry out layer series complementarity. Through the layer series complementarity of infill wells and basic well pattern, the well spacing is reduced, the injection production relationship of narrow sand body is improved, the water drive control degree and multidirectional connectivity ratio are improved, and the feasibility of improving the water drive development effect of block n is improved. In this paper, through the analysis of various remaining oil distribution types, the hole filling mode is optimized, so as to obtain better social and economic benefits.

1. Introduction
The oil field enters the exploitation stage of ultra-high water cut stage [1]. With the improvement of reservoir production degree, the water flooded thickness and water flooded proportion increase, and the plane residual oil distribution is scattered, in the process of production, the measures of oil wells to tap the potential and the comprehensive adjustment of water injection wells will change the distribution of remaining oil, and the description of remaining oil is becoming more and more difficult. Because the distribution of remaining oil is complex and scattered, we must adhere to the dynamic principle for mining this kind of remaining oil.

The water content of water drive foundation and infill layer series in block n is very close [2]. Infill well pattern is mainly used to supplement holes, implement layer series complementarity, reduce the well spacing of foundation layer series, improve the injection production relationship in narrow river channel, broaden the adjustment space of storage and production structure, and increase the mining thickness and affected direction of infill layer series, which is conducive to improving the development situation of small thickness and low production.

2. Study on boundary of strata complementary technology

2.1 Determination of reasonable well spacing limit
According to the calculation methods of well pattern density at home and abroad, combined with the existing four-point area well pattern, the complementary well spacing of strata is determined to be about 200m.
2.2 Determination of thickness and oil saturation limit of supplementary shooting sublayer

It can be seen from the relationship curve between the supplementary opening thickness of the newly added layer and the initial daily oil increase that the supplementary opening thickness is more than 2.7m, and from the relationship curve between the number of water injection directions and daily oil increase, the newly added water injection directions are more than 1.5, and the oil increase effect is better. According to the actual situation of block n and the development characteristics of reservoir, the boundary of supplementary opening thickness is determined, and the supplementary opening thickness of river sand is more than 2.7m, The thickness of inter river sand is greater than 1.1m. The number of increasing directions of channel sand is greater than 1, and the number of increasing directions of inter river sand is greater than 1.5, which can achieve good oil increase effect.

Fig.1 Relationship between newly added layer thickness and initial daily oil increase

Fig.2 Relationship between water injection direction number and daily oil increase

According to the numerical simulation results, combined with the macro and micro residual oil distribution characteristics, in order to improve the injection production relationship of single sand body and the effect of oil increase and precipitation, the residual oil in the hole filling horizon is relatively enriched, and the high water cut and strong water washing reservoirs are strictly controlled, it is determined that the oil saturation of the hole filling horizon of river sand body is greater than 55%, and the oil saturation of the hole filling horizon of inter river sand and thin differential layer is greater than 50%, so as to accurately tap the potential.

2.3 Determination of reasonable limit of permeability difference

The plane and vertical heterogeneity of oil layer in block n is relatively strong, the interlayer interference is serious, and the thin and poor layer with low permeability can not be well developed. Therefore, when optimizing the hole filling horizon, we should not only consider the remaining oil potential of the reservoir and the perfection of the injection production relationship of single sand body, but also consider the impact of interlayer contradictions on the development effect [3]. By optimizing and adjusting the interlayer combination of single wells and reducing the interlayer difference, the purpose of improving the water injection and liquid production structure of single wells and improving the effect of water injection development is achieved, so as to improve the overall water drive production degree of development intervals or reservoirs.

According to the relationship between permeability level difference and recovery factor and advancing speed and the numerical simulation study of multi-layer combination of different permeability, it is determined that the permeability level difference between the supplemented interval or the adjacent upper and lower original shooting interval should be controlled within 3.

3. Basic principle of strata complementarity

In order to improve the degree of water drive control in Block N and further improve the injection production relationship, the formation complementary well area was selected in team A in 2011. There are 16 oil production wells and 9 water injection wells in the well area. In view of the imperfect
injection production in the well area, different types of hole patching work have been carried out \[4\]. For the low efficiency wells produced by flow limiting fracturing, re-injection and hole filling in the flow limiting section are carried out to improve the seepage conditions near the wellbore; Improve the injection production relationship through layer series complementarity to improve the low efficiency of oil wells \[5\].

The principle of layer complementarity:

1) Through the hole filling of oil and water wells, reduce the well spacing, complement the basic layer series and infill layer series, and strengthen the injection production relationship;

2) Improve the injection production relationship of single sand body and improve the production degree of reservoir;

3) The hole filling horizon is optimized according to the type of remaining oil.

4. Analysis of patching horizon

4.1 Types of remaining oil near the fault
Well B: A total of 16 sub layers are drilled in the whole well. The thickness of the drilled sandstone is 13.7m, the effective thickness is 4.4m, and the formation coefficient is 0.719 \( \mu \text{m}^2 \cdot \text{m} \). The well is a production well at the edge of the fault. It can be seen from the sedimentary facies belt map that there is only one water injection well C around for water injection, and the injection production is not perfect. In 2010, a new well for polymer flooding was drilled in Block N. According to the water flooded interpretation data of the new well, we re understood the formation. For the undeveloped layer of the newly put into production well, due to the short drilling completion time, the logging interpretation results reflect the current water flooded condition of the reservoir. For the undeveloped layer of the old well, due to the long drilling completion time, the original water flooded condition may have changed, and the logging interpretation results can not reflect the current water flooded condition of the oil layer. At this time, refer to the logging results of the surrounding new wells. Therefore, we can see that the water flooding degree of the well is low with the help of the water flooding interpretation data of the new polymer flooding well.

The well was patched on April 7, 2012. The thickness of the supplementary sandstone is 23.8m, the effective thickness is 10.2m, and the formation coefficient is 3.181 \( \mu \text{m}^2 \cdot \text{m} \). At the initial stage after supplement, the daily liquid production is 66t, the daily oil production is 7.1t, and the water content is 89.2%. The production profile in August 2012 shows that the relative liquid production of layer M is 49.3%. It can be seen from the sand body diagram that layer M is located at the edge of narrow strip channel sand, and the oil reservoir in channel sand cannot be developed. Blocked by the fault, only one well injects water for it, and the connection between oil and water wells is a kind of connection. After hole patching, it is confirmed that this layer is the main production layer.

4.2 Types of remaining oil at the riverside
Well D: It can be seen from the sedimentary facies belt map that the well is located at the edge of the river channel in layer S. the water flooded interpretation data of the surrounding polymer flooding new wells show that the layer is medium and low water flooded, so it is considered that the hole can be supplemented. Since there is only one water inflow direction in this layer, but due to the different development of oil layers, it is difficult to inject water into the river channel. Therefore, it is recommended to supplement the holes of the surrounding water wells E while supplementing the oil wells, so as to not only fully excavate the remaining oil at the end of the sand body, but also improve the injection production relationship with the old wells. After hole patching, the daily liquid production increased by 97.8t, the daily oil production increased by 15.2t, and the water cut decreased by 5.5%. At the same time, the subdivision adjustment of well E makes the water absorption of the whole well more uniform. The surrounding basic well F is affected, the daily fluid production increases by 55t, the daily oil production increases by 2.8t, and the water cut decreases by 0.25%.
4.3 Re-injection hole patching in current limiting section
Due to the poor development of the target oil layer of infill wells, nearly 30% of the wells were fractured and completed by flow limiting method when they were put into operation. In the flow limiting section, due to the small diameter of the borehole, with the effect of water injection, the liquid production intensity and borehole wear resistance of the oil well continue to increase, and non radial flow occurs in some oil layers with strong liquid output capacity, which hinders the further increase of productivity. Timely hole filling in this part of the well layer can reduce the seepage resistance near the wellbore and release the reservoir productivity.

Well G: The well drilled sandstone is 12.9m, the effective thickness is 5.9m, and the formation coefficient is 1.491µm²·m. among them, the flow limiting method drilled sandstone is 6.1m, the effective thickness is 3.2m, and the formation coefficient is 0.467 µm²·m. On March 22, 2012, the well was re-drilled. While opening the flow limiting section, the potential layer for enriching remaining oil was also re-injected. From the production profile, it can be seen that after hole patching, the oil reservoir is produced more evenly. After patching, the hump of pressure recovery curve slows down and the freewheeling effect weakens. After hole patching, the daily liquid production increased by 103.9t, the daily oil production increased by 5.2t, and the water cut decreased by 1.3%.

4.4 The injection production is not perfect, and the remaining oil type in narrow river channel
Take well H as an example. The well is located in the narrow river channel in layer X, and there is only one basic well in the river channel to inject water. In order to improve the injection production relationship, it is considered that the well can be supplemented. On April 2, 2012, the well was patched. Before hole patching, the well has a daily liquid production of 18t, a daily oil production of 1.7t and a water cut of 90.7%; After hole patching, the well has a daily fluid production of 44.3t, a daily oil production of 9.1t and a water cut of 79.4%. The analysis shows that good results have been achieved.

5. Measure effect statistics
As of June 2013, a total of 13 additional oil wells have been produced, with an average thickness of 17.5m, an effective thickness of 13.2m and a formation coefficient of 4.554µm²·m. Cumulative liquid increase of production wells 13.5 × 10⁴t, cumulative oil increase 0.67 × 10⁴t, water content decreased by 4.3 percentage points.

6. Conclusion
(1) The well spacing is reduced after the layers are complementary, which further improves the injection production relationship and improves the water drive development effect of block N.
(2) At the same time, the oil and water wells are supplemented correspondingly, which strengthens the potential tapping of the remaining oil in the thick oil layer, improves the oil production speed, and achieves the good results of oil increase and precipitation.
(3) The mutual utilization of different well patterns increases the water inflow direction of production wells and further improves the degree of water drive control.

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