Research on Residual Petroleum in Complex Ultra-low Permeability Fuyu Oil Layer in the Peripheral Area of Western Daqing City and Effect Analysis of Potential Tapping Countermeasures

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Abstract. Qijiabei Oilfield belongs to ultra-low permeability and secondary pore development reservoirs. After years of water injection development, it is difficult to establish effective displacement, poor long-term low-efficiency wells and low development efficiency. problem. In view of the above problems, this paper uses fine reservoir description and multi-disciplinary integration technology to finely describe the fault location, subdivided sedimentary microfacies, partition segmentation fitting physical parameters and fine residual oil research, and find out the main problems of poor oilfield development. the reason. On this basis, according to the dynamic development characteristics, under the premise of quantifying the remaining oil to the permeability level, the targeted measures are formulated for the main remaining oil types, especially for the remaining oil with poor effect, according to the divisional adjustment ideas. The sub-well distinguishing area shall be formulated with individualized measures for tapping and digging potential, that is, comprehensively considering reservoir development, connectivity, and residual oil distribution rules, and implementing targeted oil and water wells corresponding adjustment and production techniques based on the detailed description of remaining oil. The water absorption ratio of oilfield sandstone increased by 8.4%, the output ratio of small layer increased by 18.7%, the natural decline rate decreased by 6.9%, the ultimate recovery rate increased by 1.22%, the oilfield development effect became better, and the research and synthesis of residual oil in complex ultra-low permeability reservoirs Digging potential provides a reference.

Keyword: Ultra-low permeability, Poor development effect, Remaining oil, Individualization, Oil well adjustment.

1. Introduction
With the continuous development of oilfields, the quality of newly invested and developed oilfields is getting worse and worse, mainly due to ultra-low permeability. The causes are complex and various
types. After the development, the oil recovery rate is low, the production decreases rapidly, and the development benefits are poor. To this end, it is of great significance to find out the main reason for the poor effect of the development of ultra-low permeability complex reservoirs after development. Based on the actual low-permeability and secondary pore development of Fuyu oil layer in Qijiabei Oilfield, the reservoir and fault research are the main line, and the detailed reservoir description and residual oil research are carried out, and the remaining oil distribution law and oilfield development effect are found. The main reason for guiding the comprehensive potential tapping provides an exploratory study and useful reference for the development and adjustment of similar oil reservoirs.

2. The block overview

2.1. Geological characteristics
Qijiabei Oilfield belongs to ultra-low permeability and secondary pore development reservoirs [1]. The main mining horizon is the Fuyu oil layer, and the reservoir depth is 2174m. The main body of the structure is a north-west extension and a nose-like structure that slops into the depression. It is a shallow lake sedimentary system and belongs to the delta front subfacies. The sand body types are mainly underwater distributary channel sand, main body sand and non-main body seats. Sand [1]-[2]. The reservoir has poor physical properties, with an average porosity of 13.7%, an average air permeability of 5.2 mD, a ground crude oil density of 0.86 t/m³, and a crude oil viscosity of 22.1 mPa.s. The original formation pressure was 22.23 MPa and the saturation pressure was 5.99 MPa.

2.2. Development Status
In 2008, a 350m × 170m rectangular well pattern was used for simultaneous water injection, and the development was carried out in the early stage of development. The water injection development technology policy was adopted to promote the balanced use and slow down the production decline. In July 2011, Affected by the fault and sand body scale, there is no injection well in rapeseed, and the injection-production relationship is improved to 23 wells. In August 2012, in order to improve the development effect, the formation energy was increased by transfer, and the side water propulsion was suppressed, and 5 wells were transferred. At present, there are 390 oil wells in the oil field, with an average daily oil production of 0.8t, integrated water content of 56.7%, cumulative oil production of 96.67 × 10⁴t, and mining degree of 8.07%. There are 134 water well injection wells in the oil field, with an average daily water injection of 17m³. The water injection is 405.54 × 10⁴m³, and the cumulative injection-production ratio is 2.0.

3. The main problems in development
After years of water injection development, the oilfield exposed the following contradictions:
(1) The Fuyu oil layer is poorly affected by the physical properties of the reservoir, and it is difficult for some blocks to establish an effective displacement. Poor water injection conditions, the oil field has a total of 56 wells, accounting for 41.8% of the total number of wells, including 16 secondary pore development areas, mainly distributed in the fault clamping area, the main reason for the lack of communication is the direction of communication, rolling; There are 40 weak development zones in the pores, and the contiguous distribution is mainly due to the poor physical properties of the reservoir. Affected by the difference in water absorption, the oil well suffered from poor efficiency, the effect rate was only 17.3%, the single well production was 0.5t; the output decreased rapidly, and the natural decline rate was 17.30%.

(2) The long-term low-efficiency well has a high proportion and poor development efficiency. There are 203 long-term low-efficiency wells, accounting for 46.8% of the total wells; the oilfield development benefits are gradually worsening, the oilfields are the three types of benefits, and the three types of wells are beneficial, with a total of 329, accounting for 75.7%.
4. Development and adjustment technology

4.1. Finely depicting the location of the fault, the fault is more accurate
Using the well-seismic combination technology, the fault description is refined from the top surface of the oil layer group to each sedimentary unit. The refinement of each sedimentary unit reflects the relative position of the well point and the fault, and the injection-production relationship between the oil and water wells is near the late fault. Development adjustment provides the basis. Due to the complex development of the Fuyu oil layer fault in Qijiabei Oilfield, in order to make the subsequent development adjustment more targeted, based on the well-seismic combined faults, the actual drilling breakpoint data and fault tendency are applied to the 19 sedimentary unit wells of the Fuyu oil layer. The relative position of the fault is finely adjusted to make the three-dimensional depiction of the fault location finer.

![Figure 1. Cross-well seismic profile profile](image1)
![Figure 2. FI1 deposition unit fault location](image2)
![Figure 3. FI16 deposition unit fault location](image3)

4.2. Subdivided sedimentary microfacies, plane heterogeneity is clearer
Based on the comprehensive application of core, earthquake, well logging and logging data, combined with the results of sedimentary research in the western part of Daqing, it is determined that the Qijiabei oilfield is mainly affected by the northern provenance, and the Fuyu oil layer develops the low-water delta front facies deposit. The sedimentary type is mainly water. Distribute the river sand, the main mat sand and the non-main body mat sand. Using sedimentary microfacies identification technology, combined with the actual development of the oilfield area, the river sand, the main mat sand mat and the non-main body mat sand are further subdivided into river sand, crevasse channel, abandoned river channel, and sluice sand. The floodplain, the inner front main body, the sand, the outer front main body, the inner front edge non-body mat sand and the outer front edge non-body mat sand, 9 kinds of microfacies type, the plane heterogeneity after subdivision Be clearer and provide the basis for later research.

4.3. Interpretation of fine chemical parameters to improve fitting accuracy
The interpretation of physical parameters directly affects the later modeling, digital model, residual oil research and development adjustment. It is necessary to fit the relationship between porosity and permeability according to the core data of the preliminary exploration wells, and to develop single well single-layer physical properties for later development wells. The explanation provides the basis.

The Fuyu oil layer in Qijiabei Oilfield is an ultra-low permeability reservoir and secondary pore development. According to the secondary pore development degree of Qijiabei Oilfield, it is divided into secondary pore development zone and secondary pore weak development zone. When interpreting the physical property parameters, the plane partitioning and the porosity fitting method are used to explain the reservoir permeability and improve the formula fitting accuracy.
4.4. Fine residual oil research,

4.4.1. Residual oil genesis. Comprehensively apply the results of fine reservoir description, comprehensively analyze the dynamic and static data such as logging, structure, annulus, isotope, etc., and determine the remaining oil type by layer by layer. The remaining oil has poor water injection effect, plane contradiction, inter-layer contradiction. There are six types of imperfect injection and production relationships, formation water intrusion and unutilized. From the perspective of the remaining oil, the water injection is poorly affected, the injection-production relationship is imperfect, and the unused residual oil is the main remaining oil, which is the main target for further tapping potential.

Table 1. Table of remaining oil types in Fuyu oil layer of Qijiabei Oilfield

| Remaining oil cause                          | Remaining recoverable reserves /10^4t | Degree of recovery/% | Remaining recoverable reserves/10^4t | The proportion/% |
|---------------------------------------------|--------------------------------------|----------------------|-------------------------------------|------------------|
| Water injection is poorly affected          | 48.22                                | 38.6                 | 0.1056                              | 6.82             |
| Plane contradictory type                    | 15.56                                | 12.5                 | 0.0751                              | 8.31             |
| Inter-layer contradiction                   | 9.88                                 | 7.9                  | 0.0584                              | 7.45             |
| Incomplete injection and production relationship | 18.90                          | 15.1                 | 0.0161                              | 5.30             |
| Formation water intrusion                   | 2.58                                 | 2.1                  | 0.0460                              | 2.76             |
| Unused type                                 | 29.79                                | 23.9                 | 0.0130                              | 0.00             |
4.4.2. Distribution of remaining oil level. According to the residual oil situation of single well single layer, the remaining oil level distribution of each sedimentary unit is studied. According to the size of remaining oil, it is divided into three types: large area distribution type, local distribution type and scattered distribution type.

(1) Large-area distribution type means that the number of remaining oil wells in a sedimentary unit accounts for more than 20% of the total number of wells in a block, and is distributed in a plane. It is mainly distributed on 13 sedimentary units such as F11, 2-1, 2-2, 3, 5, and 6. The remaining recoverable reserves account for 40.1% of the total remaining recoverable reserves, mainly due to poor water injection efficiency and injection-production relationship. Perfect, plane contradictions and unused causes are formed.

(2) Local distribution type means that the remaining oil well points account for 10 to 20% of the total number of well points in the whole area, and are distributed in strips or small pieces in the local well area; mainly distributed in F12-1, 2-2. On the 15 sedimentary units of 3, 4, 5, 6 and so on, the remaining recoverable reserves accounted for 31.7% of the total remaining recoverable reserves, which were mainly caused by poor water injection efficiency, unutilized, and plane contradictions.

(3) The scattered distribution type means that the remaining oil well points account for less than 10% of the total number of well points in the whole area, and distribute the remaining oil in a small range to form potato-like or small strips; each sedimentary unit has a distribution, mainly due to the relationship between injection and production. The imperfect and unutilized reasons are formed, and the remaining recoverable reserves account for 28.2% of the total remaining recoverable reserves.

4.5. Remaining oil tapping potential countermeasures

4.5.1. Inadequate injection and recovery and unused fuel adjustment measures. Unused residual oil is mainly formed by reservoirs with poor physical properties or small perforations that are newly explained after fine-drawing. However, the remaining oil with imperfect injection-production relationship is mainly formed by mining without injection and with no main mining. These two types of residual oil are distributed over 1,345 small layers, accounting for 39.0% of the total remaining recoverable reserves.

For the actual difference of the unutilized residual oil property, the corresponding measures are taken according to the permeability level to achieve the maximum effect. For the reservoir with the permeability less than 1.8mD, the seam fracturing and the oil-water well corresponding pressure are adopted. For the reservoir with a permeability of 1.8-10mD, the combination of the pore filling and the conventional fracturing is used. For the reservoir with the permeability greater than 10mD, the direct pore filling method is adopted, and a total of 22 wells are preferably used. Measures are used.

For the remaining oil with imperfect injection-production relationship, it is mainly to improve the local injection-production relationship through the method of filling holes in wells and transferring oil wells. At present, there are 62 sand bodies in Qijiabei Oilfield with imperfect injection-production relationship. Under the mining relationship, according to the development of single well reservoir, 10 sand layers of 4 wells are used to fill the hole, and 3 wells are transferred to each other to improve the local injection-production relationship. After filling and transfer, there will be 16.9% of the remaining oil can be tapped further.
4.5.2. **Residual oil adjustment countermeasures for poor water injection efficiency.** The reservoirs in the Fuyu oil layer of Qijiabei Oilfield are poor in physical properties, and the well network adaptability is poor, resulting in poor oil well performance. In order to make the potential tapping countermeasures more targeted, according to the development of dynamic characteristics of various regions of the oilfield, the oilfields are divided into two blocks that can establish effective displacement zones and difficult to establish effective displacement zones. According to the zoning, the current potential digging measures of the oilfield mainly focus on promoting the water absorption of the wells and establishing an effective displacement to promote the effect of the oil wells. According to the numerical simulation of the fine reservoir description and the dynamic analysis of the residual oil results, the remaining oil types are mainly due to the poor water injection efficiency. Type is the main target for tapping potential. In order to further clarify the reasons for the formation of remaining oil, the formulation of measures is more targeted. The remaining oil is quantified to the permeability level, depending on the type of physical property optimization measure.

**Table 2.** Water injection efficiency difference type remaining oil according to permeability classification statistics table

| Partition                        | Remaining oil ratio at different permeability levels (%) | Cause of formation                                      | Attack direction                                      |
|----------------------------------|---------------------------------------------------------|--------------------------------------------------------|-------------------------------------------------------|
|                                  | K<1 | 1≤K<10 | 10≤K<50 | 50≤K<500 |                                                      |                                                       |
| Ability to establish effective displacement | 20.6 | 41.2  | 33.6   | 4.6      | Large difference in plane properties, uneven effect | Optimize the combination of measures, increase injection, and promote efficiency |
| Difficult to establish an effective displacement | 55.3 | 38.7  | 5.3    | 0.7      | Under the conditions of the well network, no effective displacement has been established. | Develop new process technologies and establish effective displacement |

According to the calculation results of the effective displacement well spacing, the district conducts an effective flooding field test for oil-water wells corresponding to fracturing, pressure-injection combined with seam fracturing.
(1) It is possible to establish an effective displacement well area, and to form an oil-water well corresponding fracturing technology.

The first is the optimization of reasonable fracturing methods. In view of the fact that the plane is unbalanced and the effect is low, the numerical simulation is applied to compare the corresponding fractures of oil and water wells, separate fracturing oil wells or wells, and the corresponding fracturing of oil and water wells transforms the interwell displacement into interstitial displacement. The best effect.

Figure 9. Numerical simulation of the relationship between the degree of production and water content in different fracturing methods

The second is the rational timing of fracturing. The numerical simulation of the reservoir is used to optimize the timing of water injection. According to the formation pressure at the end of the stage, the end of the low water cut period and the end of the middle water cut stage, the corresponding oil well fracturing timing is determined to be water injection for 6 months.

The third is the optimization of reasonable fracturing scale. According to the existing injection well pattern and geostress direction, optimize the relationship between well pattern and seam, shorten the displacement distance, design the injection well with a half-slit length of 180m, the oil well fracture half length is 150m, and the displacement distance is shortened by 244m. At 83m, the effective displacement distance is established.

According to the optimization results, it is preferred to carry out corresponding fracturing tests for 14 well groups, and corresponding fracturing is performed on 16 surrounding oil wells. Compared with the single fracturing, the effective period of the increase is extended, the daily oil increase in a single well is increased by 0.6t, the annual increase of oil is 324t, and the annual slowdown is naturally decreasing by 3.75 percentage points.

(2) It is difficult to establish an effective displacement well area, and the combination of pressurized water injection and seam network

In view of the fact that it is difficult to establish an effective displacement under the current well network conditions, it can be seen from the formula of starting pressure gradient and effective displacement distance that increasing the displacement pressure difference and shortening the displacement distance are two effective ways to establish an effective displacement.

The injection end implements pressurized water injection to increase the displacement pressure difference between the oil and water wells and promote the oil well to be effective. The overburden pressure method is used to calculate the fracture pressure of the injection well. According to the current injection pressure, the potential space for the pressure increase and injection is determined. It is preferred to implement 24 wells with potential space. The effect of increasing the injection is significant. The daily increase of single well is 21t. The formation pressure was gradually restored from 9.42 MPa to 9.75 MPa.

The production end implements corresponding fracturing of the joint net. On the basis of the pressurized water injection to restore the formation energy, the inter-well displacement is transformed into the displacement between the well and the seam by the fracturing of the seam, shortening the displacement distance and achieving effective Displacement. The brittleness characteristic index of the
Fuyu oil layer is as high as 47.3, which can form a seam and multiple seams. The design of the oil well draining well is 350m long, the slit width is 160m, and the displacement distance after fracturing is 90m. The design of the water well draining well is 270m long, the slit width is 160m, and the displacement distance after fracturing is 80m. It is preferable to implement 13 wells corresponding to the fracture of the oil well corresponding to the seam, and the initial average daily oil increase of the single well is 3.7t, which is 1.1t higher than the average single well daily increase of the conventional fracturing well in the block, the effective period is 4 months, and the cumulative oil increase is 110t. Greatly improved.

5. The development of adjustment effects
After the comprehensive tapping of the Fuyu oil layer in Qijiabei Oilfield, the development situation has obviously improved. The number of unfilled wells was 46, the daily water injection increased by 361m3, and 26 new oil wells were added. The daily oil production increased by 23t. The proportion of sandstone water absorption increased from 78.7% to 87.1%, and the small layer output ratio increased from 58.8% to 77.5%. The output rebounded and the natural decline rate decreased from 17.05% to 10.14%, a decrease of 6.91 percentage points.

Using the water content of the children's chart and the degree of recovery curve to evaluate the potential of the potential tapping, the actual recovery rate before the comprehensive tapping of the potential is 30% away from the theoretical curve, and is 30% away from the theoretical curve before and after the excavation, and the theoretical curve is 35%. Better. The A-type water flooding characteristic curve was used to predict the ultimate recovery of Fuyu oil layer by 1.22 percentage points and the increase of recoverable reserves of 124,600 tons.
6. Conclusion
(1) The development and adjustment of complex ultra-low permeability and secondary pore development reservoirs have special characteristics. In view of the poor adaptability of well pattern and poor water injection efficiency after water injection development, it is necessary to formulate individualized adjustment and potential tapping measures.

(2) Finely depicting the spatial location of the fault, the subdivision sedimentary microfacies, the partitioned segmentation fitting physical parameters, the fine residual oil research and multi-disciplinary integrated technology, which is the fine comprehensive potential tapping and precision development in the later stage of the oilfield. Provide a reliable basis.

(3) Based on the study of fine reservoir description, optimize the countermeasures for the under-reaction treatment of classified reservoirs and effective production measures, flexibly optimize the mature technology combination method and the new technology test, solve the bottleneck of development of the target layer, and effectively reduce the production decline. Improve the development of oil fields.

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