Analysis on the Development Status and Countermeasures of Fault Block Reservoir in Middle and Late Stage

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Abstract. China is a country with rich oil reserves. With the development of the reservoir, the proportion of fault block reservoir (hereinafter referred to as FBR) discovery increases gradually. At present, FBR has occupied a considerable proportion of China's oil reserves. Zhongyuan Oilfield is mainly composed of complex FBR. FBR has unique characteristics, such as small fault block and complex geological structure, which will greatly increase the difficulty of development in the middle and late development. Therefore, we must comprehensively adjust and tap the potential of FBR, which will achieve long-term stable production in the middle and late stage of fault block oilfield. Therefore, based on the characteristics and classification of FBR, this paper analyzes the development status in the middle and late stage. Then, according to the characteristics of fault block oilfield in the middle and late stage, this paper puts forward some comprehensive adjustment technical measures, which will better adapt to the reasonable development mode of FBR in the middle and late stage.

Keywords: Fault Block Reservoir, Reservoir Development

1. Introduction

At present, many fault block oilfields in China have entered the stage of mid late development. However, there are many problems in the middle and late development, such as low recovery degree, comprehensive water content, water production increased significantly, oil production gradually decreased, production cost increased, etc., which will lead to the utilization rate of reservoir development. With the adjustment of drilling well pattern and the effect of stimulation measures becoming smaller and smaller, the technical problems of oilfield development will be more and more serious, which will be more difficult to achieve the urgent need of economic benefits. Therefore, tapping the potential of remaining oil in fault block oilfield has become the main contradiction to improve recoverable reserves of FBR, which will improve the development effect of oilfield. At the same time, there are many problems in complex FBR, such as fault development, complex structure, poor regularity, small oil-bearing area and so on[1]. At the same time, the FBR also has the following
characteristics, such as multiple oil-bearing series, long oil-water interval, complex oil-water relationship, large buried depth range, great changes in reservoir physical properties, serious heterogeneity, etc.

2. Classification of FBR

2.1. According to oil bearing area of oil reservoir

According to the different oil-bearing areas, FBR can be divided into five levels: large FBR, large FBR, FBR, small FBR and fragmentary reservoir. The standard is shown in Table 1.

| Classification       | Standard                          |
|----------------------|-----------------------------------|
| 1                    | Large FBR                         |
| 2                    | Large FBR                         |
| 3                    | FBR                               |
| 4                    | Small FBR                         |
| 5                    | Fragmentary reservoir             |

| Classification       | Standard                          |
|----------------------|-----------------------------------|
| 1                    | Oil bearing area > 1.0 km²        |
| 2                    | Oil bearing area ≤ 1.0 km²        |
| 3                    | Oil bearing area ≤ 0.4 km²        |
| 4                    | Oil bearing area ≤ 0.2 km²        |
| 5                    | Oil bearing area ≤ 0.1 km²        |

2.2. According to reservoir natural energy and development mode

Based on the analysis of 452 development units of medium high permeability thin oil sandstone FBR in Shengli, Zhongyuan, Jiangsu, Henan and Jianghan Oil areas under the jurisdiction of Sinopec, this paper divides the FBR into two types: those with sufficient natural energy and those with insufficient natural energy. The former is mainly reservoir with active edge and bottom water, which can be developed by natural energy. The latter is mainly weak edge water or closed reservoir, which is mainly developed by water injection. For the reservoir with insufficient natural energy, we can further divide it into simple FBR with perfect injection production well pattern, imperfect complex FBR and extremely imperfect extremely complex FBR according to the perfection degree of injection production well pattern and fault development condition[2].

2.3. According to reservoir geometry

According to the geometry and characteristics of fault blocks, FBR can be divided into four types: strip FBR, semicircular FBR, triangle FBR and quadrilateral FBR. Different shape description can reflect the difference of fault sealing and natural energy. First, long FBR. It is generally formed by several equal or nearly parallel faults[3]. Generally, the fault blocks are cut into strips, horsts and grabens by the simultaneous development of echelon or stepped faults. Second, quadrilateral FBR. Generally, it is formed by the intersection of four faults. The structure is relatively complex, the area is small, and the fault blocks are independent of each other. The reservoir has independent oil, gas, water and pressure systems, generally without edge water or less edge water, and lack of natural energy. Third, triangular reservoir. It is usually formed by two faults cutting fault blocks at the same time.
Generally, triangular reservoir has small oil-bearing area and sufficient natural energy. Fourth, fan FBR. Fan FBR are usually relatively simple in structure and large in area. Generally, there are active edge water, large sand body distribution area and sufficient natural energy[4].

3. Prediction of FBR by Tong's chart method

According to Tong Xianzhang's research results, the statistical relationship among comprehensive water cut (FW), recovery degree (R) and final recovery factor (RM) of water drive sandstone reservoir is shown in Formula 1. According to the relationship between water content and recovery degree under different RM series, the theoretical chart is shown in Figure 1.

\[
\lg \frac{f_w}{1-f_w} = 7.5(R - R_m) + 1.69
\]  

(1)

According to the variation law of actual water cut and recovery degree in Liu416 FBR, the water cut rising curve of Liu416 FBR mainly fluctuates around the curve with final recovery rate of 25%. Therefore, the final recovery rate of Liu416 FBR is finally determined as 25% by Tong's chart.

4. Development of different types of FBR

4.1. Complex and extremely complex FBR

The fault system of complex and extremely complex FBR is complex, which makes the structural interpretation difficult. It is mainly reflected in the fine interpretation of faults of grade 4 and below, fault combination and division of complex small fault blocks. The fault block area of complex and extremely complex FBR is small, which will be difficult to form a perfect injection production relationship. Therefore, complex FBR will lead to low formation energy and insufficient fluid supply to oil wells. According to statistics, the total pressure drop of oil layer in 1999 was 11.82 Mpa. In 2000, the average dynamic liquid level of production wells was 1356 m, resulting in low liquid production of oil wells, and the average liquid production of single well was only 22.0 T/d.

4.2. Simple, complex and edge bottom water FBR
There are many oil-bearing series vertically in FBR, which will cause serious heterogeneity. In the initial stage of development, we mainly adopt the mode of large section combined production and injection. In the late stage of development, the interlayer contradiction is increasingly prominent, especially in the simple FBR. For example, there are 15 oil-bearing sand groups and 76 oil-bearing small layers in xin-47 fault block, and the permeability difference between layers is more than 10 times, which will lead to great difference in recovery degree and water absorption capacity between layers. The contradiction between layers is more prominent, which seriously affects the development effect[5].

4.3. Lithologic structural reservoir

Lithologic structural reservoir has poor physical properties and serious heterogeneity. Therefore, the production of oil wells decreases rapidly and the effect of water injection is slow. The gradual increase of water injection pressure will affect the development effect. Due to the rapid decline of formation pressure near the production well, the production rate decreases rapidly. In lithologic structural reservoirs developed by water injection, the water injection pressure generally increases. The rapid rise of water injection pressure and the rapid decline of production well production will seriously affect the water injection, oil production, production rate and recovery factor.

4.4. Water injection technology

In FBR, the effective period of subdivision water injection technology is short and the water injection effect is poor. The main reasons are as follows. First, the number of wells with damaged casing is increasing, and separate layer water injection cannot be realized. Secondly, the injection water quality is poor, and the oil and casing scaling and corrosion affect the sealing effect of the packer. Thirdly, the performance of packer and water distributor is poor, which shortens the separate layer water injection string working life.

5. Measures to increase production

5.1. Adjustment of well pattern

It is an effective method to tap remaining oil, maintain stable production and improve water drive effect by drilling infill wells. Under geological conditions, we can drill more adjustment wells and carry out secondary infill adjustment, which is an effective measure to improve the development effect of FBR. In the process of development, we need to comprehensively apply a variety of matching stimulation technologies according to the geological characteristics of the reservoir, which will improve the recoverable reserves of the reservoir in the middle and later period. Through the well pattern optimization model, the effectiveness of water injection in FBR is effectively improved, which will strengthen the stable production of old oilfield[6].

5.2. Make comprehensive adjustment

It includes more reasonable and detailed division and combination of strata, well pattern layout, adjustment of injection production relationship, profile control and water shutoff. Water flooding has been carried out in complex fault block oilfields, and the degree of control and the production status of oil layers have been improved obviously, and the recoverable reserves have been greatly increased. In
order to improve the recovery efficiency and develop the reservoir reasonably, the dynamic and static adjustment development plan can be adopted to fully and reasonably study the remaining oil distribution, and the scale comparison and demonstration of different infill schemes are carried out.

5.3. Fracturing reconstruction

Through fracturing, we can form artificial fractures, which will achieve many purposes, such as increasing reservoir permeability, increasing oil production rate, improving injection production system, improving production profile and delaying oilfield decline. The key to the effect of fracturing lies in the determination of fracturing wells and the selection of fracturing methods. Generally, the following oil layers should be fractured: medium and low permeability layers with permeability less than $50 \times 10^{-2}$ m$^2$. This kind of oil layer has a large number and large geological reserves. Through fracturing, the water injection situation of corresponding water injection wells can be improved and the degree of water drive production can be improved. This part of the oil layer is polluted during drilling or oil well operation, with low production capacity and large oil increase potential; the oil layer corresponding to water injection well but with low effectiveness.

6. Conclusion

The types of FBR and their sedimentary environments are quite different. The development mode of different reservoirs in different development stages will be very different. Therefore, we must have the remaining oil distribution characteristics and control factors. Through reasonable adjustment of injection production mode, we can improve the recovery rate of different types of FBR. By using dynamic monitoring data, we can determine a better working system, which will maximize the remaining oil in the reservoir.

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