Research on Sand Body Description and Perforation Plan Optimization of Off-surface Reservoir in Block a of X Oilfield

Yuanyuan Zhang
Geological Brigade of the Fourth Oil Production Plant of Daqing Oilfield Co., Ltd., Daqing, Heilongjiang, 163000, China
Yuanyuan@petrochina.com.cn

Abstract. Based on the previous understanding of off-surface reservoirs of closed coring wells in Block B of X Oilfield, this paper selects the "four injection and nine production" test well group in Block A as the research object, and studies the distribution characteristics of dominant bands in off-surface sand bodies. The results show that the off-balance-sheet reservoirs can be vertically subdivided into two types and seven sub-types of sand body connectivity patterns, and the understanding of sand body connectivity is deepened by finely depicting sedimentary facies belts on the plane. On the basis of the above research, according to the sedimentary environment and distribution characteristics of the dominant zones, the perforation scheme of the tertiary infill wells is further optimized, and the three principles of "no shooting in the inner front, type I and II selective shooting in the outer front, and type III and IV full shooting in the outer front" are defined, which provides a new research direction for effectively controlling the rapid rise of water cut in the initial stage of new wells and further tapping the potential of the off surface remaining oil.

Keywords: Off surface reservoir, connectivity mode, perforation scheme.

1. Introduction
According to the production data of each block in the whole study area, the water cut of tertiary infill wells with off-balance-sheet reservoir as the main adjustment object increased rapidly at the initial stage of production. In 2015, five sealed coring wells were drilled in Block B, and the water washing condition showed that the off-balance sheet reservoirs showed high oil displacement efficiency, low water washing ratio and low recovery degree. Both of them indicate that there are great development contradictions in off-balance-sheet reservoirs.

Through the core identification of sealed coring wells, it is found that there are not only low permeability and ultra-low permeability sandstone (the lowest permeability is less than 10mD) in off-balance-sheet reservoirs. There are also a large number of banded medium-high permeability sandstones (the maximum air permeability can reach 1300mD), which are less than 0.2m thick and unrecognizable by logging curves. In addition, the thickness ratio of dominant bands is low and the oil displacement efficiency is high, while the conventional off-balance sheet thickness accounts for a large proportion and the unwashed ratio is high.
Combined with the understanding of coring wells, it is considered that the dominant zone is the main factor causing the "one high and two low" of coring wells and the rapid increase of water cut in tertiary infill wells. This sandstone has good physical properties and can be used first. Once washed with water, it is easy to form a dominant channel, and the upper and lower conventional off-balance-sheet sand bodies can no longer be used. For this reason, this paper takes the three infill wells in Block A as the research object, focuses on the vertical and horizontal connections of off-surface sand bodies, and discusses the perforation schemes of new and old wells in combination with the characteristics of the dominant bands.

2. The development characteristics of sand body in the outer surface reservoir

By identifying the dominant bands in 273 off-balance-sheet units of 13 tertiary infill wells in the experimental area, 126 dominant bands were finally identified. The dominant bands are mainly developed in a single well is 11.3, accounting for 53.8%, and the average number of layers off-balance sheet concentrated in C1 and C3 reservoir groups. Among them, the average number of layers with dominant experimental area, 126 dominant bands were finally identified. The dominant bands are mainly determined (Table 2). There are no inner front facies sandbodies in the test area; outer front type I develops 20 sedimentary units dominated by C2 and C3; outer front type II develops 7 sedimentary units; outer front type III develops 19 sedimentary units; outer front type IV develops 49 sedimentary units. According to the analysis results of sedimentary environment of coring wells, the inner front facies is mainly bordered, embedded and extended due to the double action of rivers and lakes. The outer front facies is mainly affected by lakes. In the lower energy environment, low permeability and ultra-low permeability sandstones are mainly developed in the outer front class III and IV. The dominant bands are only developed in a small amount in the outer front class I and II, and the plane is mainly embedded and extended.

Table 1. Development status of dominant bands in the experimental area

| Oil formation | Embedded type | Extended type | Continuous type | Isolated type | Total |
|---------------|---------------|---------------|----------------|--------------|-------|
|               | Quantity      | Proportion (%)| Quantity       | Proportion   | Quantity| Proportion (%)| Quantity| Proportion (%)| Quantity| Proportion (%)|
| C2            | 23            | 37.7          | 38             | 62.3         | 0      | 0.0           | 0       | 0.0           | 0       | 0.0           | 61     |
| C3            | 28            | 60.9          | 12             | 26.1         | 6      | 13.0          | 0       | 0.0           | 0       | 0.0           | 46     |
| D1            | 4             | 40.0          | 2              | 20.0         | 3      | 30.0          | 1       | 10.0          | 1       | 11.1          | 10     |
| D2            | 0             | 0.0           | 5              | 55.6         | 3      | 33.3          | 1       | 11.1          | 9       |               |       |
| total         | 55            | 43.7          | 57             | 45.2         | 12     | 9.5           | 2       | 1.6           | 126     |               |       |

According to the statistics of the drilling rate of various types of sand bodies in Block B and the plane sedimentary facies belt map, the sedimentary environment of each unit in each experimental area is determined (Table 2). There are no inner front facies sandbodies in the test area; outer front type I develops 20 sedimentary units dominated by C2 and C3; outer front type II develops 7 sedimentary units; outer front type III develops 19 sedimentary units; outer front type IV develops 49 sedimentary units. According to the analysis results of sedimentary environment of coring wells, the inner front facies is mainly bordered, embedded and extended due to the double action of rivers and lakes. The outer front facies is mainly affected by lakes. In the lower energy environment, low permeability and ultra-low permeability sandstones are mainly developed in the outer front class III and IV. The dominant bands are only developed in a small amount in the outer front class I and II, and the plane is mainly embedded and extended.

Table 2. Sedimentary environment of the four injection and nine mining test area

| Depositional environment | Depositional unit | Quantity | Distribution types of dominant bands |
|-------------------------|-------------------|----------|-------------------------------------|
| Outer leading edge I    | C22, C23-1, C24, C25-1, C28, C210, C211-1, C211-2, C211-3, C212, C216, C32-1, C32-2, C35, C35-1, C39-1, C311, D142, D15-1, D23 | 20       | Embedded type and extended type     |
| Outer leading edge II   | C25, C27, C29, C214, C215, C37-1, D141 | 7        | The probability gradually decreases, and occasionally the extended type is seen |
| Outer leading edge III  | C21-1, C21-2, C23, C211, C213, C215-1, C31, C31-1, C32, C34, D142-1, D22-1, C21, C22-1, C26, C36-1, C37, D16, D27 | 19       | Basically no developmental dominant bands |
| Outer leading edge IV   | C11, C24-1, C29-1, C210-1, C215-2, C33, C33-1, C36, C38, C39, C310, C311-1, D142-2, D142-3, D15, D17, D17-1, D18, D21, D22, D24, D25, D26, D26-1, D27-1, D28, D28-1, D29, D29-1, D210, D211, D212, E11, E12, E12-1, E13, E13-1, E14-5, E16-7, E18, E19, E1102, E111, E112, E113, E114-17, E118+19, E120 | 49       |                                |
3. Fine description of sand body in extra surface reservoir

Core data show that the physical properties (permeability and porosity) of the dominant bands in off-balance-sheet reservoirs are similar to those of effective sandstones, but the thickness is thin and cannot be identified. Therefore, in the analysis of sand body connectivity model, it is considered that the off-balance-sheet reservoirs with dominant bands are connected with effective sandstone. Therefore, the off-surface reservoir is divided into two types, seven and seven small types of sand contact mode, which is composed of two major types and 7 small types, and describes the plane development characteristics of the dominant strip in typical reservoir.

3.1. Vertical connectivity model of sand body

In the past, there were two ways to connect off-surface reservoirs, namely: off-surface reservoirs were connected to off-surface reservoirs, and off-surface reservoirs were disconnected from effective sand bodies. After identifying the dominant bands, the connectivity mode of the off-surface reservoirs is refined: Type I connectivity is effective connectivity, which mainly includes the docking between effective sandstone and off-surface dominant bands, and off-balance dominant bands communicating with effective sandstone and dominant bands Effective docking between. Type II connectivity is subdivided into four types: effective sandstone and conventional off-surface butt, dominant bands pinch out, off-surface dominant bands are spatially dislocated, and contiguous conventional off-surface (Figure 1). After subdividing, it is more accurate in judging the connectivity of sand bodies.

![Figure 1. Diagram of the connection pattern of the sand body of the off-surface reservoir](image)

3.2. Plane characterization of sand body

The identification results of dominant bands in the test area are characterized by special purple in the sedimentary facies map, and the five microfacies types in the original sedimentary facies map are expanded to six types (Figure 2). The plane connectivity of off-balance-sheet reservoirs has changed obviously. For example, in C211-1 sedimentary unit, injection well 1 before identification is an off-balance sheet sand body, while its corresponding three production wells 2, 4 and 5 are developed with effective sandstones, which are main thin sand and non-main thin sand. According to previous understanding, the communication between injection-production wells is poor. After the dominant zone is reidentified, the dominant zone is developed in the sand body outside the injection well 1, which is better connected with the effective sandstone of the corresponding three production wells. The connectivity has changed completely, and the perforation scheme and development measures have changed accordingly.
4. Optimization of perforation scheme for new and old wells

4.1 Optimization of perforation scheme for new wells with tertiary infill

The adjustment objects of the tertiary infill wells in Block B are mainly unexploited and poorly produced off-balance-sheet reservoirs, and some off-balance-sheet thin layers are perforated to improve the injection-production relationship. On the basis of this adjustment purpose, the dominant bands in the sand bodies outside the new wells are identified, the sand body connectivity relationship is re-depicted, the used surface layers with dominant bands are not perforated, and the unused surface layers with dominant bands are perforated, and the perforation scheme of new wells is optimized to achieve the purpose of controlling water and increasing oil production.

- The outer sandbodies with dominant bands in the inner front facies are not perforated

In the sedimentary environment of the inner front, the main thin-layer sand is developed, and the off-surface sand bodies are sporadically developed and basically contain dominant bands. The distribution types are mainly edging type and embedding type, which are directly connected with effective sandstones such as river channel sand body, main thin sand and non-main thin sand, forming a good connection. After years of water flooding development, the sand body has a high degree of production, and it is easy to form a dominant channel for water injection. In order to avoid these dominant channels, the off-balance-sheet sand bodies in the internal front facies are not perforated.

- In the outer leading edge facies I and II, whether to perforate or not is determined according to the actual injection-production situation.

Under the I and II sedimentary environments of the outer front, the main non-thin sand bodies are mainly developed, and the distribution area of off-balance-sheet reservoirs increases. The dominant bands are embedded and extended. If the dominant zone develops outside the new well surface and is at or near the main injection-production line, which may have been used, then this layer will not be perforated (Figure 3).
Taking C29 unit as an example, after new wells 101, 102 and old wells 103 are re-identified, dominant bands develop in the off-surface sand bodies, which are well connected with the surrounding non-main thin sand. According to the perforation of old well pattern and isotope data of water wells, the secondary infill wells 104 and 105 and the primary infill wells 106 form effective injection-production lines with the oil wells 107 and 103. The dominant zones of new well 101, 102 and old well 103 are close to the main stream line, so there is a great possibility of water flooding, and this layer is not perforated.

- In the outer front facies class III and IV, the off-balance-sheet reservoirs are perforated.

Under the class III and IV sedimentary environment of the outer front, the off-surface sand bodies develop continuously in a large area, with few dominant bands and poor production, so they can be perforated completely to tap potential remaining oil.

On the basis of this principle, the perforation scheme in the test area was finally optimized. According to the injection, production and water absorption of old wells, it is determined that 11 of the 27 sedimentary units with dominant bands in the outer front I and II are not perforated.

4.2 Optimization of hole patching scheme for old wells
The principle of replenishing holes and selecting layers in old wells is to judge whether the off-balance-sheet reservoirs are produced first. On the basis of judging the dominant bands of off-balance-sheet reservoirs, combining with the communication modes of seven types of sand bodies, injection-production and water absorption of well patterns, it is determined whether this layer is perforated or not. For example, in order to improve the production status of thin and poor layers in Block A, it is planned to make up holes for old well 108 in Unit C32-1. After fine identification, the well 109 and 110 off-surface sand bodies have developed dominant bands, which are well connected with the surrounding main and non-thin sands. The water absorption profile shows that the absolute water absorption of Well 110 in the C32-1 unit is 12.28 m³/d. Therefore, injection well 110 and production well 111 form an effective injection-production relationship, and well 108 and well 109 are just on the mainstream line. Therefore, it is judged that the non-main thin sand of well 108 in C32-1 has been flooded with medium to high water content, and the probability of high water cut after hole patching is high, so it is considered not to patch holes (Figure 4 and Figure 5).

Figure 4. Sedimentary facies belt of C32-1 in Block A
Figure 5. Well 110 isotope absorption profile

5. Conclusions
In this paper, based on the study of the "four injection and nine production" off-balance-sheet reservoir test area in Block A, the communication relationship of off-balance-sheet sand bodies is deeply
described, and the influence of the dominant bands on the perforation scheme of new and old wells is discussed, and finally the perforation scheme is optimized to guide the dynamic development.

1. The dominant bands of off-balance-sheet reservoirs in the "Four Injection and Nine Production" test area of Block A are mainly developed in Sarthou oil layer, accounting for 53.8%, mainly embedded and extended.

2. Vertical sand body contact modes of 2 categories and 7 subcategories are established. The sedimentary facies belt map is optimized on the plane, and the dominant belt is characterized by special purple, which is well connected with effective sandstone. Green is the conventionally known low-permeability and ultra-low-permeability sandstone, which has poor communication with effective sandstone.

3. The perforation schemes of 13 new wells in the test area were optimized based on the principle of "no shooting at the inner leading edge, selective shooting at the outer leading edge I and II, and total shooting at the outer leading edge III and IV". On the basis of the original perforation layer selection, 11 out of 27 sedimentary units of the outer front I-II type were re-determined. In view of the old well patching scheme, it is proposed to judge whether this layer is flooded through the off-balance sheet reservoir connectivity mode to determine whether perforation is possible.

References
[1] Wang Qimin. Research and development of off-surface reservoirs in oil fields. Foreign Oil Field Engineering, 1998: 5-7.
[2] Yuan Chunjing, Research and Application of Fracture Network Fracturing Technology in Tight Fuyang Reservoir of Daqing Oilfield, Collection of Oil Production Engineering, September 2017.
[3] Chi Hongtao, Application of Fracture Network Fracturing Technology in Low Permeability Reservoir Development, Chemical Engineering and Equipment, No.7, 2019.