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Study on the Development Effect and Well Pattern Adaptability of Eastern Xing No.1 - No.2 Area

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Abstract: The eastern part of Xing No.1 ~ No.2 area is located in the northeast of Xingbei development area, Daqing oilfield. This block has the "double height" feature of high degree of production and high comprehensive water cut. Because the block has produced oil for a class of reservoirs for three times, the overall production degree is relatively high. In order to effectively improve the block water flooding development effect, this paper adopts several evaluation indexes to study the block development effect and well pattern adaptability.

1. Introduction

Located at northeastern of Xingbei development zone, eastern Xing No.1 ~ No.2 area is currently having the "double height" feature of high degree of production and high comprehensive water cut. As the block has undergone three times oil recovery of first class of oil layers. The overall recovery degree is relatively high, reaching 61.3%, and the average comprehensive water content of water drill well network has reached 97.7%. Among them, the secondary infill well network developed for thin- poor reservoirs has a water content of 97.5, and the average single well daily oil production is only 0.8t, resulting in the development effect of water flooding getting worse and worse [1-4].

2. Evaluation of Development Effect

2.1. Utilization Rate of Water Injection

Analysis of water injection utilization status: the water injection utilization rate mainly reflects the completion degree of injection-production system within the corresponding time, including well pattern completion degree and oil formation utilization degree.

2.1.1. Evaluation of Water Retention Rate. The cumulative water retention is usually expressed as a percentage by the following formula:

$$C = (\sum Q_i - \sum Q_w) / \sum Q_w \quad (1)$$

Where: Q_i - water injection volume, 10^4m^3 ; Q_w - water production, 10^4m^3 .



The higher the water content is, the larger the displacement is, the smaller the underground water storage rate is, and the effect of water flooding becomes worse. The above equation is used to calculate the curve of actual cumulative water storage rate of eastern Xing No.1 ~ No.2 reservoir (FIG. 1).

As can be seen from the figure, the water production in the initial production stage of the research area was small, and the water retention rate was high, reaching above 90%. Later, the water production gradually increased, and the cumulative water retention rate continued to decline. It is still in the slow decline stage till now, indicating that the utilization rate of water injection in the primary well pattern is relatively poor.

2.1.2 Evaluation of Water Consumption Rate. Water consumption is another important index to measure the utilization rate of water injection. Low water consumption indicates high utilization rate of water injection and is an important basis for adjusting injection volume.

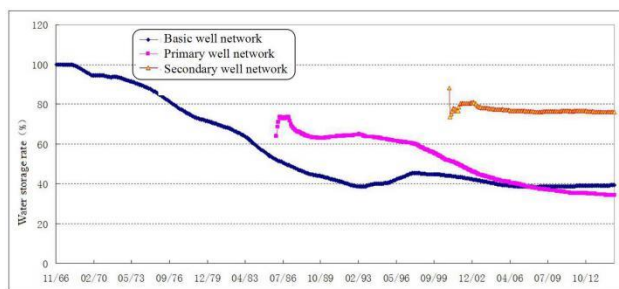


Figure 1. change curve of water retention rate over time

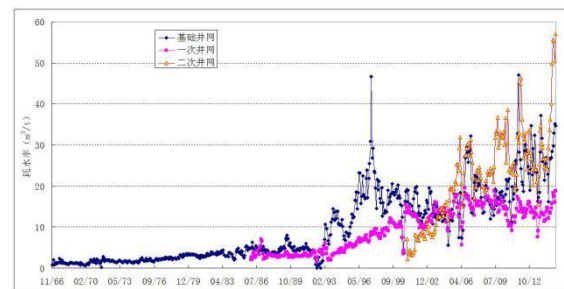


Figure 2. change curve of water consumption over time

As can be seen from FIG. 2, since water injection in Xing No.1~ No.2 area, the reservoir has entered water- containing stage and the water consumption rate has been rising rapidly, as water consumption rate of the basic well pattern was mostly more than 30m³/t at present. The water consumption of primary well pattern is relatively stable, currently floating around 15m³/t. The water consumption of secondary well pattern continued to rise to more than 50m³/t at present (FIG. 2). This situation not only accelerated the increase of water content, but also increased the cost of oil production, so the injector production relationship needs to be adjusted.

2.2. Rising Characteristics of Water Content

Water content rise rate is defined as the rise in moisture content per 1% of produced geological reserves. The difference between the moisture content at the end and the beginning of the use phase in the actual reservoir is calculated from the difference between the end of the previous phase and the initial recovery.

From the curves of moisture content and water content rise rate (FIG. 3), water content in the early stage rose higher and changed around 5. From 1999 to now, the increase rate of water content has been less than 5, with an average of 0.848, indicating that the increase rate of moisture content will not be too large in the future.

2.3. Evaluation of Water Drive Characteristics

Firstly, select the representative phase permeability curves in the research area. Once again, select each S_w , and calculate the corresponding K_{ro} 、 K_{rw} . Then, calculate R and f_w with equations 2 and 3, finally make $R \sim f_w$ relationship curve (FIG. 4), and compare with the mine data.

$$R = \frac{S_w - S_{wi}}{1 - S_{wi}} \times 100 \quad (2)$$

$$f_w = \frac{1}{1 + \frac{\mu_w K_{ro}}{\mu_o K_{rw}}} \times 100 \quad (3)$$

Where: R_{--} extraction degree, %;

μ_w -- viscosity of water, mpa.s;

S_{wi} -- irreducible water saturation, %;

μ_o -- formation crude oil viscosity, mpa.s;

S_w -- water saturation, %;

f_w -- moisture content, %;

K_{ro} -- oil phase relative permeability; K_{rw} -- Water relative permeability.

It can be clearly seen from FIG. 4 that compared with the standards- shaped curve, the type of water content in Xing No.1~No.2 area, is closer to convex type, that is, the water content in the early stage rises fast, the water content in the later stage rises slowly, that is, most recoverable reserves should be produced in the high water-cut stage. At present, the recovery degree is 44.15%, while the water content is 92.69%, which is basically consistent with the theoretical value.

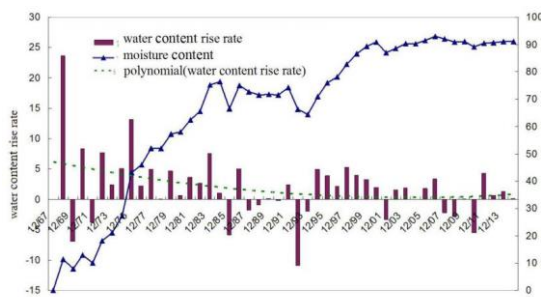


Figure 3. curve of water content rise rate

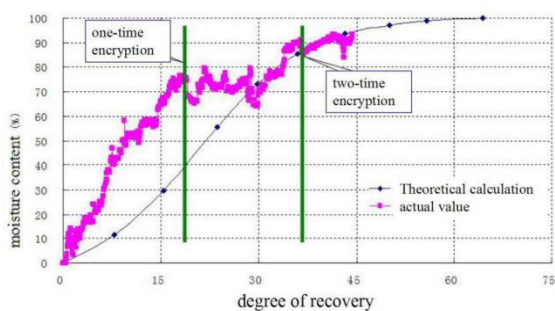


Figure 4. curve of recovery degree and moisture content

2.4. Actual Water Drive Effect Evaluation

2.4.1 A type Water Drive Characteristic Curve. Water drive characteristic curve can be used not only in the entire reservoir, but also in the analysis of a single well. The calculation formula is as follows:

$$\lg W_p = A + BN_p \quad (4)$$

$$N_p = \frac{1}{B} \left[\lg \frac{f_w}{2.303B(1-f_w)} - A \right] \quad (5)$$

$$N_d = 7.5/B \quad (6)$$

Where: W_p -- cumulative water production, $10^4 m^3$; N_p -- cumulative oil production, $10^4 t$;

N_d -- water-driven reserves, $10^4 t$.

A and B values can be obtained from A type water drive characteristic curve (table 1).

Table 1. Statistical table of predicted results of A type water drive characteristic curves

Indicators	Basic well pattern	Primary infill pattern	Secondary infill pattern
A	1.2215	1.3278	0.8505
B	0.0039	0.0071	0.0023

2.4.2. B Type Curve Water Drive Characteristics Curve. There is a relationship between the water content and the degree of recovery in any water drive reservoir. If the reservoir properties are similar, the B type curve tends to be consistent after a certain development stage. In the process of development, if we know the relationship between the water content and the degree of production of the reservoir, we can calculate the ultimate recovery rate of the reservoir. The expression of B type water drive characteristics curve is:

$$\lg[f_w/(1-f_w)] = 7.5 \times (R - E_R) + 1.69 \quad (7)$$

Where: f_w -- moisture content, decimal; R -- production degree, decimal;

E_R -- ultimate recovery, decimal.

According to equation 7, the $f_w \sim R$ relationship map under different recovery rates (E_R) can be produced with recovery rate as the modulus. Then, according to the actual production data of the oil field, the $f_w \sim R$ relation curve is drawn (FIG. 5).

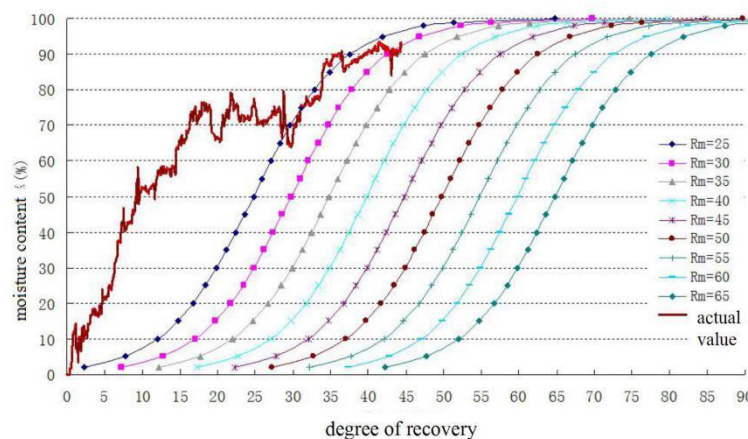


Figure 5. relation curve between the degree of recovery and moisture content

As can be seen from FIG. 5, the rise and fall of water content is very large, and the fitting with the theoretical curve is poor, mainly because the number of wells is small, the well pattern of each layer is extremely imperfect, and the overall effect is poor.

After primary and secondary well pattern encryption, the development effect of eastern Xing No.1~No.2 area is getting better, and recovery degree is consistent with the theoretical value. But fine development adjustment and remaining oil tapping potential need to be carried due to fast production decline, high water consumption rate, poor water flooding efficiency, uneven use of layers and other contradictions. Better development results will hopefully be achieved.

2.5. Development Effect Prediction

Based on the existing well network, the development effect is predicted while working system is kept unchanged. It is estimated that the comprehensive water content of eastern Xing NO.1 ~ NO.2 area will reach 96.76% by 2024 (5 years later), and the recovery degree of water drive will be 46.78% at the end of the period. The prediction results of development indicators after 5 years are shown in Table 2.

Table 2. five-year development index forecast of current well pattern

The serial number	Year/month	Annual oil production (10 ⁴ t)	Cumulative oil production (10 ⁴ t)	Degree of Recovery (%)	Speed of oil Production (%)	Comprehensive water content (%)
1	2020/12	3.79	20.58	45.73	0.292	96.30
2	2021/12	3.64	24.21	46.01	0.280	96.49
3	2022/12	3.47	27.69	46.28	0.267	96.62
4	2023/12	3.31	31.00	46.53	0.255	96.70
5	2024/12	3.16	34.16	46.78	0.243	96.76

3. Evaluation of Well Pattern Adaptability

3.1. low control degree of thin-poor reservoir

From control degree of different oil layer groups, the connectivity of SII group is the best, which is 89.6%, the control degree of PI4 and below groups is the worst, which is 51.1% while the multi-directional connectivity ratio is only 5.6% (Table 7). The large distance of wells is the main reason for the low control degree of thin- poor reservoirs.

Table 3. water drive control degree of different oil layer groups

Reservoir group	SII	SIII	PI4 and below	total
One-way connected (sandstone, %)	26.8	29.1	33.2	34.9
Two-way connected (sandstone, %)	31.9	29.6	12.3	26.4
Multidirectional connected (sandstone, %)	30.9	28.1	5.6	16.3
Total (sandstone, %)	89.6	86.8	51.1	77.6

3.2. Low use degree of Thin-poor Reservoirs

From the current water absorption status of three types of oil reservoirs in eastern Xing No.1 ~ No.2 area, the proportion of water- absorbing sandstone is 68.1%, and the effective ratio of water absorbing is 76.8%. Among them, The proportion of water- absorbing in thin sandstone layer (effective thickness is less than 0.5m) is 75.4%, the effective ratio of water absorption is 74.2%, while the water- absorbing of reservoir outside the table is 52.4%, showing low using degree of thin- poor oil layers (Table 4).

Table 4. accumulative statistics of 3 times of isotopic water absorption

Reservoir group	SII	SIII	PI4 and below	total
Thick layer in the table (sandstone, %)	95.2	87.3	52.7	79
Thin layer in the table (sandstone, %)	88.2	78.4	34.4	75.4
Reservoir outside the table (sandstone, %)	77.1	63.9	31.9	52.4
Total (sandstone, %)	87.1	73.5	40.1	68.1

3.3. Imperfect of Thin-poor Reservoirs Well Network

In eastern Xing No.1 ~ No.2 area, three sets of water drive development well networks are deployed, which are basic, one-time encryption and two- time encryption water drive development well network. Among them, three sets of development series was deployed in 1985, respectively are 350m×250m anti- nine- point area well pattern of Saertu oil layer, 250m×250m five- point area well pattern of PI4 and below oil layer. Two- time encryption well network of this block is 250m×250m five- point area well pattern and mining target is thin- poor reservoir of Portugal I4 and below. Moreover, the distance

between injection and production well of one- time encryption and two- time encryption well network are all above 250m, showing poor adaptability to thin- poor reservoir.

4. Conclusion

Under the condition of the existing well network, the control degree of thin- poor reservoir is relatively low. The control degree is 82.8% in the thin- poor reservoir, whose effective thickness is less than 0.5m. In addition, the multidirectional connectivity ratio of thin- poor reservoir is relatively small, and the control degree is low. Thin- poor reservoir shows poor physical properties and low resource utilization degree. From the current well spacing and perforation situation of encryption well network, the well pattern of thin- poor reservoir is not perfect and its adaptability to thin- poor reservoir is poor.

Acknowledgments

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