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Analysis on the current situation of water injection development in a block of sunenoer Oilfield

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Abstract. Surennuoer oilfield is located in the north of Wuerxun Sag, beierhu depression, Haita basin. This paper introduces the geological characteristics of the oilfield from the aspects of oilfield structure and reservoir physical properties; On the basis of carefully combining the dynamic and static data, this paper analyzes the dynamic development characteristics of the oilfield since it was put into development. At the same time, combined with its characteristics, it summarizes the main understanding of the current oilfield development, which provides reference experience for the future water injection development adjustment of low permeability oilfields, and has certain reference significance for the efficient and rapid development of similar oilfields.

1. Survey

1.1 Development profile

By the end of 2021, the proved geological reserves of more than 6 million tons and the oil-bearing area of 16.7km2 have been submitted to the south 2nd member of the sunenor structural belt. At present, 21 oil and water wells have been put into operation in a certain block, including 17 oil production wells and 4 water injection wells. The produced oil-bearing area is 1.8km2 and the produced geological reserves are 72 × 104t. By December 2021, the cumulative water injection is 12.85 × 104m3, with cumulative oil production of 1.86 × 104t, oil production rate 0.24%, recovery degree 3.42%, cumulative injection production ratio 3.46, comprehensive water cut 41.7%.

1.2 Oilfield geological characteristics

Surennuoer oilfield is located in the north of Wuerxun Sag, beierhu depression, Hailar Basin, on both sides of the northern Wubei fault. The North Urumqi fault divides the surinnor structural belt into two parts: the north and the south. The Haican 4 block is the main part of the south block, and the S1, S2 and S3 development and test areas are the main part of the North block.

It can be seen from the top structural map of the second member of the south section that the S1 fault block is controlled by a NE trending fault and a NS trending fault, and the whole structural trend is a nose structure with low northwest southeast and high middle. The whole stratum inclines to NNW with a dip angle of 5 ~ 8 °, and the strike is ne. The structural high point is near well S11 with an altitude of -738m, and the low point is at the southeast corner of the study area with an altitude of -983m and a structural height difference of 245m. There are three faults in the area. The main fault is an inherited fault with early development, long extension and large scale. All faults are normal faults.

From bottom to top, sunenoer oilfield can be divided into low base, Xing'anling group, Tongbomiao formation, Nantun Formation, Damoguaihe Formation, Yimin formation and Qingyuangang. The main oil-bearing horizon in sunenoer oilfield is Nantun Formation, followed by Tongbomiao formation. The main oil-bearing horizon of Su 102 fault block is the upper part of the second member of Nantun Formation, which is divided into three sandstone formations and 19 small layers.

The reservoir rock types of Naner member include siltstone, fine sandstone, medium coarse sandstone and unequal grain sandstone. According to the statistics of the content of clastic components of Su 102 and Su 1 (table 2-10), the type of sandstone is lithic arkose. The clastic components are mainly rock debris, feldspar and quartz. The absolute component of acid volcanic rock in rock debris accounts for the majority of rock debris, and the rest are metamorphic rock debris. The average feldspar content is 39.7%, the average quartz content is 27.0%, and the average rock debris content is 19.9%. The pore filler is mainly the mixture of argillaceous and kaolinite, calcite is crystalline and carbonate is banded and lumped; The clastic structure is characterized by equal deviation, roundness, sub edge, sub circle and moderate weathering, the contact relationship is mainly point contact, and the cementation type is mainly pore type or contact type, showing the multi source and near source sedimentary characteristics of low maturity of rock composition and rapid change of composition plane[1].

The physical property of the reservoir is poor. The porosity of the reservoir is 5.2% ~ 25.8% and the average porosity is 14.2%; Permeability is 0.02 ~ 657 × $10^{-3}\mu m^2$,

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average permeability $74.3\times10^{-3}\mu m^2$。Among them, the number of samples with porosity less than 10% accounts for 41.3% of the total samples, the number of samples with porosity between 10% ~ 25% accounts for 54.3%, and the number of samples with porosity greater than 25% accounts for 4.3%.This shows that the reservoir porosity of this block is mainly medium low porosity. Permeability below $1\times10^{-3}\mu m^2$ The number of samples in accounts for 66.7% of the total, 1 ~ $100\times10^{-3}\mu m^2$,The number of samples between accounts for 15.5% of the total, more than $100\times10^{-3}\mu m^2$ The number of samples accounts for 17.7% of the total, indicating that the reservoir permeability is mainly ultra-low permeability, and there are a small number of medium high permeability reservoirs locally.

The vertical oil-water distribution in a development block generally presents the characteristics of upper oil and lower water, which can be expressed in three forms: the upper part is oil layer, the lower part is dry layer, the upper part is oil layer, the lower part is oil-water same layer, the upper part is oil layer, and the lower part is oil-water same layer and water layer. On the plane, there is no unified oil-water interface in this block. Whether the oil bottom or the top bottom boundary of the same layer, the water top interface is basically in a scattered distribution state, and there is no unified interface, which also changes with the change of structure. It is comprehensively analyzed that the oil reservoir in the South second member of Su 102 development fault block is a lithologic structural oil reservoir.

2. Characteristics of waterflooding development

2.1 Oil production characteristics

The wells with low oil production, low oil production intensity and high oil production are located at the shaft. The oil wells in the block were put into operation in october2003, with an average daily oil production of 2.50t, daily water production of 0.97t and water cut of 28.5% in the initial stage of a single well. There are only 2 wells with water content greater than 70% at the initial stage of production. In October, 2010, the average daily oil production of a single well was only 0.49t, the daily water production was 0.35T, and the water content was 42.0%. The average initial oil production intensity of a single well is 0.6t/d.m3. At present, the oil production intensity is 0.1t/d.m3. The average cumulative oil production of a single well is 1243t, and the cumulative water production is 762m3. Most of the cumulative oil production of a single well is less than 1000t. Only three wells have a cumulative oil production of more than 2000t, and the oil production of these three wells accounts for 42.0% of the total oil production, which is located at the structural axis. At present, there is only one well with a daily oil production of more than 1t.

Table 1. Cumulative oil production classification statistics of a block

Cumulative oil production classification	Number of wells	Cumulative oil production (t)	Accumulated water production (t)	Moisture content (%)	Oil production ratio (%)
<1000	8	3203	3229	50.2	15.2
1000~2000	6	9054	6448	41.6	42.8
>2000	3	8880	3183	26.4	42.0
total	17	21137	12960	38.0	100.0

2.2 Pressure characteristics

The reservoir pressure drops rapidly and the formation pressure level is low. The production decline of elastic mining is large; The daily oil production has decreased from 2.5t in the initial stage to 0.49t. The annual average comprehensive decline rate is 11.5% and the decline range is 80.4%. The original formation pressure of the oilfield is 13.59mpa. At present, the formation pressure is 3.99mpa, the pressure maintenance level is 29.4%, the recovery degree is only 3.41%, and the formation pressure drops rapidly.

Table 2. Pressure variation diagram of a block over the years

Year	Formation pressure MPa
1	6.12
2	4.83
3	5.44
4	4.18
5	4.13
6	3.99

2.3 Water injection characteristics

The water injection of water wells varies greatly. The water absorption capacity of the shaft water well is strong. The dynamic data of water injection wells are collected. Well 4 and well 1 are closed for a long time. By the end of December 2021, the cumulative water injection of well 4 is only $0.46\times10^4m^3$. The cumulative water injection of well 1 reaches $1.20\times10^4m^3$; The water injection of well 2 and well 3 of the other two wells is in good condition, and the cumulative water injection reaches 4.63% respectively $\times10^4m^3$、$4.52\times10^4m^3$。 At present, the daily injection allocation is $60m^3$, the daily actual injection is $43m^3$, the average injection pressure is 12.2mpa, the injection intensity is $2.43m^{3/}d.m$, the water absorption index is $3.5m^3/MPa$, and the cumulative injection production ratio is 3.46.

The well with good water injection condition is located in the middle of a block, and the sand body is well developed and connected. Wells with poor water injection status are distributed at the edge of the block and near the fault area at the edge. Adverse factors such as poor sand body development, poor connectivity and thin thickness lead to rapid increase of water injection pressure in a short time, resulting in difficulties in water injection.

3. Preliminary understanding

3.1 Strong reservoir heterogeneity

According to the well logging interpretation statistics, the permeability grade difference of each well in the second oil formation of the South second member of a certain block varies greatly, ranging from 1.35 to 17427, and the average permeability grade difference is 1040.78. The permeability breakthrough coefficient ranges from 1.35 to 6.8, with an average breakthrough coefficient of 2.63. The permeability variation coefficient ranges from 0.35 to 2.37, with an average variation coefficient of 0.99.

According to the log interpretation statistics, the permeability grade difference of each small layer in the second oil formation of the South second member of a certain block is very different. There are great differences in the plane distribution of porosity and permeability values. The average porosity of each small layer interpreted by logging of oil formation II is 10.8 ~ 16.73%, with an average of 15.15%, and the average permeability is 14.90 ~ $529.63\times10^{-3}\mu m^2$, on average 178.40 $\times10^{-3}\mu m^2$。

In general, the physical property changes of each small layer in the South second member of a block are characterized by alternating distribution of high and low values from southwest to northeast.

3.2 The scale of reservoir sand body is narrow

The proportion of unidirectional connected thickness and disconnected thickness is relatively large. The average effective thickness encountered in single well drilling of development well is 5.9m, the average number of effective layers encountered in single well drilling is 4.8, the average effective thickness of single layer is 1.2m, and the maximum effective thickness encountered in single well drilling is 11.8M and the minimum is 1.7m.

By dissecting the connectivity of different small layers, the results show that the connectivity of reservoirs less than 1.0m is poor. Compared with the thickness of reservoirs greater than 2.0m, the connectivity is 22.8% lower. Due to the narrow scale of sand body, the vast majority of development wells are in one-way connected state, with a large proportion of one-way thickness and disconnected thickness. However, the water injection effect has not been obvious, and the current well pattern and well spacing form have not achieved effective displacement.

3.3 High reservoir water storage rate

Water storage rate is an index to evaluate the utilization rate of water injection in oil field. It indicates the ratio of injected water remaining in the formation. The higher the water storage rate, the lower the utilization rate of injected water. According to the definition, the calculation formula of stage water storage rate is:

$$C = \frac{Q_i - Q_w}{Q_i} = 1 - \frac{1}{IPR} \times \frac{1}{1 + B(\frac{1}{f_w} - 1)} \quad (1)$$

Where:C-water storage rate;Q_i-water injection volume,10^4m^3;Q_W-water production,10^4m^3;B- conversion coefficient;IPR-injection production ratio;FW - water content, F.

It can be seen from the above formula that the injection production ratio is certain. With the increase of recovery, the water content increases, the water injected into the formation is continuously discharged, and the water storage rate decreases with the increase of water content. After the development of a block, the actual water storage rate is 0.91, and the water storage rate is at a high level, reflecting the extremely low utilization rate of water injection energy.

3.4 Poor water injection efficiency of oil production wells

In the tracer test of well cluster 3 in 2009, the surrounding oil wells 1, 2 and 4 received certain water injection effect, but it was not obvious, and the produced tracer was discontinuous.

From the logging curves of infill wells, it is found that only the electrical logging curves of two wells show obvious positive anomalies, and there are weak signs of water injection effect.

4. Conclusion

1. The natural energy of the oil field is low, the formation pressure of elastic production decreases rapidly, and the production decreases greatly.
2. The oil-water relationship in the block is complex, there is no unified oil-water interface, and it is generally high in the South and low in the north.
3. Due to the narrow size of sand body and poor connectivity, no obvious water injection effect has been observed.

Table 3. Tracer recovery of well cluster 3

Water injection well	Connected production well	Well spacing（m）	Days of exposure (d)	Propulsion speed(m/d)	Maximum produced concentration(mg/l)
Well3 (NH4SCN)	Oil1	425	84	5.05	1.84
	Oil2	300	72	4.17	2.07
	Oil3	425	--		
	Oil4	300	210	1.43	3.53
	Oil5	425	75	5.67	0.21
	Oil5	300			
	Oil7	425			
	Oil8	300			

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