Optimization of the combination method for tertiary oil recovery layers in Block N

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Abstract. This article analyzes the development status of oil layers in Zone N, and based on the principles of layer combination in other injected blocks in Zone X, compares the development status of oil layers in Block M, and formulates two sets of layer combination plans for tertiary oil recovery in Block N. By comparing and optimizing the two sets of layer combination plans, the final decision is made to conform to the combination plan for tertiary oil recovery in Block N.

Keywords: sedimentary characteristics; Tertiary Oil Recovery; Stratigraphic combination.

1. Introduction

Block N is located in the southern part of X development zone, with relatively single reservoir development and overall small development thickness; Compared with other main oil layers in the X development zone, the main oil layer has a relatively thin single layer thickness, relatively low permeability, and a small development scale of a single channel sand body. The reservoirs available for tertiary oil recovery are also extremely limited. From the injection polymer block in X development zone, it is recognized that the deployment and combination of tertiary oil recovery well networks should consider the actual situation of a single reservoir in a certain block, and cannot fully adopt the thinking formula. The overall development mode and specific technical implementation of tertiary oil recovery in N block should be different from other blocks in X development zone.

2. Development status of oil layers in Block N

The oil bearing area of Block N is 33.6km2, with an average single well developed sandstone thickness of 36.8m, an effective thickness of 18.1m, and a geological reserve of 5840.7 × 104t, K2, K3, and Y oil layers are developed in the entire area, with Y2-3 being the main oil layers and the rest being non main oil layers.

Table 1. Parametric statistics of Lithology in Block N

Layer number	Medium sand content（%）	fine content（%）	Silty sand content（%）	shale content（%）	Median particle size（mm）
$Y1_{21}$	0.13	36.59	57.57	5.70	0.08
1_{22}	5.98	61.88	22.37	6.95	0.14
1_{23}	8.64	41.31	38.03	10.42	0.11
2_{1a}	5.53	61.16	25.87	6.51	0.13
2_{1b}	11.60	71.70	9.90	6.80	0.20
3_2	19.17	56.13	17.63	6.17	0.18
3_{3a}	10.01	52.81	23.43	10.62	0.14
3_{3b}	0.96	73.39	19.56	5.94	0.15
	9.17	59.95	23.15	6.88	0.15

The main oil layers are delta distributary plain facies (Y group 31, 32 layers) and inner front facies sedimentation (Y group 21a, 21b, 22, 33a, 33b layers), with sand bodies distributed in strips and blocks; Except for Y12, which is a delta inner front facies, the non main oil layers are sedimentary deposits of delta outer front facies, and the sand bodies are sheet-shaped, locally banded, or scattered. According to the analysis of lithologic data of 4 sealed coring wells (Table 1.), the channel sandstone of oil layer in Group Y is mainly composed of fine sand and Siltstone, with the contents of fine sand and siltstone being 59.95% and 23.15% respectively.

3. Stratigraphic combination principle

Based on the theoretical research results and combined with the actual experience of polymer injection blocks, the principle of layer combination for N block polymer flooding is determined as follows:

⑴The thickness of a set of layers should be determined based on the scale and production succession of the surface polymer injection system, as well as the total thickness of the upper layer. The thickness of the layers should be as uniform as possible.

⑵The polymer flooding units within a set of layers should be relatively concentrated, and the geological conditions of the oil layers within the layers should be as close as possible.

⑶ Strata combination is carried out using sandstone formations as units. To meet the requirements of polymer injection process and avoid water polymer flooding channeling, it is required that there should be a stable distribution of interlayer between two sets of polymer injection layers. The drilling rate of wells with interlayer thickness greater than 1.5m should be greater than 80.0%.

⑷The adjustment objects of polymer flooding are mainly river sand and main thin layer sand.

4. Layer combination scheme

4.1. Stratigraphic combination of Block M

The M block combination in X development zone that has undergone polymer flooding is divided into three sets of layers: Y3 layer, a separate set of layers, the first time returning to Y1+2 layer, and the second time returning to K2+K3 group.

Table 2. Statistical Table for Adjustable Thickness and Permeability of Block M.

Oil reservoir group	H 有≥1.0m		1.0m > H 有≥0.5m		Total	
	sandstone (m)	effective (m)	sandstone (m)	Effective (m)	sandstone (m)	effective (m)
K2 group	3.3	2.5	5.0	2.2	8.3	4.7
K3 group	0.2	0.2	0.6	0.3	0.8	0.4
Y1	0.8	0.6	1.2	0.8	2.0	1.4
Y2	2.4	1.9	1.8	1.4	4.1	3.3
Y3	5.8	4.7	3.3	2.7	9.1	7.4
summation	12.5	9.9	11.8	7.2	24.3	17.1

From the thickness distribution of each set of strata, the adjustable effective thickness is basically close (Table 2, Table 3)

Table 3. Combination Results of Tertiary Oil Production Layer Series in Block M

Oil reservoir group	H 有≥1.0m			1.0m > H 有≥0.5m			Total		
	sandstone (m)	effective (m)	Permeability ($10^{-3}\mu m^2$)	Sandstone (m)	effective (m)	permeability ($10^{-3}\mu m^2$)	sandstone (m)	effective (m)	permeability ($10^{-3}\mu m^2$)
K2 group	4.0	2.9	198	5.5	3.3	102	9.5	6.2	150
K3 group	0.6	0.5	145	1.9	1.2	101	2.5	1.7	124
Y1	1.1	0.9	209	0.6	0.3	116	1.7	1.2	161
Y2	4.0	3.0	226	0.4	0.2	143	4.4	3.2	218
Y3	7.4	6.0	357	0.4	0.2	139	7.8	6.2	344
summation	17.2	13.3	301	8.9	5.2	125	25.9	18.5	288

4.2. N Block Stratigraphic Combination

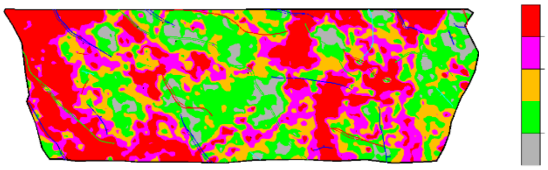
Block N is calculated using the thickness of old wells, with an average adjustable sandstone thickness of 25.9m per well and an effective thickness of 18.5m (Table 4).

The interlayer between the sandstone formations in the permeability N block is well developed, providing good interlayer conditions for measures such as layered injection and fracturing during polymer injection. The drilling rate of intervals with a thickness greater than or equal to 2.0m between each oil layer group is above 76% (Table 4), which meets the requirements of polymer flooding layer combinations for intervals.

Table 4 Statistical Table for the Development of Interbedded Interbedded Layers in Each Layer System

stratum	1m> compartment >0m (%)	1.5m> compartment≥1.0m (%)	2.0m> compartment≥1.5m (%)	compartment≥2.0m (%)	Average interlayer thickness (m)
K311---Y1_{1a}	0.6	0.5	0.6	98.3	5.0
Y1_{2b}---Y 2_{1a}	8.0	7.7	7.4	76.9	4.5
Y2_{2}---3_{1}	7.2	6.5	5.7	80.6	5.7
Y3_{3b}---4_{1}	4.2	7.6	6.7	81.5	4.8
Y3_{3b}---4_{1}	4.2	7.6	6.7	81.5	4.8

From the perspective of the adjustable effective thickness plane distribution, this block cannot continue to use the layer series combination method of Block M, mainly due to two factors:



Fog.1 Thickness Contour Map of Layer Y3 in Block N

One is that Y3 layer serves as a separate set of layers, resulting in a high proportion of inefficient and ineffective wells. The adjustable effective thickness of layer Y3 can reach 6.2m, which is 1.2m smaller than the adjustable thickness of block M. From the plane distribution of adjustable thickness for single wells in Block N, there are significant differences in the adjusted thickness of oil layers in different regions. The implementation of large-scale well layout results in a high proportion of inefficient and ineffective wells.

The thickness contour map of Y3 layer in Block N predicts the drilling situation of each subdivision unit thickness of the new well Y3 layer after uniform well distribution. The proportion of wells with an effective thickness of less than or equal to 4m reaches 27.98%. Compared with Block M, the proportion of wells with an effective thickness of less than 4m is 14.58 percentage points higher (Table 5)

Table 5 Prediction Table for Adjustable Thickness of Y3 Layer Polymer Flooding New Wells

block	Number of wells (Mouth)	Average interlayer thickness		$H_{有}$<1m		1m≤$H_{有}$<4m		4m≤$H_{有}$<6m		6m≤$H_{有}$<8m		$H_{有}$≥8m	
		sandstone (m)	effective (m)	Number of wells (Mouth)	proportion (%)	Number of wells (Mouth)	proportion (%)	Number of wells (Mouth)	proportion (%)	Number of wells (Mouth)	proportion (%)	Number of wells (Mouth)	proportion (%)
N block	2098	9.6	6.2	61	2.91	526	25.07	502	23.93	461	21.97	548	26.12
M block	2174	11.51	7.6			228	10.49	575	26.45	694	31.92	677	31.14

The second is to vertically combine into three sets of layers, with a high proportion of inefficient and ineffective wells returning to the Y1+2 layer. The adjustable thicknesses of Y1 and Y2 layers are 1.2m and 3.2m respectively, with a total thickness of only 4.4m. From the results of uniform well distribution, the proportion of new wells with effective thickness less than 4m in Block N reaches 55.39%, which is 23.32 percentage points higher than that in Block M. The proportion of inefficient and ineffective wells in the Y1+2 layer developed separately is too high (Table 6).

Table 6 Prediction of Adjustable Thickness for New Polymer Flooding Wells in Layer Y1+2

block	Number of wells (Mouth)	Average interlayer thickness		$H_{有}$<1m		1m≤$H_{有}$<4m		4m≤$H_{有}$<6m		6m≤$H_{有}$<8m		$H_{有}$≥8m	
		sandstone (m)	effective (m)	Number of wells (Mouth)	proportion (%)	Number of wells (Mouth)	proportion (%)	Number of wells (Mouth)	proportion (%)	sandstone (m)	effective (m)	Number of wells (Mouth)	proportion (%)
N block	2098	6.1	4.4	237	11.30	925	44.09	424	20.21	325	15.49	187	8.91
M block	2174	7.8	4.9	117	5.38	580	26.68	680	31.28	578	26.59	219	10.07

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If a local well layout method is adopted in an area with an effective thickness greater than 4m, the injection production relationship will be incomplete for the first Y3 layer and the first upward Y1+2 layer, which will have a significant impact on the development effect of polymer flooding and a significant loss of geological reserves.

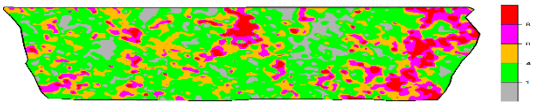

Fig.2 Thickness Contour Map of Layer Y1+2 in Block N

5. Comparison and optimization of layer combination schemes

Therefore, according to the principle of formation combination and the development of oil layers in Block N, a study on the optimization of formation Combinatorial optimization is carried out in Block N, and two sets of formation combination schemes are designed (Table 7).

Table 7 Comparison of Polymer Flooding Layer Series Combination Schemes in Block N

programme	Stratigraphic combination	adjustable thickness		permeability ($10^{-3}\mu m^2$)	Adjustable geological reserves (10^4t)	pore volume (10^4m^3)	Well section length (m)
		sandstone (m)	effective (m)				
Scheme 1	Y2+3	12.4	9.4	301	3922	7167	32
	Y1+ K2~K2I	13.6	9.1	156	2352	4621	103
Scheme 2	Y1-3	14.0	10.6	290	4417	8071	49
	K2~K3	12.0	7.9	147	1857	3717	86

Option 1: Y2 and Y3 are combined into a set of layers, and the oil layers of Y1+K2~K2I groups are returned upwards

(1) Y2+3 oil layer. The thickness of sandstone developed in layers Y2 and Y3 is 15.0m, with an effective thickness of 9.6m (Table 8). The adjustable effective thickness is 9.4m, which can form a certain scale.

(2) Y1+K2~K3 oil layers. The developed sandstone has a thickness of 38.7m, an effective thickness of 13.1m, and an adjustable effective thickness of 9.1m.

Table 8 Thickness Statistics Table for Option 1

Oil reservoir group	$H_{有} \geq 0.5$m		$H_{有} < 0.5$		Off balance sheet (m))	合计	
	sandstone (m)	effective (m)	sandstone (m)	effective (m)		sandstone (m)	effective (m)
First set of layers	12.2	9.4	0.7	0.2	2.0	15.0	9.6
Upper regurgitation system	13.7	9.1	9.9	4	15.2	38.7	13.1

Advantages:

The adjustable thickness of both layers is relatively large, and the proportion of inefficient wells is low.

The first set of Y2+3 layers with adjustable geological reserves of 2922 × 10^4t, pore volume 7167 × 10^4m^3. 76.7% of wells have an adjustable effective thickness of over 6.0m. 74.5% of wells have an adjustable effective thickness of over 6.0m in the upper layer system. Control adjustable reserves to 2352 × 10^4t, pore volume 3621 × 10^4m^3.

The first series of well sections is relatively short, with a length of 32m.

The properties of the upper return layer series oil layers are similar, which is beneficial for development.

From the statistical results of permeability, it can be seen that the average permeability of layers K2, K3, and Y1 is not significantly different (Table 4-2), with a value of 150, respectively × $10^{-3}\mu m^2$,124 × $10^{-3}\mu m^2$, 161×$10^{-3}\mu m^2$, the average permeability of each sub layer is greater than 100 × $10^{-3}\mu m^2$ satisfies the conditions for the combination of layers.

Disadvantage: The well section of the upper return layer system is relatively long, with a length of 103m, which has a certain impact on the development effect of polymer flooding.

Option 2: Y1, 2, and 3 are combined to form a set of layers, and the K2-K3 oil layers are returned upwards

(1) Y1-3 layers: The thickness of sandstone developed in Y1-3 layers is 19.0m, the effective thickness is 11.1m, and

the adjustable effective thickness is 10.6m, which can form a certain scale.

⑵ K2~K3 oil layers: The developed sandstone has a thickness of 34.7m, an effective thickness of 11.6m, and an adjustable effective thickness of 7.9m (Table 4-3). 64.5% of wells have adjustable effective thicknesses above 6.0m.

Advantages:

The first set of polymer flooding has a large adjustable thickness.

The first set of layers Y1-3 has an adjustable effective thickness of 10.6m and an adjustable geological reserve of 4417 × 10^4t, pore volume 8071 × $10^4 m^3$. 82.4% of wells have adjustable effective thickness above 6.0m.

The upper return well section is relatively short compared to Scheme 1, with a length of 86m.

Disadvantages:

The adjustable reserves of the upper layer system are small, and the economic benefits are poor. The adjustable reserves of the upper layer system are only 1857 × 10^4t.

The first set of layers has significant interlayer differences, which affect the polymer flooding effect.

Table 9 Thickness Statistics Table for Option 2

Oil reservoir group	H 有≥0.5m		H 有 < 0.5		off-balance sheet	add up the total	
	sandstone (m)	effective (m)	sandstone (m)	effective (m)	sandstone (m)	sandstone (m)	effective (m)
First set of layers	13.9	10.6	1.5	0.5	3.5	19.0	11.1
Upper regurgitation system	12.0	7.9	9.1	3.7	13.7	34.7	11.6

From the perspective of development, the thickness ratio with an effective thickness of over 0.5m is above 85% (Table 9), but the Y1 oil layer is poorly developed, mainly with narrow and small river channels, and an average permeability of 161 × 10-3 μ M2, the average permeability of river sand is 218 × 10-3 μ M2, the proportion of sand drilling layers in river channels is very low, only 14.65%; And the average permeability of channel sand in Y2 and Y3 layers is 226 × 10-3 μ M2 and 344 × 10-3 μ M2, the proportion of sand layers in the river is higher than 50%. From the perspective of permeability grading (Table 10), Y2 and Y3 layers are better than Y1 layers. The effective permeability of layers Y1, 2, and 3 is greater than 100 × 10^{-3} μm^2 .The effective thickness ratios of m2 are 56.5%, 85.7%, and 90.1%, respectively.

The difference between layers Y1 and Y2 and Y3 is greater, and using only one molecular weight polymer is difficult to meet the adaptability of the polymer to all oil layers.

Table 10. Y1-3 Layer Thickness Classification Table

oil layer	Thickness grading(m)	≥2m	1 ~ 2m	0.5 ~ 1m	≥0.5 m subtotal	< 0.5m	off-balance
Y1	Number of layers(%)	4.9	7.2	11.5	23.6	18.6	57.8
	sandstone thickness(%)	19.0	15.9	15.0	49.9	16.2	33.9
	effective thickness(%)	39.7	25.9	19.9	85.5	14.5	
Y2	Number of layers(%)	24.0	13.9	10.3	48.2	9.4	42.3
	sandstone thickness(%)	58.5	17.0	7.6	83.0	4.2	12.8
	effective thickness(%)	73.8	17.4	6.3	97.5	2.5	
Y3	Number of layers(%)	28.3	8.6	8.4	45.3	8.8	45.9
	sandstone thickness(%)	70.2	8.7	5.0	83.9	3.3	12.8
	effective thickness(%)	86.5	8.0	3.7	98.2	1.8	

Table 11. Permeability Grading Table for Layer Y1-3

oil layer	Permeability grading ($10^{-3}\mu m^2$)	≥400	400 ~ 300	300 ~ 200	200 ~ 100	≥100 subtotal	100 ~ 50	< 50
Y1	Number of layers(%)	4.9	3.2	9.5	18.5	36.1	26.6	37.3
	sandstone thickness(%)	6.1	4.3	14.0	25.9	50.3	26.3	23.4
	effective thickness(%)	5.9	4.6	17.6	28.4	56.5	24.4	19.1
Y2	Number of layers(%)	12.1	8.5	17.2	33.4	71.2	18.3	10.5
	sandstone thickness(%)	14.1	10.0	20.1	37.4	81.6	12.9	5.5
	effective thickness(%)	15.9	10.3	22.0	37.6	85.7	10.7	3.6
Y3	Number of layers(%)	18.7	10.3	18.4	28.6	75.9	14.5	9.6
	sandstone thickness(%)	23.4	11.9	21.0	30.8	87.1	8.9	3.9
	effective thickness(%)	25.4	12.4	21.6	30.7	90.1	7.3	2.6

Through the comparison of two sets of layer series combination schemes, Scheme 1 can ensure that the first stage of polymer flooding can achieve good development results, and the thickness of the adjusted layers in different blocks is uniform, which can fully utilize the potential of Y group reserves, which is conducive to the overall development adjustment of the block and the smooth replacement of upstream production. Therefore, Scheme 1 is recommended as the layer series combination scheme for N block polymer flooding.

6. Conclusion

(1) There is a significant difference in plane thickness during the combination of tertiary oil recovery layers, and implementing large-scale well layout can lead to a high proportion of inefficient and ineffective wells.
(2)The significant difference in interlayer permeability during the combination of tertiary oil recovery layers can affect the selection of polymer injection molecular weight.
(3) When combining the tertiary oil recovery layers, factors such as the interval, well section length, and the replacement of upper return layer reserves should be considered.

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