Research on infill adjustment method for XX narrow and thin sand body oilfield

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Abstract: The sedimentation of XX oilfield is mainly composed of underwater distributary channel sedimentation, and the sand body has the characteristics of "narrow, thin, and scattered". Although basic well network development, primary and local secondary infill, edge expansion adjustment, and corresponding injection production relationship adjustments have been carried out, there are still problems in current development, such as poor well network adaptability, low utilization degree of thin and poor layers, fast production decline rate, long shut-in wells, and many inefficient wells. In order to explore the potential of infill adjustment in narrow and thin sand body oilfields and further improve oilfield recovery efficiency, well pattern infill adjustment work has been carried out, achieving good results. A supporting infill adjustment technology has been formed, which includes "well seismic joint fine reservoir prediction, multi-disciplinary research on remaining oil quantification, multi-parameter evaluation of infill well location optimization, and multi information fusion perforation layer optimization", effectively improving the development effect.

Keywords: narrow and thin sand body oilfield; Non uniform encryption; Remaining oil; Reservoir Description

1. Introduction

XX Oilfield is located in the southern part of XX structure, with a main development of one set of XX oil layer. It belongs to delta front facies sedimentation with low permeability and is mainly composed of underwater distributary channel sedimentation. The sand body is narrow and thin, with obvious banding characteristics, generally between 100-200m in width. The sand body is small in scale and scattered in distribution. Although it has entered the stage of ultra-high water cut development through basic well pattern development, primary and local secondary infill, expansion adjustment, and corresponding injection production relationship adjustment, there are still problems such as poor adaptability of the well pattern, low degree of utilization of thin and poor layers, fast production decline rate, long shut-in, and many inefficient wells, resulting in significant technical difficulties in readjustment. In order to explore the potential of infill adjustment in XX narrow and thin sand body oilfield and further improve oilfield recovery efficiency, infill adjustment work has been carried out, achieving good results. A supporting infill adjustment technology has been formed, which includes "well seismic joint fine reservoir prediction, multi-disciplinary research on remaining oil quantification, multi-parameter evaluation of infill well location optimization, and multi information fusion perforation layer optimization".

2. Fine reservoir prediction combined with well seismic analysis

Through precise reservoir description, precise understanding of structures and reservoirs can effectively guide reservoir prediction and well location optimization for infill wells.

2.1 Fine characterization of faults

Using multiple methods such as breakpoint data guidance, coherent body, ant body recognition, etc. to comprehensively identify small faults with a fault distance of more than 5m and an extension length of more than 100m. By accurately identifying faults, it effectively guides the deployment of internal well locations and the adjustment of injection production structures in the well network.

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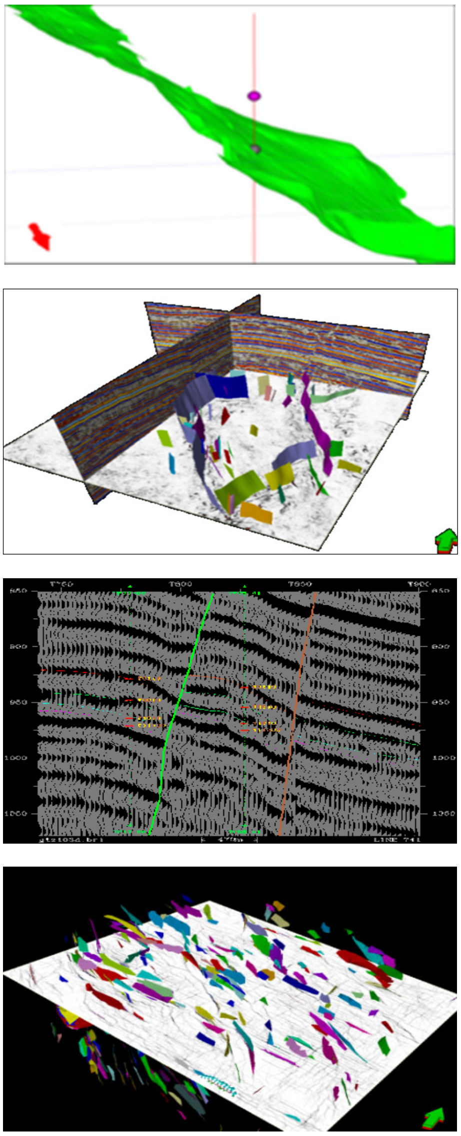
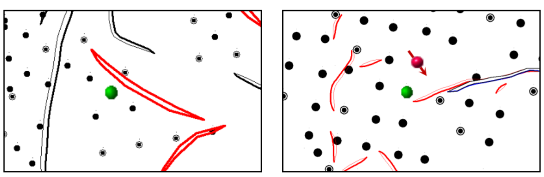


Fig. 1-1 Fault identification method

One is to newly identify small fault occlusion, change the injection production relationship, and deploy infill wells at positions with adjustable thickness increases. As shown in Figure 1-2, due to fault occlusion, residual oil is formed between the three oil wells, and one infill well can be deployed.

The second is that the extension length of the fault has changed, the injection production relationship has changed, and the adjustable thickness has been increased to deploy infill wells. As shown in Figure 1-3, the extension length of the fault has changed, and due to the obstruction of the fault, residual oil is formed between the three oil wells. One infill well and one injection well can be deployed.



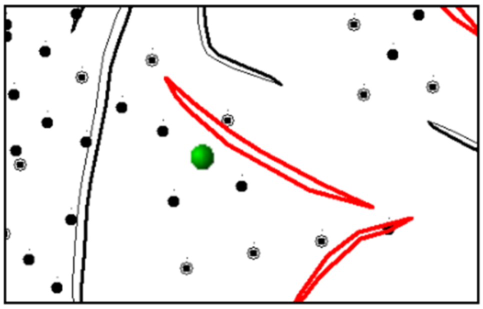


Fig. 1-2 Newly identified faults

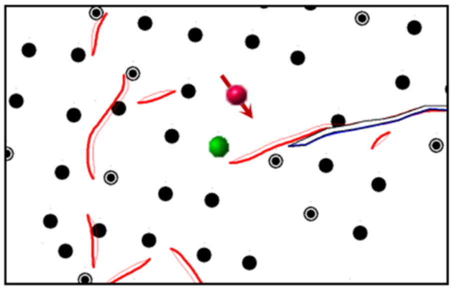


Fig. 1-3 Change in fault extension length

2.2 Fine characterization of reservoirs

By fine reservoir description, we can improve our understanding of sand bodies, accurately predict reservoirs, and effectively guide reservoir prediction and well location optimization for infill wells.

One is to control the time window according to sedimentary units under dense well network conditions, and apply a multi type attribute fusion method to improve the correlation between seismic attributes and sand bodies, with a correlation coefficient of 0.46, an increase of 0.03 (Figure 1-4).

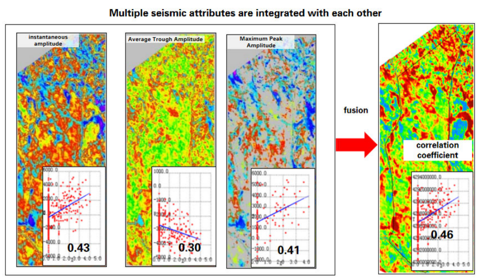


Fig. 1-4 Seismic Attribute Optimization

Secondly, based on the sedimentary environment and sand body characteristics, the seismic attribute control of the main channel and the indication control of seismic waveform in thin and poor layers are adopted. The inversion method is optimized by unit, and the prediction accuracy of sand bodies above 2m is 80.9%, an increase of 1.1%, and that of thin sand bodies between 1m and 2m is 63.1%, an increase of 12.8% (Figure 1-5).

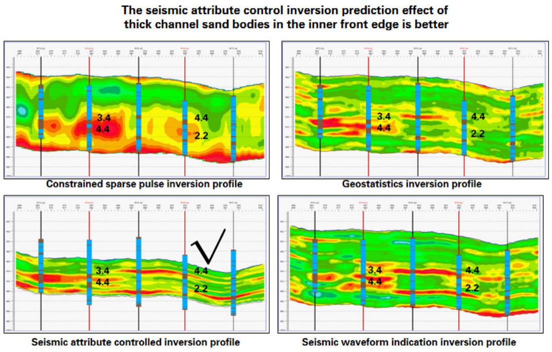


Fig. 1-5 Fine reservoir prediction

Thirdly, based on the prediction results of sand bodies, combined with the sedimentary understanding of each unit, the characterization method of "attribute control, inversion boundary, and logging facies" is adopted to complete the fine characterization of well seismic combined sedimentary facies.By comparing the new and old facies belts, the development characteristics of sand bodies are confirmed, and there are four main types of sedimentary microfacies changes, which effectively guide the optimization of infill well locations and increase the adjustable thickness of infill wells.

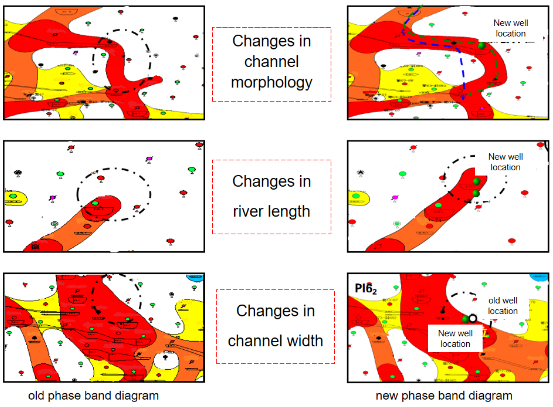


Fig. 1-6 Fine reservoir characterization guides well location deployment

3. Multidisciplinary research on quantification of remaining oil

By using multi-disciplinary fine description as a means, on the basis of fine geological research, high-precision phase control modeling technology and fine numerical simulation technology are applied to quantify the distribution of remaining oil and select potential areas for infill and adjustment.

3.1 Combining Well and Earthquake to Establish a Fine Geological Model

Structural modeling: Based on the combination of "well seismic" and structural achievements, establish precise fault and layer models; Sedimentary facies modeling: Based on the results of unit sedimentary microfacies, establish a sedimentary facies model; Attribute modeling: Using sedimentary microfacies as constraints, establish a reservoir attribute model with a planar grid step size of 20m.

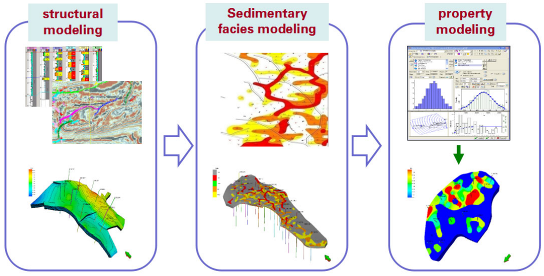


Fig. 2-1 Fine Geological Modeling

3.2 Numerical simulation of phase separation zone to quantify overall remaining oil

Based on the heterogeneity of the reservoir, lithofacies zoning was carried out, and different permeability curves were selected for numerical simulation based on the differences in microfacies properties. The single well fitting rate was increased to over 83%, quantifying the distribution of remaining oil in the entire area.

On the plane, the distribution of remaining oil is controlled by factors such as structure, reservoir, sedimentary microfacies, and well network, and there are mainly five types. The remaining oil is mainly composed of incomplete injection and production, uncontrollable well network, and thick oil layers, accounting for 69.34% of the total remaining reserves.

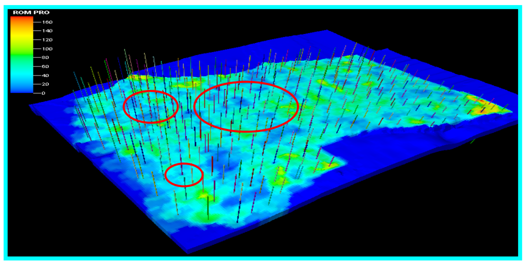


Fig. 2-2 Residual oil plane distribution map

Vertically, due to interlayer interference, there is a significant difference in the utilization of the XX Formation oil reservoir, with the remaining oil mainly concentrated in the XX1-9 sandstone formation, accounting for 70.11% of the remaining reserves. Among them, XX23, XX62, XX82, and XX92 have the most abundant remaining oil, accounting for 48.87% of the remaining reserves. Entering the ultra-high water cut development period, although the remaining oil distribution in XX Oilfield is scattered, there is still potential for infill adjustment in some areas.

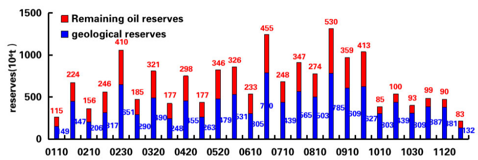


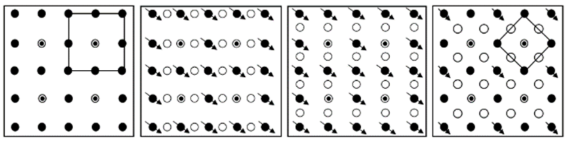
Fig. 2-3 Vertical residual oil distribution map

4. Multi parameter evaluation and optimization of infill well location

In response to the characteristics of narrow, thin, and scattered sand bodies in narrow and thin sand fields, as well as the high proportion of inefficient wells with uniform well distribution, a non-uniform infill adjustment principle of "uniform well distribution and selective drilling" is proposed. The multi-parameter comprehensive evaluation method is used to optimize the infill well location to improve the effectiveness of infill wells.

4.1 Well network encryption method

By using numerical simulation technology for comprehensive evaluation, the original well pattern is a reverse nine point area injection production well pattern, and the best adjustment method is diagonal center encryption. This method has a slow water cut increase speed and high recovery degree, which is conducive to later adjustment (Table 3-1, Figure 3-2).



(a) (b) (c) (d)
(a) Original well network
(b)Add columns between columns
(c)Adding rows between rows
(d) Diagonal center encryption

Fig. 3-1 Optimization of encryption adjustment methods

Table 3-1 Prediction Results of Different Well Pattern Indicators

Well network adjustment method	Initial oil recovery rate	Adjust for five years		Adjust for ten years		Adjusting for fifteen years	
		Extraction degree	to contain water	Extraction degree	to contain water	Extraction degree	to contain water
	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Original well network	0.46	32.70	95.91	33.51	96.91	34.21	97.31
Add columns between columns	0.75	33.92	96.51	35.41	98.01	36.17	98.76
Adding rows between rows	0.73	33.65	96.16	35.32	97.66	36.23	98.16
Diagonal center encryption	0.69	33.53	95.66	35.73	97.41	37.26	97.91
Adjustment of injection and production system	0.48	32.89	96.01	34.42	97.26	34.95	97.76

4.2 Optimization method for infill well location

Based on the characteristics of "overall scattered and local concentrated" distribution of remaining oil, the method of "uniform well distribution and selective drilling" was adopted to determine seven main control indicators. Combined with the research results of technical and economic boundaries, the principle of selecting infill wells was determined. In order to effectively reduce the proportion of inefficient wells, a multi-parameter comprehensive evaluation method is introduced to achieve multidisciplinary intervention analysis and avoid errors caused by using adjustable thickness as a single evaluation indicator.

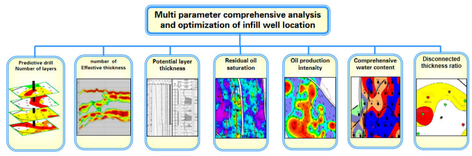


Fig.3-2 Multiparameter comprehensive evaluation method

Taking the XX encryption area of XX oilfield as an example, 61 encryption wells were uniformly deployed using diagonal center encryption (Figure 3-4) as the preferred object. By establishing parameter relationship diagrams such as layer number effective thickness, remaining oil saturation adjustable thickness, and comprehensive water content daily oil production (Figure 3-3), 13 encryption wells were finally selected through comprehensive screening. In the initial stage, an average of 10 small layers were encountered during single well drilling, with an effective thickness of 4.3m. The daily oil production in the initial stage was 3.1t, and the water content was 75.6%.

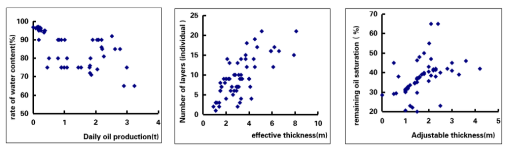
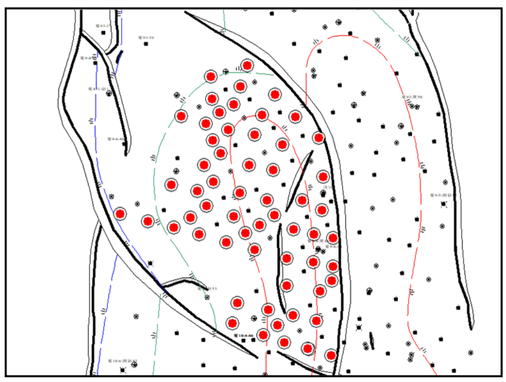
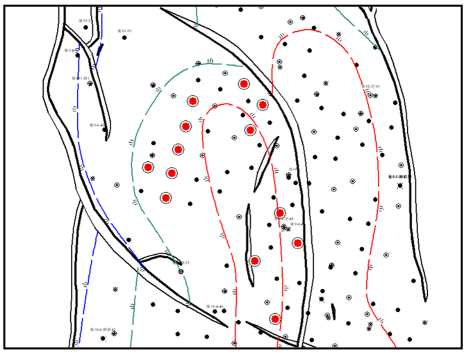


Fig.3-3 Encryption Adjustment Parameter Relationship Chart



Uniform well distribution



Optimization results

Fig. 3-4 Optimization Example of Multi parameter Comprehensive Evaluation Method

5. Optimization of Perforation Horizon Based on Multiple Information Fusion

Using various data such as logging, means of production and sedimentary facies belt, the water flooded layer can be accurately identified, the perforation horizon can be optimized, and the initial water cut of infill wells can be controlled.

5.1 Comprehensive Determination of Water Flooding Degree

Based on logging interpretation, combined with various data such as remaining oil distribution, production situation, and testing, comprehensively analyze the degree of water flooding in the encrypted well reservoir, laying the foundation for perforation layer selection.

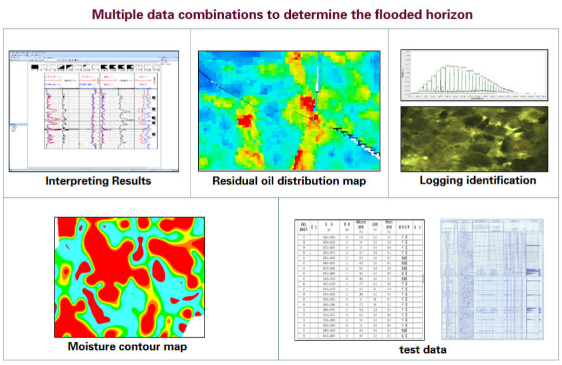


Fig. 4-1 Multiple data combinations to determine the flooded horizon

5.2 Optimization of perforation layer selection principles

Due to the high degree of water flooding, poor sand body thickness, scattered distribution of remaining oil, and imbalanced water flooding conditions in the Putaohua Oilfield, the selection of perforation layers is optimized based on the principle of "classification evaluation and control of water content". In the initial stage, in order to ensure the production effect, the optimization of perforation layers was mainly focused on low water flooded and non water flooded layers. With the continuous understanding of the reservoirs in the infill adjustment zone, the optimization method was gradually improved, and supplementary and modified perforation modes were added.

The perforation and completion modes of reservoirs are mainly divided into the following four categories (Table 4-1):

One is the selective perforation mode. Under the condition that the adjustable thickness can meet the production capacity needs, strictly control the perforation thickness and only inject reservoirs with low water flooding degree;

The second is the extended perforation mode. In response to the high degree of water flooding in the entire well and the lack of development of thin and poor reservoirs, due to the very small adjustable thickness, it is considered to appropriately relax the water content limit to increase single well production and open up medium to high water flooded risk reservoirs;

The third is the supplementary perforation mode. In response to the situation of high water flooding but relatively developed thin and poor reservoirs, due to the small adjustable thickness, selective expansion of mud and sandstone layers can be used to increase the adjustable thickness of a single well while shooting out oil layers with lower water flooding levels. Depending on the specific situation, the completion method should be considered and determined;

The fourth is the modified perforation mode. Considering the poor development of reservoirs and the difficulty in achieving the designed production capacity of the plan, based on the thickness of the reservoir, the properties of the oil layer, and the connectivity relationship on the sand body plane, consideration is given to adjusting the potential through fracturing transformation.

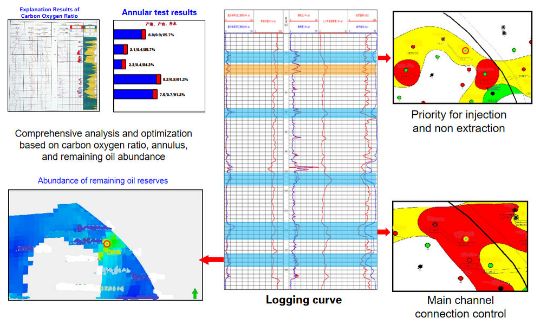


Fig.4-2 Example of perforation layer optimization

6. Encryption adjustment effect

A total of 425 infill wells were put into operation in XX Oilfield. In the initial stage of infill wells, the average daily liquid production of a single well was 12.5 tons, daily oil production was 2.7 tons, and the comprehensive water content was 78.40%. The decline in production slowed down by 2.5 percentage points, achieving good results. After the encryption adjustment, the degree of water drive control has increased to 77.6%, an increase of 2.6 percentage points. The application of set encryption adjustment technology can effectively improve the encryption adjustment effect and improve the oilfield development effect.

Table 5-1 Comparison of Initial Production of Infill Wells

region	Design			initial stage		
	Nissan liquid	Daily oil production	to contain water	Nissan liquid	Daily oil production	to contain water
	(t)	(t)	(%)	(t)	(t)	(%)
XX Oilfield	8.0	1.6	80.00	10.9	2.2	79.82

6.1 Analysis of Typical High Yield Wells

According to statistics, there are 12 infill wells with a daily oil production of more than 10t in the initial stage of production. The average single well encountered 10 small layers, with a sandstone thickness of 13.1m and an effective thickness of 7.4m. In the initial stage of production, the average daily liquid production of a single well was 16.9t, with a daily oil production of 13.7t and a comprehensive water content of 18.97 (Table 5-2). From the distribution area, it is mainly concentrated in areas with abundant residual oil at the fault edge, areas with imperfect injection production relationships, and areas with newly added sand bodies.

Table 5-2 Production Statistics of High Yield Infill Wells

Serial number	Well number	Number of layers (piece)	Sandstone thickness (m)	effective thickness (m)	Number of shooting layers (piece)	Effective shooting (m)	Nissan liquid (t)	Daily oil production (t)	to contain water (%)
one	Well 1	6	7.3	4.0	6	4.0	14.4	13.4	6.94
two	Well 2	8	17.4	12.3	4	7.6	27.2	10.0	63.24
three	Well 3	7	13.4	9.5	3	5.4	28.1	18.5	34.16
four	Well 4	10	13.4	10.9	8	10.0	17.5	13.5	22.86
five	Well 5	11	15.0	3.2	5	2.0	12.5	10.8	13.60
six	Well 6	11	13.2	5.6	8	3.4	17.2	15.0	12.79
seven	Well 7	10	14.9	10.0	4	6.3	25.4	13.0	48.82
eight	Well 8	9	13.5	7.5	5	8.9	14.3	13.0	9.09
nine	Well 9	10	9.9	5.0	15	7.5	13.0	13.0	0.00
ten	Well 10	10	11.2	5.4	9	5.4	11.1	11.1	0.00
eleven	Well 11	11	15.6	10.3	7	8.7	13.6	13.6	0.00
twelve	Well 12	11	14.6	10.8	10	10.8	15.2	15.2	0.00
average		10	13.3	7.9	7	6.7	17.5	13.3	23.58

7. Conclusion

(1) The application of fine reservoir structure interpretation and fine reservoir prediction can effectively guide the adjustment of well network encryption, providing guarantee for improving the production effect of encryption wells;
(2) Entering the ultra-high water cut development period, the remaining oil distribution in XX Oilfield is scattered, but there is still potential for infill adjustment in some areas;
(3) The gradually improved multi information fusion optimization perforation layer technology has played an important role in ensuring production and controlling water content;
(4) The application of the supporting encryption and adjustment technology of "well seismic joint fine reservoir prediction, multi-disciplinary research on remaining oil quantification, multi-parameter evaluation of encryption well location optimization, and multi information fusion perforation layer optimization" can effectively improve the encryption and adjustment effect.

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