

Development Unit Division of Low Permeability Reservoir in Y Block, Ordos Basin

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Abstract: The Y block reservoir in Ordos Basin is a typical low porosity and permeability tight sandstone reservoir with poor physical property and strong heterogeneity. On the plane, the small layer sand body changes quickly, the continuity is poor, the pressure distribution is uneven, and the principal side effect is uneven. In the section, the liquid production in the stratification is not clear, the washing degree of the small layer is different, and the water contradiction in the multi-direction of the single layer is prominent. At present, the overall reservoir decline is fast, some wells have low productivity and high water cut, and most of the wells have more open layers. In this paper, based on geological factors and development dynamic factors, combined with fracture identification, the first development unit of Y block reservoir is divided, and on the basis of the first development unit division, the second development unit is further divided according to the situation of small layer division and correlation. The division of the secondary development units can correspond to the development contradiction to the small layer, and has guiding significance for the evaluation of the subsequent reservoir development effect and the fine adjustment of development policy.

Keywords: Low permeability reservoir; Partition parameter correlation analysis; Development unit division.

1. Introduction

Oil and gas resources are a relatively important energy in our country. China has been committed to developing traditional conventional oil and gas energy. However, with the application of energy, traditional conventional oil and gas energy gradually becomes unable to support daily consumption, so energy development gradually shifts from conventional oil and gas energy to unconventional oil and gas energy. Unconventional oil and gas resources mainly refer to shale oil, shale gas, coalbed methane and tight gas. It is of great significance to accelerate the development of unconventional oil and gas energy. Block Y, located in the middle part of Yishan Slope in Ordos Basin, is a typical large complex stratigraphic and lithologic trap gas reservoir with low permeability, low abundance and low production. The main development horizon is the Middle Jurassic Yan 'an Formation and the Upper Triassic YanChang Formation. The reservoir type is mainly dolomite solution cavity, and the reservoir plane has strong heterogeneity. Due to the "three-low" characteristics and strong heterogeneity of gas reservoirs, it brings great challenges to the balanced exploitation of gas fields. The division of development units is an important means to improve the management level of gas fields. Through the reasonable division of development units, gas wells with similar regional production dynamic characteristics are regulated, and targeted development technology policies are formulated to achieve fine dynamic evaluation and adjustment of gas reservoirs, so as to improve the development effect of gas reservoirs.

2. Geological Setting

Ordos Basin, located in the central and western part of North China Plate, is the second largest sedimentary basin in China. It is a giant craton superimposed basin with a total area of $37 \times 10^4 \text{ km}^2$ formed by continuous cyclic evolution and various sediments. The whole shape of the basin is rectangular,

in which the east and west span is large, surrounded by mountains, and there are 6 structural units. From the overall structural characteristics, it is a monoclinical structure with high east and low west slope. The surface is covered with Quaternary loess, the surface gullies are interlinked, the landform belongs to the typical northwest Danxia landform, the climate is dry. At present, the accumulation area of oil and gas resources in the basin has the characteristics of large area and wide distribution, and the formed reservoirs are characterized by simple structure, stable sedimentation, complex pore throat structure and natural micro-fracture development, etc. Most of them belong to low porosity and ultra-low permeability sandstone reservoirs. The study area is Tiebiancheng Block of Ordos Basin, whose structural location belongs to the transitional zone between Yishan Slope and Tianhuan depression of Ordos Basin. The overall structural morphology is relatively gentle, the overall regional stratum relief Angle is $< 1.0^\circ$, and a series of low-amplitude nose uplift structures are developed in the east-west direction, with a uplift amplitude of 10~20m and a nose uplift axis width of 2~5km. The structure has good inheritance; The main oil-bearing development strata are the Middle Jurassic Yan 'an Formation and the Upper Triassic YanChang Formation.

3. Development Unit Division Basis

3.1. Geological basis

The geological basis for the division of development units, starting with the division and comparison of small layers, studies the planar distribution of sedimentary microfacies and the thickness distribution of sand bodies in block Y, defines the characteristics of sedimentary microfacies, and analyzes the distribution and connectivity of single sand bodies on the basis of the study of sand body distribution. Finally, combined with the identification of cracks, the geological basis is analyzed comprehensively.

3.1.1. Small layer division and contrast

In this paper, based on the application of logging and

drilling data in Block Y, the Chang 4+5 oil formation in Block Y is divided into two sand groups: Chang 4+5₁ and Chang 4+5₂, and the Chang 4+5₁ subgroup is subdivided into Chang 4+5₁¹ and Chang 4+5₁² subgroups, and the Chang 4+5₂ subgroup is subdivided into Chang 4+5₂¹ and Chang 4+5₂² subgroups. Further Chang 4+5₁¹ layers can continue to be divided into 3 sub-layers, Chang 4+5₁² layers can continue to

be divided into 2 sub-layers, Chang 4+5₂¹ layers can continue to be divided into 3 sub-layers, Chang 4+5₂² layers can continue to be divided into 2 sub-layers. The Chang 6₁ sand formation is subdivided into Chang 6₁¹ and Chang 6₁² layers, and the further Chang 6₁¹ layers can be further divided into two secondary layers. The Chang 6₁² layers can be further divided into three sub-layers (Figure 3-1).

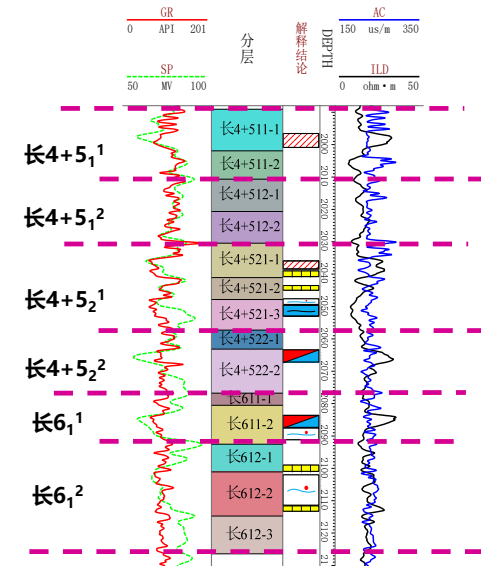


Figure 3-1. Y small layer correlation scheme

3.1.2. Small layer division and contrast

The distribution of sedimentary microfacies in Y block was characterized through core observation and literature investigation in the study area. The sedimentary microfacies of each small layer in Block Y are mainly composed of

underwater distributary channels and underwater interdistributary bays. According to the sedimentary microfacies Changes of each small layer, it can be seen that the sedimentary process from Chang 6₁²⁻³ to Chang 4+5₁¹⁻¹ is a three-stage sedimentary process with large water recession-water inflow and then fluctuation (FIG. 3-2~ FIG. 3-5).

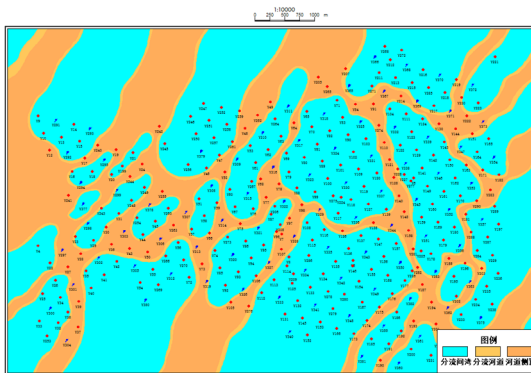


Figure 3-2. Sedimentary microfacies map of Chang 4+5₁¹⁻¹ reservoir in block Y

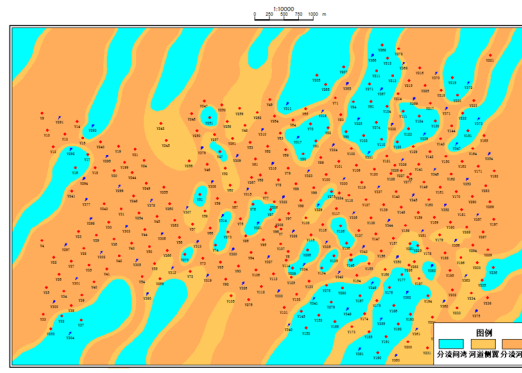


Figure 3-3. Sedimentary microfacies map of Chang 4+5₂¹⁻³ reservoir in Block Y

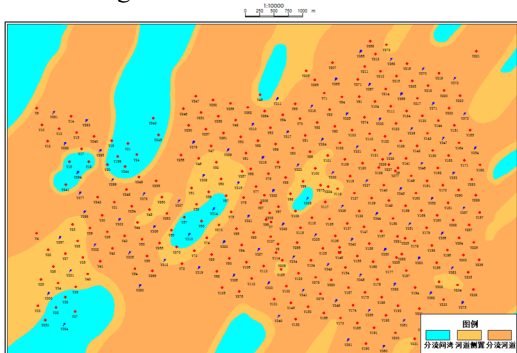


Figure 3-4. Sedimentary microfacies map of Chang 6₁²⁻² reservoir in Block Y

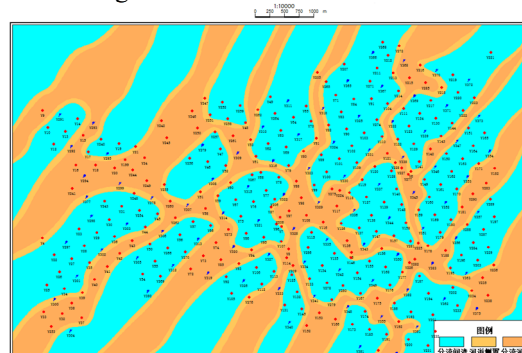


Figure 3-5. Sedimentary microfacies map of Chang 6₁²⁻³ reservoir in Block Y

3.1.3. Small layer division and contrast

Through the core observation of Block Y in Tiebiancheng area, this study confirms that the reservoir in this area is mainly gray sandstone. On the basis of core observation and small layer division and analysis of logging data, the thickness distribution of sand body in Y block is obtained. The sand bodies are distributed in a NE-SW direction, controlled by the microfacies of distributary channel. The sand bodies of main reservoirs in Y block Chang 6₁²⁻², Chang 6₁¹⁻², Chang 4+5₂²⁻² and Chang 4+5₂¹⁻³ have large overall thickness and good continuity, and the sand bodies at the intersection of channels have large thickness.

3.1.4. Small layer division and contrast

On the basis of the study of sedimentary microfacies distribution and sand body thickness distribution in the study

area, the plane distribution of single sand body in the study area is obtained according to the distribution map of sand body thickness, sedimentary microfacies and single sand body in block Y: The underwater distributary channels control the single channel, with a total of 8-15 single sand-body channels, and the lateral contact relationship of each single channel is mainly superimposed and cut overlapping. The sand thickness is large at the intersection of the single channel (Figure 3-6, Figure 3-7). In the direction of parallel source, the single sand body has good connectivity, and the superposition relationship is mainly characterized as superposition and cut superposition. In the vertical source direction, the overall connectivity of the sand body is relatively weak, and the superposition relationships are mainly isolated, superimposed, and occasionally tangential.

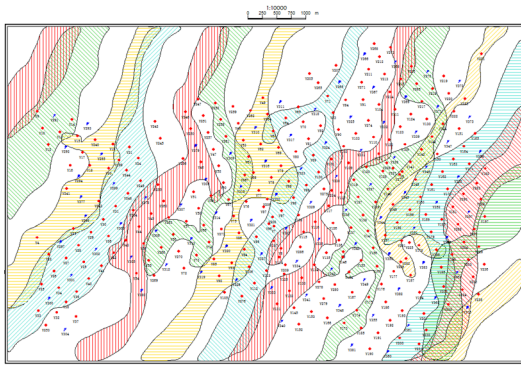


Figure 3-6. Plane layout of single sand body of reservoir Chang 4+5₂¹⁻³ in block Y

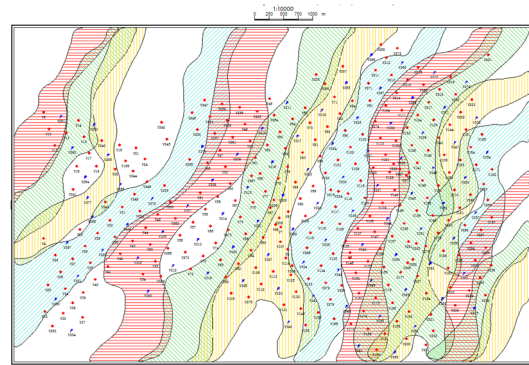


Figure 3-7. Plane layout of single sand body of reservoir Chang 6₁²⁻² in block Y

3.1.5. Small layer division and contrast

The porosity distribution of Chang 4+5 layer samples in block Y ranges from 0.51% to 27.69%, with an average porosity of 13.11%. The porosity distribution of Chang 6 layer samples ranges from 0.51% to 27.69%, and the average

porosity is 13.07%. The permeability distribution of Chang 4+5 layer samples ranges from 0.01 to 58.91mD, and the average permeability is 0.63mD. The permeability distribution of the long 6 layer samples ranged from 0.01 to 11.54mD, and the average permeability was 0.65mD (Figure 3-8 to Figure 3-9).

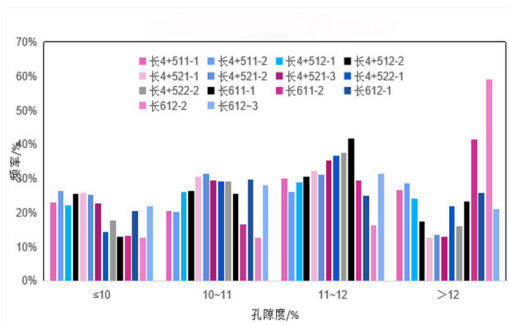


Figure 3-8. Histogram of porosity distribution in block Y

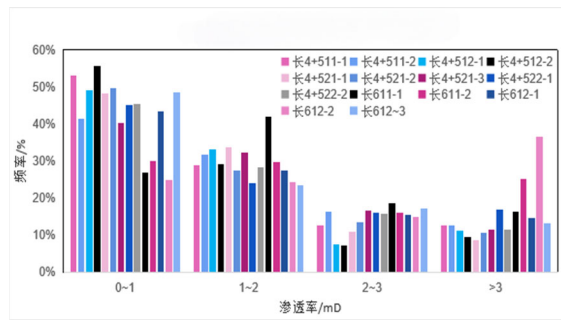


Figure 3-9. Histogram of permeability distribution in block Y

3.1.6. Small layer division and contrast

The characteristics of fracture development in the study area are studied by the method of dynamic and static combination. The qualitative and quantitative evaluation of fractures is carried out by means of static core observation and

tracer test, and the influence of fracture development on actual production is analyzed dynamically by combining production dynamic data and water flooding law. In Block Y, 42 Wells were identified as having developed fractures (Figure 3-10).

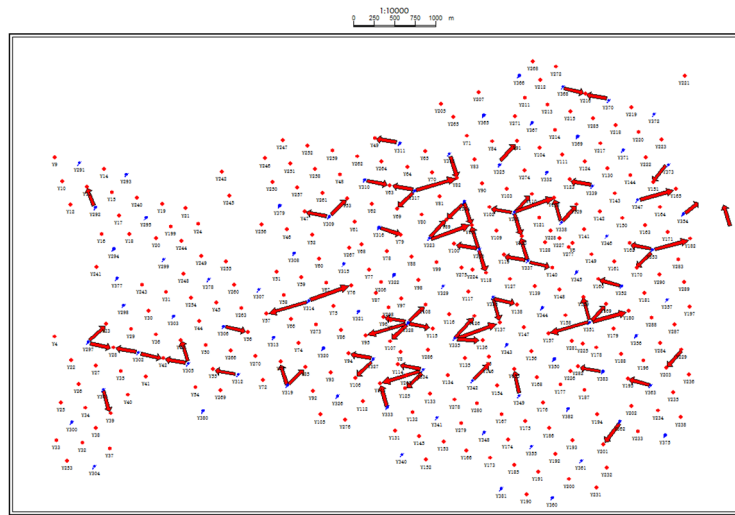


Figure 3-10. Crack identification map of block Y

3.2. Development basis

3.2.1. Development status

The oil reservoir in Block Y was established in 2005, with an oil bearing area of 99.49km², geological reserves of 34.654,000 tons, and annual oil capacity of 81,000 tons. Currently, the main reservoirs are long 4+5₂ and long 612, and the well pattern adopts 480×160m diamond-shaped reverse nine spot well pattern. The average reservoir thickness of the reservoir parameters is 10.9m, and the porosity is 12.2%. Permeability 0.83mD. In area Y, water injection has been developed since November 2006. According to the production dynamic data, by the end of December 2023, 258 oil Wells and 100 water Wells have been drilled, with a daily production level of 164.4t and a single well production capacity of 0.64t/d. Daily injection level 2084.8m³ The daily injection water of a single well is 20.8m³, and the current comprehensive water cut is 59%. At present, the reservoir is developed with a set of multi-layer well pattern, and the reservoir is highly heterogeneous. In the plane, the small layer sand body Changes rapidly, the continuity is

poor, the pressure distribution is uneven, and the main lateral efficiency is uneven. The stratified liquid production is not clear, the washing degree of small layers is different, and the water contradiction of single layer is prominent in multiple directions. In the process of division of development units, the development basis mainly refers to the current water content, pressure distribution and water-seeing effect type.

3.2.2. Current moisture content and type of water-seeing effect

According to the current water cut data of Y reservoir, the water cut map for 2023 is drawn (FIG. 3-11). By using the water intake profile and combining with the dynamic production data, the water-seeing effect types of the producing oil Wells in the whole area of Y block are identified. The proportion was 72.48%, and the effective water-seeing type accounted for 23.39%. The effective water-finding type occupies a certain proportion, reflecting the existence of reservoir fractures or waterflood hyperpermeability zones in the study area. (Figure 3-12)

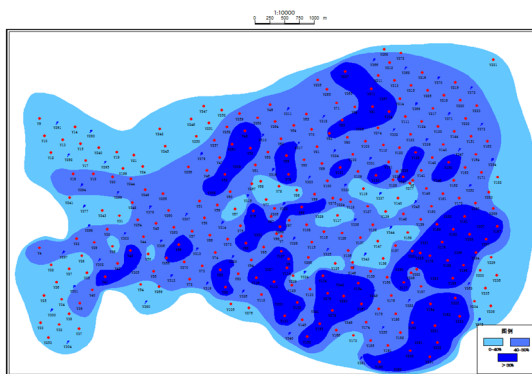


Figure 3-11. Y reservoir water cut distribution map for 2023

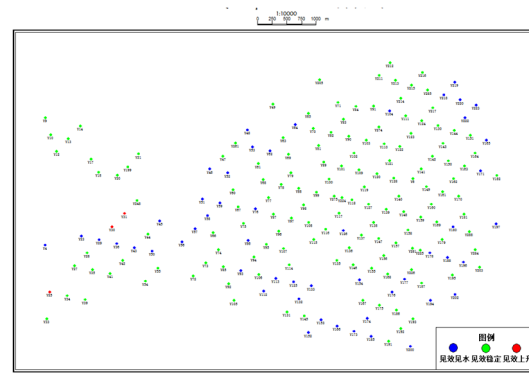


Figure 3-12. Y reservoir oil well water response type diagram

3.2.3. Current pressure distribution and individual well productivity

Based on the current pressure measurement data of block

Y, the pressure distribution map in 2023 is drawn (FIG. 3-13), and the production dynamic data is used to draw the production capacity map of the oil Wells in the whole region Y in 2023 (FIG. 3-14).

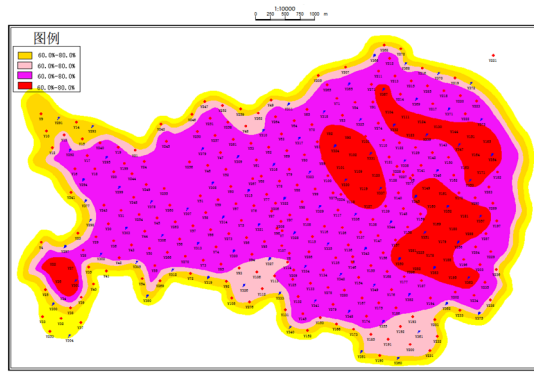


Figure 3-13. Y Reservoir pressure profile for 2023

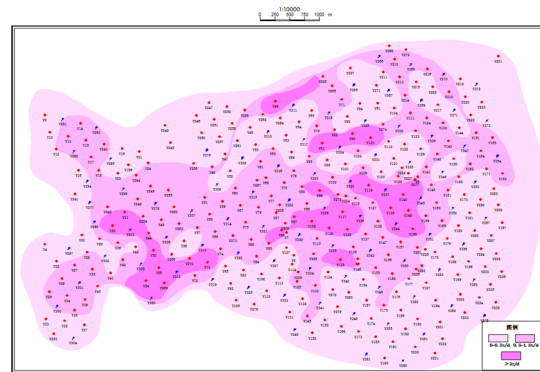


Figure 3-14. Y reservoir single well productivity map

4. Develop Unit Partitioning Methods

The division method of development units is based on the basic geological research, the comprehensive evaluation of reservoir as the starting point, the identification of fractures and the actual development dynamics, and the division results of development units are obtained, which are convenient for later development effect evaluation and development policy adjustment.

4.1. Partition parameter correlation analysis

Based on the correlation analysis of sand thickness, sand-

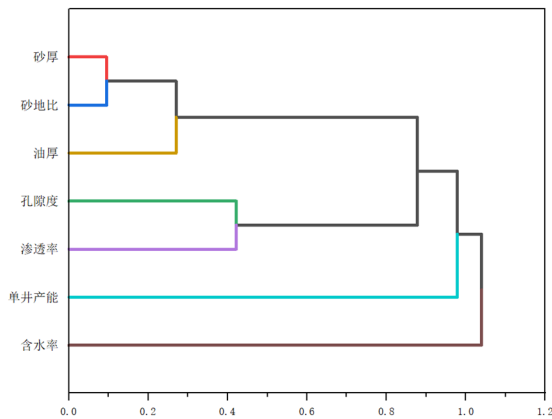


Figure 4-1. Chang 4+5₂¹ small reservoir parameters cluster analysis pedigree

4.2. Development unit division

In this research, the division of development units is mainly based on sand thickness, sand to ground ratio and effective reservoir thickness, and is modified in combination with fracture development characteristics, production horizon, current water cut and response type, so as to divide the Y block reservoir into primary development units. On the basis of the division of primary development units, according to the division and comparison of small layers, four main production small layers are selected, and the four main production small layers are divided into secondary development units by mainly referring to sand thickness, sand to ground ratio and effective oil layer thickness, and combining with the distribution of single sand body, fracture development characteristics, current water content and

ground ratio, porosity, permeability, effective reservoir thickness, and individual well productivity of the main oil-producing layer 4+521 in block Y, the system cluster analysis pedigree and correlation heat map of each parameter are obtained. By analyzing the cluster analysis pedigree and correlation heat map, the correlation characteristics of each parameter can be obtained. In other words, the sand thickness is strongly positively correlated with the effective thickness of the oil reservoir, the sand-land ratio is strongly positively correlated with the effective thickness of the oil reservoir, and the porosity is weakly positively correlated with the effective thickness of the oil reservoir. (Figure 4-1, Figure 4-2)

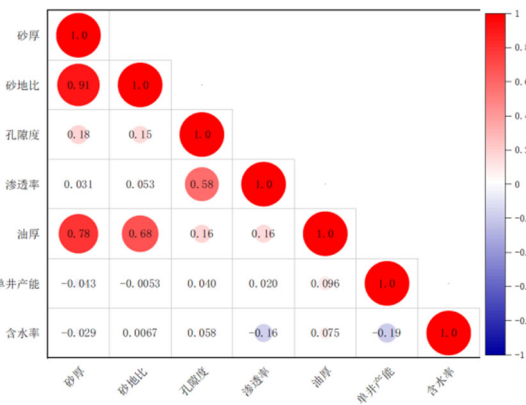


Figure 4-2. Parameter correlation heat map of Chang 4+5₂¹ small reservoir

effective type.

5. Development Unit Division Results

5.1. Result of division of first-level development units

In order to provide a basis for the further development of the oilfield, this study divided the reservoir of block Y into 8 first-level development units (Figure 5-1) based on the previous geological knowledge and relevant development dynamic research results, combined with the identification of fractures, and considering the maximum integrity of injection-production units and the convenience of the adjustment of the water injection scheme in the later stage.

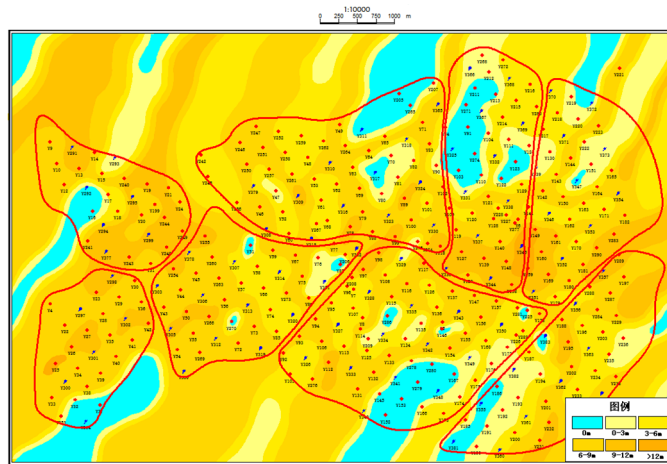


Figure 5-1. Division and sand thickness of primary development unit in Y reservoir

5.2. Results of secondary development unit division

On the basis of the division of first-level development units, the reservoir in Block Y was divided into 16 second-level development units according to the four main production units according to the division and correlation of small layers,

in order to map the development contradictions to the small layers in a targeted way, and analyze the injection and production correspondence of small layers, the distribution of fractures in small layers, and the main controlling factors of water breakthrough effect in a more intuitive way (Figure 5-2~ Figure 5-5).

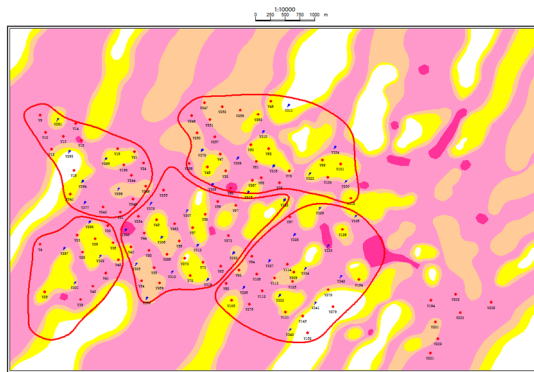


Figure 5-2. Plot and porosity of Chang 4+5₂¹ small layer development units

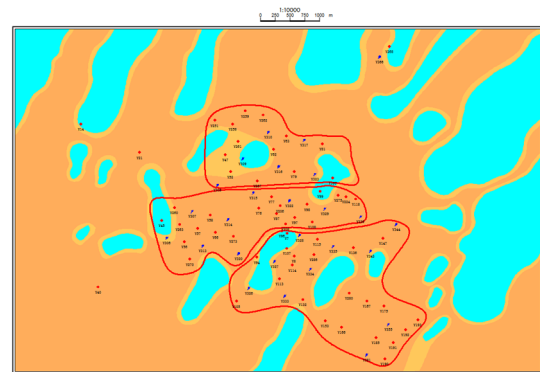


Figure 5-3. Mapping and sedimentary microfacies of Chang 4+5₂² small layer development units

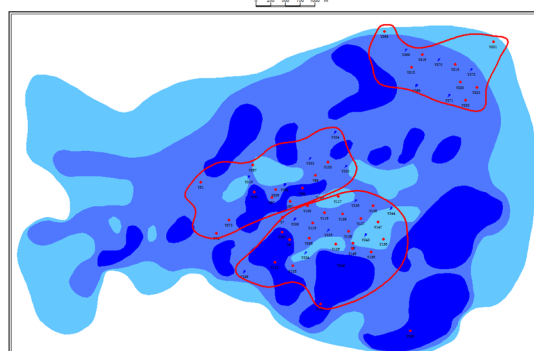


Figure 5-4. Chang 6₁¹ small layer development unit division map and water content

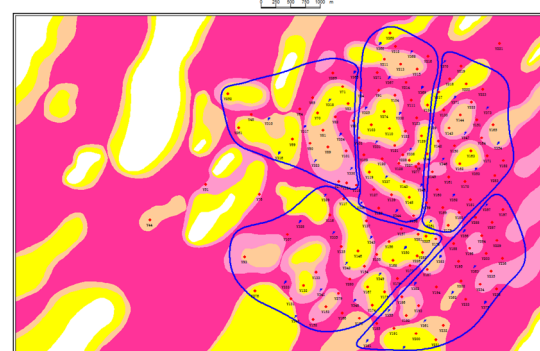


Figure 5-5. Chang 6₁² small layer development unit division map and permeability

6. Summary

In order to provide a basis for the further development of the oilfield, this project takes the previous geological understanding and relevant development dynamic research results as a reference, combined with the identification of fractures, considering the maximum integrity of injection-production units and the convenience of later water injection

plan adjustment, and divides the Y block reservoir into first-level development units, and on the basis of first-level development unit division, The four main production zones are divided into 16 secondary development units. After the division of the primary development units, the effective thickness distribution, water cut distribution, fracture distribution and individual well productivity distribution in each area of the Y block reservoir can be generally grasped,

which helps to refine the development status and development contradictions into small layers when the secondary development units are divided. These 16 secondary development units are divided into 4 main production zones respectively. According to the division results of secondary development units, subsequent work such as natural decline rate, horizontal waterflood rule, injection-production correspondence, and waterflood development effect evaluation of each development unit can be targeted at the small-layer level to analyze the fine correspondence of injection-production, fracture distribution, and main control factors of water emergence effect. This study is of guiding significance for the subsequent refinement and adjustment of reservoir development policy of this subject, and can also provide reference for the preliminary preparation for the evaluation of the development effect of similar reservoirs.

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