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Reservoir Characteristics and Favorable Area Prediction of Chang-6 Reservoir in Zhouguan Area, Ordos Basin

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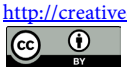

Abstract

Based on the analysis of a large number of core samples, logging results, logging interpretation data and dynamic data in the study area, the characteristics of Chang 6 reservoir in Zhouguan area of Baihe area are studied, and the favorable reservoir areas in the study area are predicted. The results show that the lithology of Chang 6 reservoir is mainly light gray and gray fine-grained to very fine-grained feldspar lithic sandstone. The pore types are mainly residual intergranular pores and feldspar dissolved pores, including debris dissolved pores and microfractures. The porosity and permeability values are low, which belongs to low porosity-low permeability and ultra-low permeability reservoirs. According to the reservoir distribution characteristics and related data, the Chang 6 reservoir in the study area is divided into two types, mainly Class II and Class III reservoirs. The comprehensive evaluation predicts that the spatial distribution of the favorable area of Chang 6 reservoir is not uniform, but the distribution area is large, which has broad exploration and development value, and provides the necessary conditions for the distribution study of the favorable oil-bearing zone in this area and the preparation for the next exploration and development.

Keywords

Extension Group, Baihe Oil Region, Sedimentary Microfacies, Basic Characteristics of Reservoir, Favorable Zone

1. Introduction

Baihe oil area is located in the west of the central part of Yishan slope in Ordos

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Basin, with an area of about 25 km^2 (**Figure 1**). There are several nose-shaped low-amplitude uplift structures with different sizes in the area (Xu et al., 2012), which are superimposed with channel sand bodies and play a certain role in controlling the formation of reservoirs. The reservoir types are mainly structural-lithologic reservoirs or lithologic-structural reservoirs. It belongs to the type of ultra-low porosity and ultra-low permeability, and has the characteristics of insufficient development energy, low production capacity, rapid decline and difficult stable production (Guo, 2016; Zou et al., 2010; Zeng, 2006; Li, 2013). The main oil-bearing formations are Upper Triassic Yanchang Formation and Jurassic Yan'an Formation. As one of the main production layers in Ordos Basin, the distribution range and reservoir performance of Chang 6 oil layer group are controlled by sedimentary characteristics, structural characteristics and diagenesis (Song et al., 2002).

Previous studies on reservoir characteristics in Baihe oil area have not been carried out in depth (Liu et al., 2023; Guo et al., 2023; Wang et al., 2023, Wang et al., 2022). Although there is rich experience in the development of low permeability reservoirs at home and abroad, there is still a lot of space for the research and development of reservoirs in the target block. In order to further expand the production scale of the oilfield, it is necessary to increase efforts to study the oil-bearing conditions of the Chang 6 reservoir group, including sedimentary microfacies and sand body distribution research, and reservoir microscopic characteristics research. On the basis of basic geological research, the reservoir development plan design is continued to lay the foundation for long-term stable production in Zhouguan area. In this paper, the sedimentary microfacies, sand body

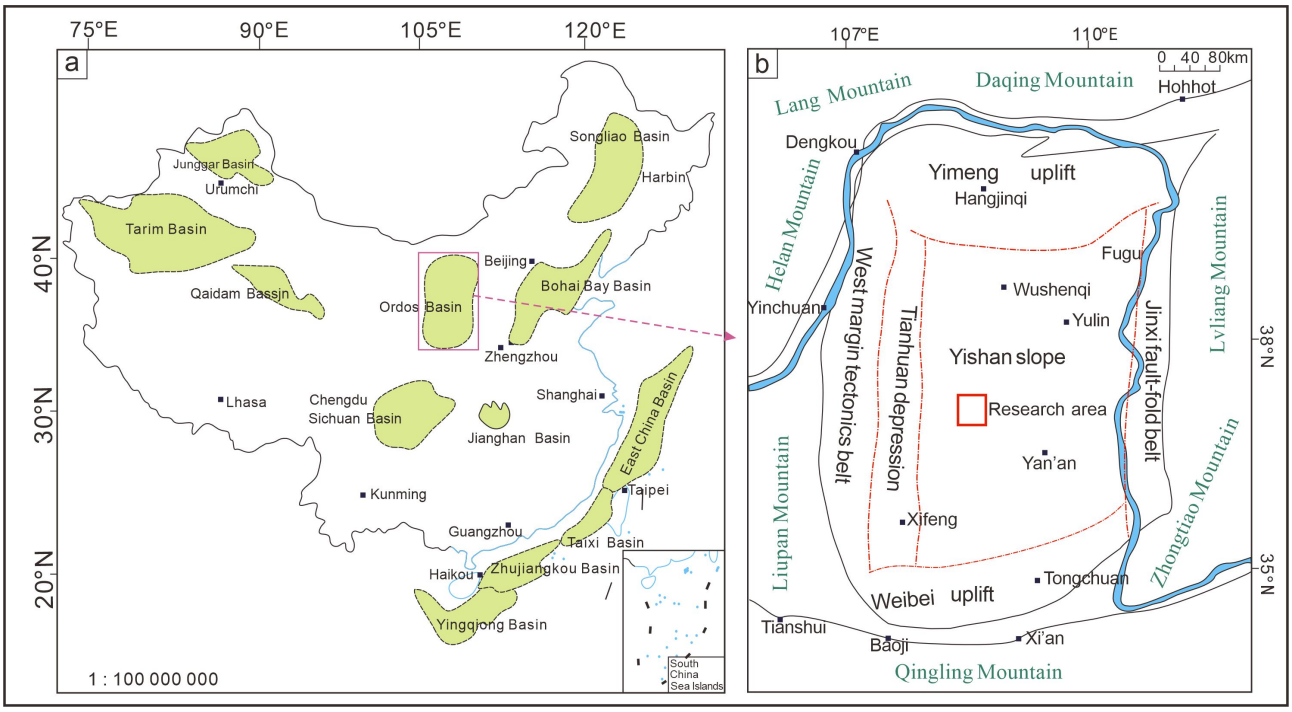

Figure 1. Regional location map of the research area 1.

distribution characteristics, diagenesis and reservoir physical properties of Chang 6 reservoir group are analyzed and studied by means of casting thin sections, rock and mineral thin sections and scanning electron microscope. The distribution of favorable reservoir areas of Chang 6_1^1 and Chang 6_1^2 in Baihe area is obtained.

2. Regional Geological Survey

The Zhouguan area of the study area is on the western edge of the Yishan slope zone near the Tianhuan depression in the Ordos Basin, and there are a series of low-amplitude nose-like uplift structures on the slope zone (Liu et al., 2013). It is a typical topographic feature of high in the east and low in the west. The strata in this area are from bottom to top, and the structural characteristics have good inheritance, showing the gentle slope characteristics of low west and high east. The tectonic trend is north-southeast-west, which is consistent with the overall tectonic pattern of the region. The Yishan slope is mainly formed in the early Cretaceous, which is a monoclinic structure inclined from east to west, and it is relatively gentle (Li et al., 2021). There are a series of low-amplitude nose-like uplift structures on the slope zone, and the size is inconsistent. There are two to three nose-like uplift structures in the central and southwestern regions. These nose-like uplifts cooperate with sand bodies to promote oil and gas migration and accumulation, forming favorable oil and gas accumulation areas (Li, 2013; Shen et al., 2019).

3. Sedimentary Environment and Reservoir Characteristics

3.1. Sedimentary Environment

Baihe oilfield is located in the central and western part of the northern Shaanxi slope. The Triassic lake basin has experienced two major lake invasion periods. During the formation and evolution process, the lake basin gradually shrank during the Chang 6 period, and the delta front zone was widely formed. It is an important period for the gradual formation of typical reservoirs in the regio (Dou et al., 2008). The lithology is composed of fine sandstone, fine sandstone, mudstone and shale, and a set of regional caprocks of silty mudstone in delta plain facies is deposited. The Yan'an Formation is affected by tectonic movement. The bottom and overall uplift of the basin are strongly denuded by external forces, which end the long-term lake basin deposition, and the underwater distributary channels are significantly developed on a large scale (Wu et al., 2004). At the end of the Triassic sedimentary period, the basin in this area was further uplifted, and the top section of the Yanchang Formation was eroded to varying degrees. The ancient topography showed the characteristics of hilly ups and downs and gully vertical and horizontal (Wu et al., 2012). There are ancient rivers around the east, north and south sides, and the middle part is a high-lying ancient landform. A set of flood plain fluvial deposits such as medium-fine sandstone, sand mudstone and coal measure strata were developed. The deep V

incision of the ancient river provides favorable conditions for the migration of oil and gas from bottom to top. The channel sandstone widely distributed in the ancient highland and slope area is a good reservoir of oil and gas. The fine-grained sediments such as mudstone and coal formed by the flood plain deposit provide excellent conditions for the shielding of oil and gas (Zhu et al., 2010). These conditions cooperate with the low-amplitude nose structure developed on the west-dipping monoclinic, forming a small reservoir with a wide distribution area in the basin (Li, 2014).

1) Sedimentary microfacies

Chang 6 period is an important sedimentary period of delta front subfacies, which mainly develops three sedimentary microfacies: underwater distributary channel, interdistributary bay and sheet sand microfacies. The sedimentary facies belt is generally distributed in northeast-southwest direction (Cheng, 2009). There are three underwater distributary channels in Chang 6 of the study area. The main river channels in the north and middle are large. The underwater distributary channels often bifurcate or converge in the process of extending to the southwest, and the river channels are distributed in a network on the plane. There are 6 underwater distributary channels in Chang 6 of the study area. The channel of Chang 6 is relatively wide, and the main channel is large, about 1.2 - 3.2 km wide.

There are three underwater distributary channels in Chang 6_1^1. The main river channels in the north and middle are large in scale. They often bifurcate or converge in the process of extending to the southwest, and the river channels are distributed in a network on the plane (**Figure 2**). There are 6 underwater distributary channels in Chang 6_1^2. The channel is relatively wide and the main channel is large (**Figure 3**).

2) Sand body distribution characteristics

Through comprehensive analysis, the sand bodies of Chang 6_1^1 plane and Chang 6_1^2 plane show a relatively developed trend in the study area as a whole. The sand body on the Chang 6_1^1 plane is distributed in the northeast-southwest direction, with a large area, a maximum thickness of 14 m, a minimum thickness of 3 m, and an average thickness of 8.7 m. Among them, the sand bodies in the northwest are well developed, while the sand bodies in the southern Wu 99 well area gradually become thinner or disappear.

On the plane of the Chang 6_1^2, it is distributed in a north-east-south-west strip, the sand body is developed in the north and south of the sand body, and the middle is pinched out, with an average thickness of 8.4 m; the high value area of sand body thickness is mainly distributed in the northern Wu 21 - 196 well area, Wu 21 - 20 well area and Wu 45 well area, with a thickness of more than 10 m. The high value area in the south is distributed in Wu 53 well area, and the thickness is more than 8 m.

On the whole, the sand bodies of Chang 6_1^1 and Chang 6_1^2 are well developed in the study area. A set of sedimentary materials with distributary channel as the main body and large sand body thickness were deposited, and good reservoirs

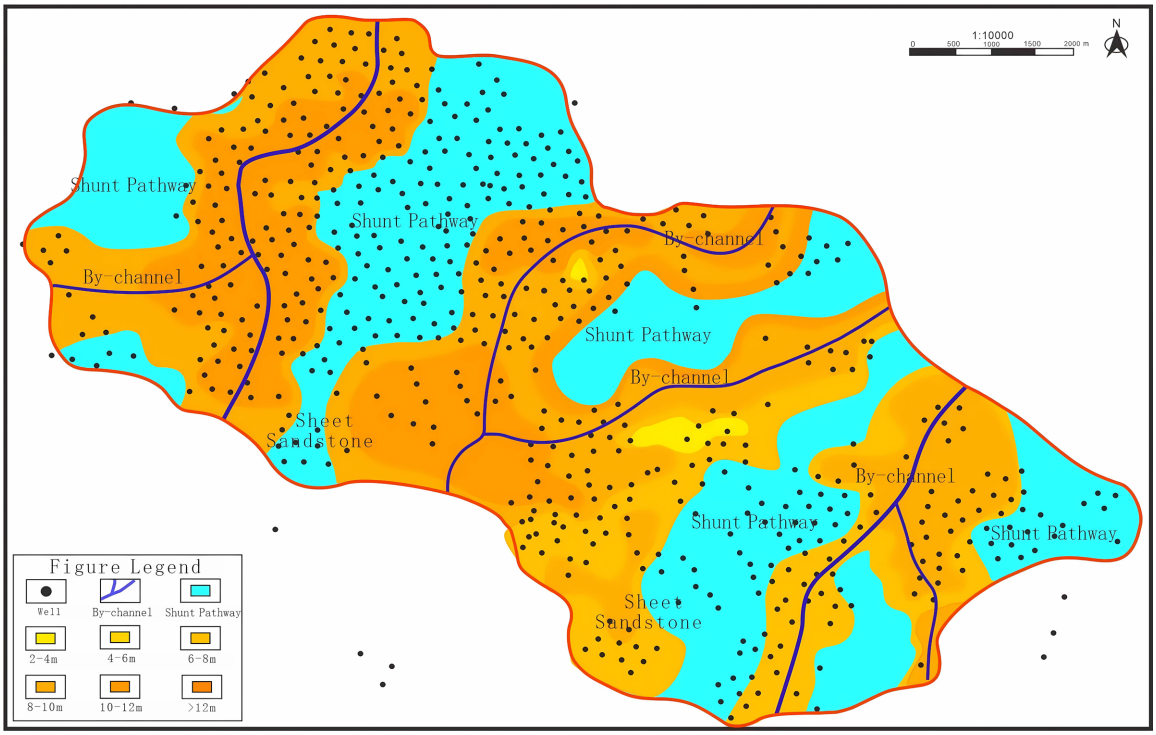

Figure 2. Sedimentary microfacies of Chang 6_1^1 in Zhouguan Area.

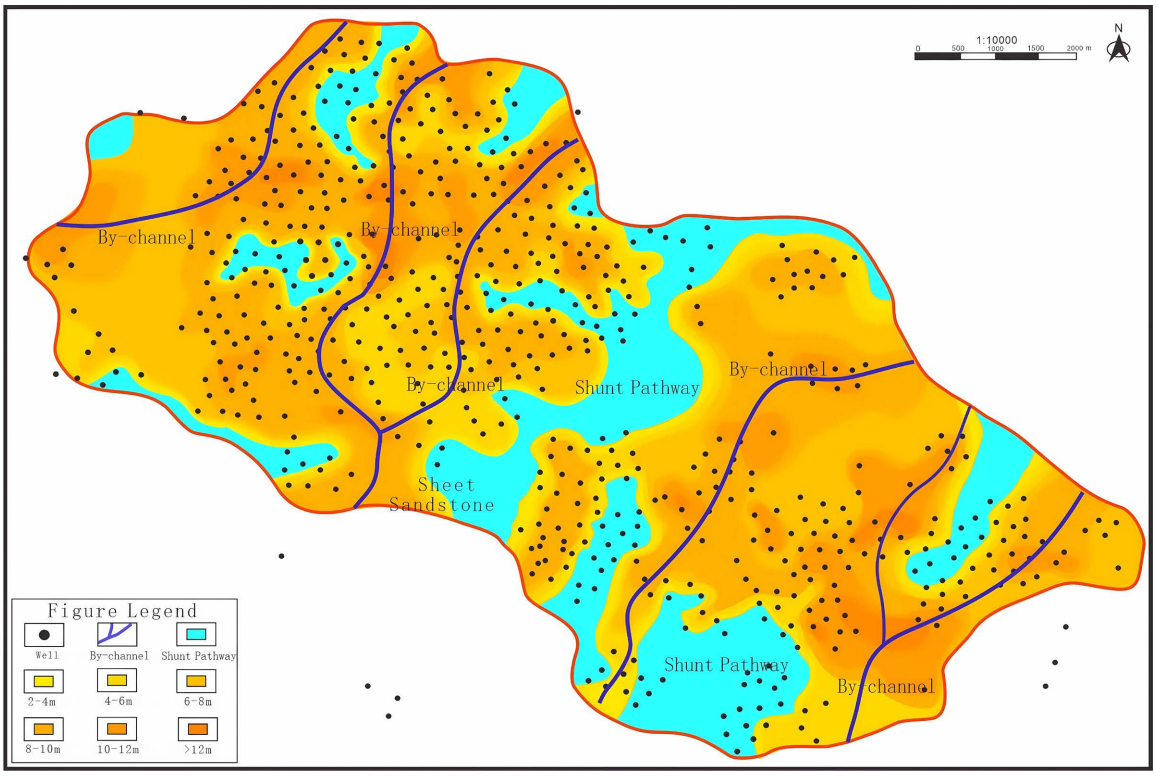

Figure 3. Sedimentary microfacies of Chang 6_1^2 in Zhouguan Area.

were formed by multi-stage sand body superposition, which provided favorable conditions for oil and gas accumulation and accumulation.

3.2. Reservoir Characteristics

This study mainly uses the mud logging data and core experimental analysis report of Baihe oil area and adjacent areas to analyze the petrological characteristics and sandstone diagenesis of the reservoirs in the study area.

1) Petrological characteristics

The Chang 6 reservoir in this area is mainly composed of light gray and gray fine-grained to very fine-grained feldspar lithic sandstone. The main mineral composition of sandstone is quartz, with an average content of about 55.1%. The secondary component is rock debris, with an average content of 15.6%. The average content of feldspar is about 11.7% (Table 1).

The content of interstitial materials in Chang 6 reservoir reaches 11.4% on average after summary. The main body of the interstitial material is the cement, and the content of the impurity is relatively small. The secondary enlargement of individual feldspar and quartz leads to further reduction of pores. At the same time, dissolution occurred in some feldspars.

2) Reservoir pore types

Through the observation and analysis of casting thin sections, rock thin sections and scanning electron microscope, it is found that the main pore types of Chang 6 sandstone reservoir in this block are residual intergranular pores and feldspar dissolved pores. The developed pore types include intergranular pores,

Table 1. Mineral composition content.

Mineral composition content (%)			Chang 6
Crumbs ingredients	Cuttings Class	Quartzoids	55.1
		Feldspathic classes	11.7
		Igneous cuttings	6
		Metamorphic rock cuttings	9.6
		Sedimentary rock debris	0
	Other	Mica	4.4
		Heavy Minerals	2.2
Interstitial composition		Argillaceous heterobase	0
		hydromica	4.9
		Chlorite	2.7
		Pyrite	0
		calcite	8.5
		Dolomites	0
		feldspathic	0
		Kaolinite	1.4
		Siliceous	0.7
		Barite	0

feldspar dissolved pores, lithic dissolved pores and microcracks. The structural characteristics of the Chang 6 sandstone are that the debris particles are relatively uniform, and the proportion of the main grain size (0.07 - 0.25 mm) can reach more than 95%. The number is large and the sorting is good, and the roundness type is mainly sub-angular. The cementation type is mainly film-pore type, followed by pore type.

Diagenesis has a strong influence on the reservoir, which has undergone a series of diagenesis, such as compaction, pressure solution, authigenic mineral filling, dissolution, metasomatism and recrystallization of clay minerals. Finally, a sandstone reservoir with typical characteristics of low porosity and low permeability was formed.

3) Reservoir physical characteristics

According to the core analysis data of 336 samples from 3 wells in Baihe Oilfield of Wuqi Oil Production Plant, the average porosity of Chang 6 reservoir is 9.25%. The average permeability can reach 0.70×10^{-3} μm^2.

The porosity of Chang 6 reservoir is concentrated between 8% and 14%, accounting for 84.4% of the whole sample, and the permeability is concentrated in the range of $(0.1 - 2) \times 10^{-3}$ μm^2, accounting for 85.9% of the whole sample (Table 2). Overall, Chang 6 has the characteristics of low porosity-low permeability and ultra-low permeability.

4. Prediction of Favorable Reservoir Area

Sedimentary facies belt is the primary basis for predicting favorable exploration areas. Sedimentary microfacies not only control the distribution characteristics of sand bodies, but also further affect the physical properties of reservoirs, and directly control the oil-bearing properties of reservoirs. The shape and distribution of sand bodies and the characteristics of reservoir performance are important contents of sand body prediction. Therefore, the study of sedimentary microfacies and reservoir characteristics of Yanchang Formation is the premise of favorable area prediction (Shen et al., 2019).

Comprehensively considering the sedimentary microfacies, sand body distribution characteristics, reservoir physical properties, porosity, permeability and other parameters in the study area, the statistics and analysis are carried out, and two levels of reservoirs are divided. Combined with the classification criteria of

Table 2. Statistics of oil layer physical district 6.

Tier	Long 6	
Physical Properties	Porosity (%)	Permeability ($\times 10^{-3}$ μm^2)
Number of samples	252	243
Maximum	15.0	6.35
Minimum	0.64	0.008
Average	9.25	0.70

sandstone reservoirs in the Yanchang Formation of the Ordos Basin (Zhao et al., 2007), it can be seen that the reservoirs in this area are divided into two categories: Class II and Class III. The specific division is as follows:

1) For Chang 6 oil layer, from the plane distribution, the favorable area is mainly located in the class II and class III favorable area, the spatial distribution is uneven and has typical distribution characteristics. In the Chang 6 oil layer, the favorable area is mainly concentrated in the main sand body part of the main underwater distributary channel, which is located within the effective thickness of 6 meters. For the long 6_1^1 layer, the class II favorable area of 3.40 km^2 and the class III favorable area of 4.10 km^2 are delineated. For the long 6_1^2 layer, a class II favorable area of 5.00 km^2 and a class III favorable area of 4.10 km^2 were delineated (**Figure 4**, **Figure 5**).

2) According to the distribution of the main sand body of the distributary channel, the superimposed favorable areas in this area are mainly concentrated in most parts of the northwest, while the well control degree in the southeast is low, and the Chang 6_1^2 small layer is developed. A total of 18.3 km^2 superimposed favorable areas were delineated. In order to improve the efficiency of single well production in Zhouguan District, it is suggested that the combined production strategy of two to three sets of small layers should be adopted in the later stage of the second type area, which is helpful to improve the production and optimize the development effect.

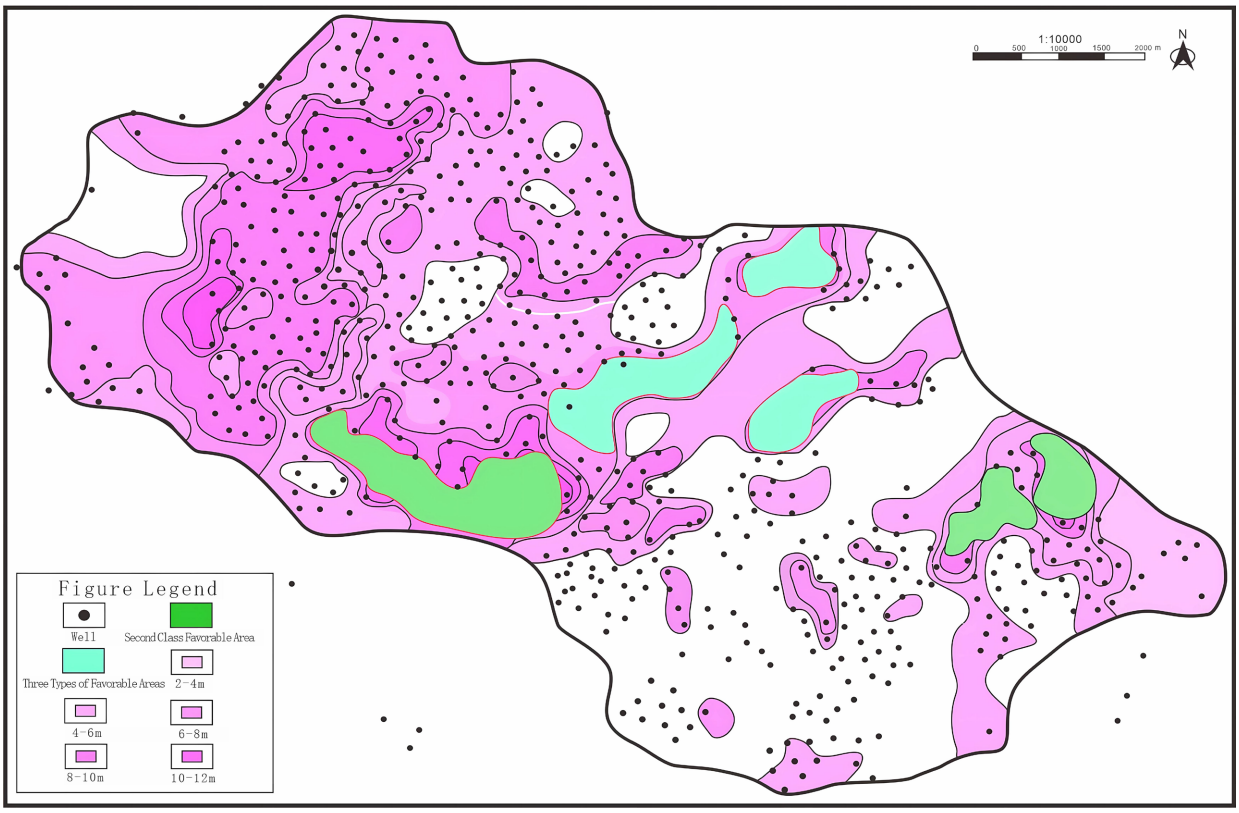

Figure 4. Plan of Long 6_1^1 vantage point.

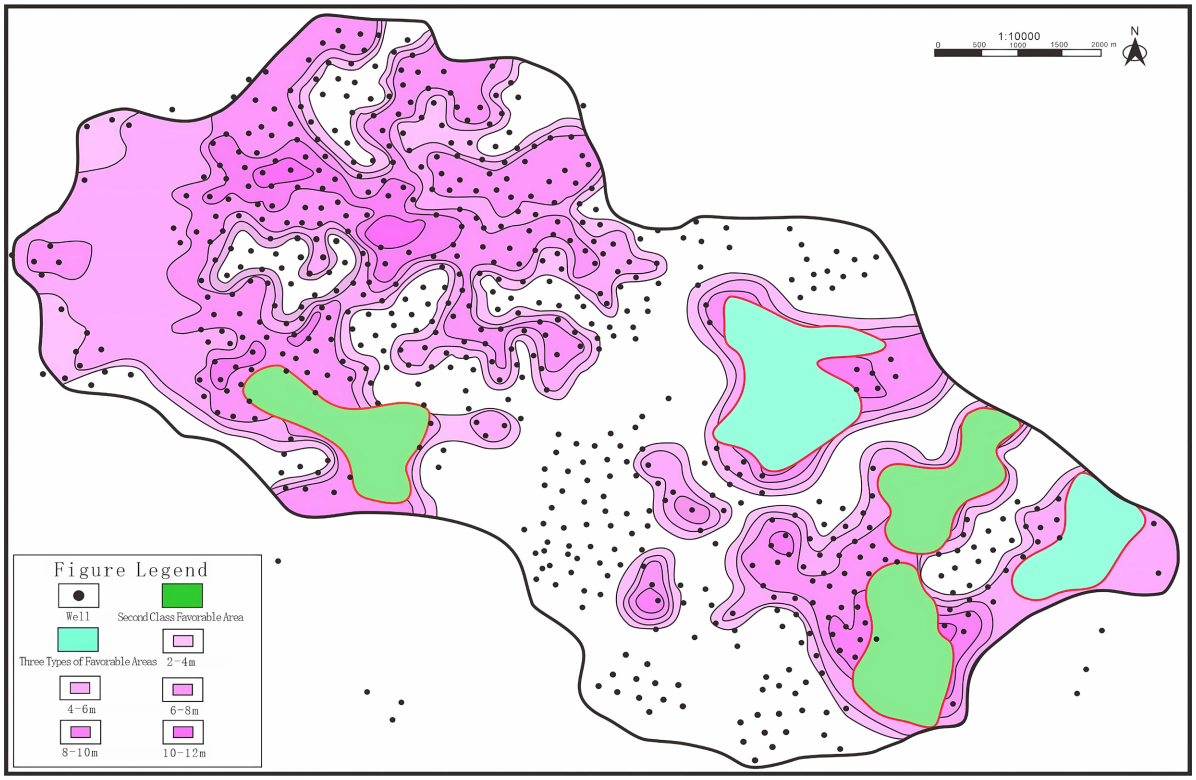

Figure 5. Plan of long 6_1^2 vantage point.

5. Conclusion

1) The Chang 6 reservoir in the study area is mainly located in the main belt of the delta front underwater distributary channel sand body, and the lithology is mainly light gray and gray fine-grained to very fine-grained feldspar lithic sandstone. The pore types are mainly residual intergranular pores and feldspar dissolved pores, including debris dissolved pores and microfractures. The porosity and permeability values are low, which belongs to low porosity-low permeability and ultra-low permeability reservoirs.

2) The Chang 6 reservoir in the study area is mainly dominated by class II and class III favorable areas, and on this basis, two small layers of Chang 6_1^1 layer and Chang 6_1^2 layer are divided. The area has good reservoir performance, and is comprehensively evaluated as Class II favorable area and Class III favorable area.

3) There are 8.40 km^2 of Class II favorable area and 8.20 km^2 of Class III favorable area in Chang 6 reservoir. Among them, within the effective thickness of 6 meters, the long 6_1^1 layer delineated Class II favorable area of 3.40 km^2, Class III favorable area of 4.10 km^2; the Chang 6_1^2 layer delineated 5.00 km^2 of Class II favorable area and 4.10 km^2 of Class III favorable area. After comprehensive evaluation, it has rich geological reserves. In order to improve the efficiency of single well production in Zhouguan District, it is suggested that the combined production strategy of two to three sets of small layers should be considered in the later stage of type II area. It can be used for further exploration and utilization in this area.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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