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Characteristics of Chang 4 + 5 Reservoir and Reservoir Distribution in Heijiabao Area, Ordos Basin

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Abstract

In this paper, in order to study the microscopic pore structure characteristics and influencing factors of its dense reservoir, the lithological characteristics and pore characteristics of the Chang 4 + 5 reservoir in Heijiabao area were studied by using casting thin section, scanning electron microscope, high pressure mercury compression and other testing techniques, and the reservoir distribution characteristics were also studied.

Subject Areas

Tight Sandstone Reservoir Characteristics, Geoscience

Keywords

Reservoir, Chang 4 + 5 Member, Ordos Basin

1. Introduction

As an important type of unconventional oil and gas reservoirs, tight sandstone reservoirs are currently a hot area for oil and gas exploration and development [1] [2] [3] [4]. Compared with conventional sandstone reservoirs, dense sandstone is characterized by poor physical properties, complex pore structure and non-homogeneity. Therefore, the microscopic pore throat of the reservoir is a key factor that restricts and influences the fluid storage and percolation capacity. Scholars at home and abroad have done a lot of research on the characteristics, diagenesis and pore evolution, and formation mechanism of dense sandstone reservoirs [5] [6] [7] [8] [9]. Xu Menglong [5] considered that diagenesis plays an important role in reservoir physical properties; Luo Jinglan [6] considered that differential diagenetic evolution is a key factor leading to reservoir quality and its strong inhomogeneity in spatial and temporal distribution; Zhang Xi [7] considered that sedimentation and diagenesis are the dominant factors affecting the relatively high-quality reservoir quality of lithologic reservoirs; Zhu Xiaomin [8] considered that the original depositional environment of the dense reservoir controls its reservoir material base, and the diagenesis controls the physical evolution of the reservoir; Wang [9] argued that the physical properties of reservoirs were controlled by pore type and pore structure. However, the differences in depositional conditions and diagenetic evolution history make the complex pore-throat systems developed in dense sandstones at the micron to nanometer scale, which show great variability depending on the study area or formation.

The Qilicun oil field located in the southeastern part of Ordos Basin was previously explored and developed mainly for the Chang 6 oil formation group of the Triassic Extension Group [10] [11] [12] [13]. After more than 100 years of exploration and development, the field is now facing the unfavorable situation of lacking favorable exploration blocks. In recent years, by changing the exploration idea, while continuing to deepen the exploration of the Chang 6 formation group, we also explored the upper part of the Chang 4 + 5 formation group, and obtained a number of industrial oil flow wells, which initially showed good exploration prospects. However, the complex pore structure of the Chang 4 + 5 dense sandstones has caused large variations in good production and restricted the exploration and development process. In this paper, taking the Chang 4 + 5 main exploration and development block (Heijiabao area) of Qilicun oilfield as an example, the Chang 4 + 5 oil formation subgroup is used as the research object, and the microscopic pore structure characteristics of the Chang 4 + 5 are studied by various testing methods, with a view to providing geological support for the subsequent development of the field.

2. Geological Background

The Ordos Basin is the second largest sedimentary basin in China, which can be divided into six primary tectonic units according to tectonic units: the Yimeng Uplift, the Weibei Uplift, the Jinxi Flexural Belt, the North Shaanxi Slope, the Tianhuan Depression and the Western Margin Retrograde Fracture Tectonic Belt. The Ordos Basin is rich in tight oil resources and is an important tight oil production and development base in China [14] [15] [16]. The Heijiabao area of Qilicun oil field is located in the northeastern part of the Ordos Basin in the North Shaanxi slope tectonic unit, in Yan'an City, Yan'chang County (**Figure 1**), and the Yan'an Formation strata in the study area are divided into ten oil formations from bottom to top. Among them, the Chang 7 formation group was deposited during the Late Triassic maximum lake flood period, and high-quality hydrocarbon source rocks were developed in the center of the lake basin [17]. The Chang 6 Formation is the main oil-bearing and developing formation in the oil field, and it has entered the late stage of development, which is more difficult

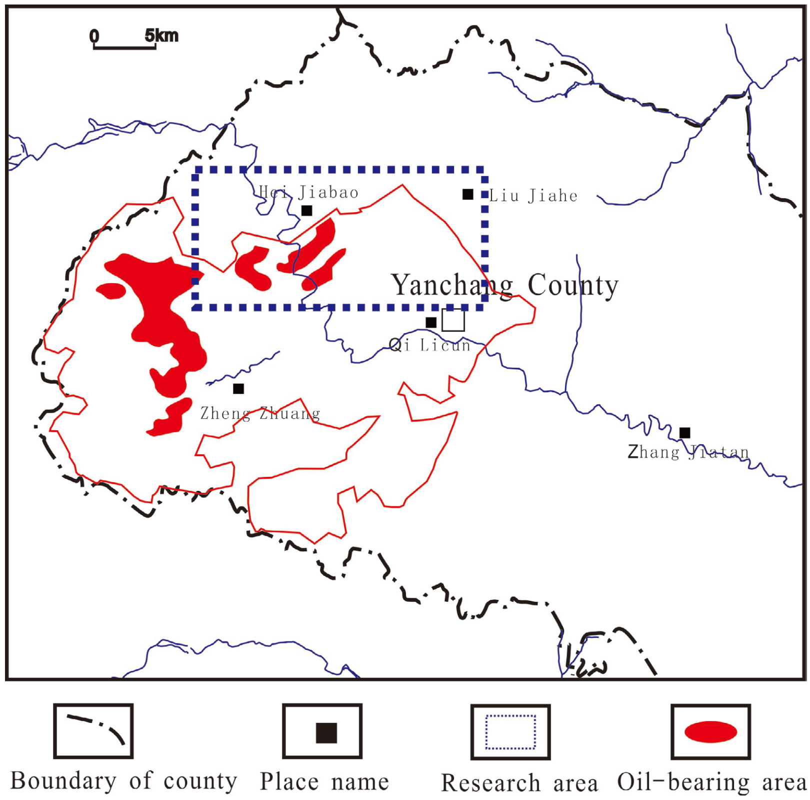

Figure 1. The location map of Heijiabao area in Ordos Basin.

for the oil field to increase reserves and production. In recent years, with the expansion of the field and the exploration of other layers, the Chang 4 + 5 oil formation has been found to have commercial oil distribution in local areas. The Chang 4 + 5 deposition period in Heijiabao area is in the period of contraction of Ordos Lake basin and shallowing of water body, mainly developing delta plain diversion river and inter-channel swamp deposition [18] [19]. The Chang 4 + 5 oil formation group is divided into two oil formation subgroups, Chang 4 + 5_1 and Chang 4 + 5_2, from bottom to top, among which Chang 4 + 5_2 shows oil and gas and is the main research formation in this paper, mainly developing light gray siltstone and dark mudstone interbedded, and the reservoir type beChangs to lithological oil and gas reservoir, with typical low pore and low permeability characteristics, and the reservoir is quasi-continuous in large area without obvious oil-water boundary [20]. Chang 4 + 5_1 is the regional cover of Chang 4 + 5_2 and Chang 6 oil formation group.

3. The Petrographic Characteristics of the Reservoir

3.1. Rock Types

The results of thin section identification and analysis of 31 core samples from 9 wells in the Qilicun oilfield indicate that the lithology of the Chang 4 + 5 oil formation in the study area is fine-grained feldspathic sandstone (**Figure 2**). The clastic volume fraction is 79% - 98%, and the clastic fraction is mainly feldspar

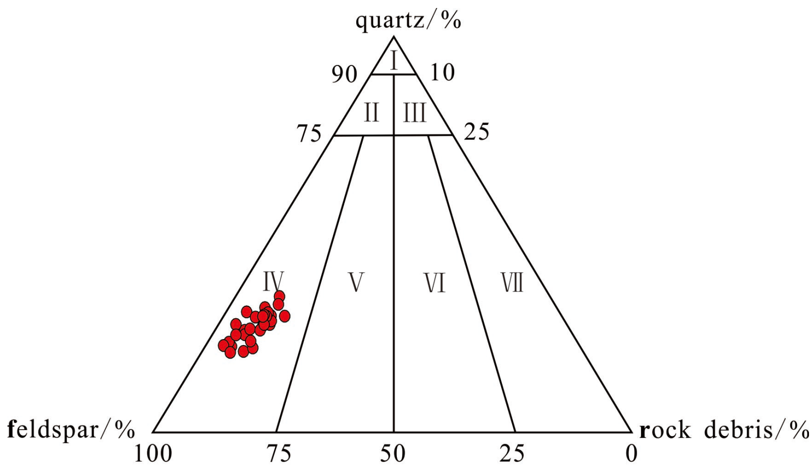

Figure 2. Triangular diagram of sandstone types of the Chang 4 + 5 formation in Heijiabao area.

and quartz. The volume fraction of feldspar in the clastic fraction ranges from 42% to 65%, with an average of 51.7%, of which potassium feldspar is dominant, followed by plagioclase; the volume fraction of quartz ranges from 17% to 30%, with an average of 23%; the volume fraction of rock chips ranges from 3% to 10%, with an average of 6.7%; and the volume fraction of mica ranges from 2% to 9%, with an average of 4.8%.

The overall variation of the gap-filling fraction of the Chang 4 + 5 Formation in the study area is large, with a volume fraction of 2%-18% and an average of 11%. The cement is mainly chlorite and calcite, of which chlorite has a volume fraction of 4.84% and calcite has a volume fraction of 3.36%, followed by hydromica (2.48%) and dolomite (1.93%).

3.2. Characteristics of Interstitial Material

According to the experimental data of 224 Chang 4 + 5 core samples from 16 core wells in Heijiabao area, the maximum value of porosity of Chang 4 + 5 in Heijiabao area is 15.12%, the minimum value is 4.16%, and the average value is 10.43%; the maximum value of permeability is 7.79 mD, the minimum value is 0.02 mD, and the average value is 0.79 mD. The percentage of Chang 4 + 5 porosity of 10% - 12% is 38%, followed by the percentage of porosity of 8% - 10% is 27%, and the percentage of greater than 12% is only 23%. The percentage of porosity of Chang 4 + 5 is 38%, followed by the percentage of porosity of 8% - 10% is 27%, while only 23% is greater than 12%; the percentage of permeability of Chang 4 + 5 is 0.1 - 0.5 mD is 50.4%, followed by the percentage of distribution of 0.5 - 1 mD is 23.6%; according to the reservoir classification scheme [21], it is determined that the Chang 4 + 5 reservoir in Heijiabao area is a dense type reservoir, and its permeability is low, which is ultra-low permeability reservoir.

According to the correlation curve between porosity and permeability (**Figure 3**), it can be seen that the porosity and permeability of the Chang 4 + 5 reservoir are positively correlated, with a low correlation coefficient of 0.6898, indicating

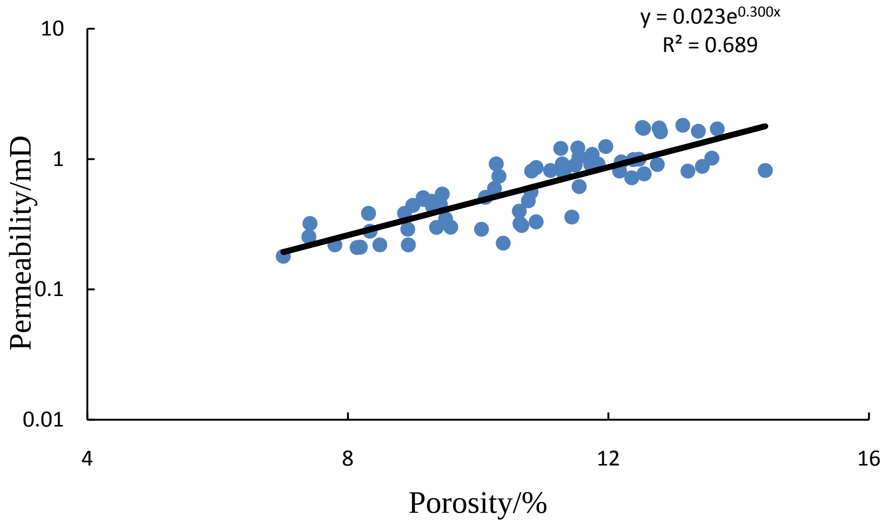

Figure 3. The correlation of porosity and permeability in the Heijiabao area.

that the reservoir pore type and pore structure are complex, and the overall has a strong non-homogeneity[22].

4. Pore throat Characterization

The correlation between the physical data and the average pore throat radius of the Chang 4 + 5 20 rock samples shows that the average pore throat radius of the reservoir has a correlation relationship with both porosity and permeability (Figure 4 and Figure 5). Based on the high-pressure mercury-pressure experimental data, it can be seen that the distribution of the average roaring radius ranges from 0.03 to 1.26 μm. Relative to the permeability of the reservoir, the correlation between the average pore throat radius and porosity is better.

It is presumed that there are two reasons, the first one is that due to the relatively isolated pores of dense sandstone reservoir, the throat channels connecting the pores are irregular, and the throat channels are mostly in the form of fine or curved flakes, which are poorly connected with each other and fail to form a good percolation network; the second point is that the widely existing authigenic clay minerals divide a large number of intergranular pores, such as the wide distribution of silk-hair illite and book-page kaolinite, which fill the pores and reduce the reservoir rock The permeability is low because of the permeability capacity. The filling of authigenic clay minerals also divides the reservoir space into numerous micro-pores, which increases the percentage of micro-pores and increases the saturation of bound water, and also makes the reservoir show the characteristics of relatively high pore and low permeability.

5. Reservoir Distribution Characteristics

5.1. Longitudinal Distribution Characteristics of the Chang 4 + 5 Reservoir

The Chang 4 + 5 reservoir in the study area is mainly a lithologic reservoir, and

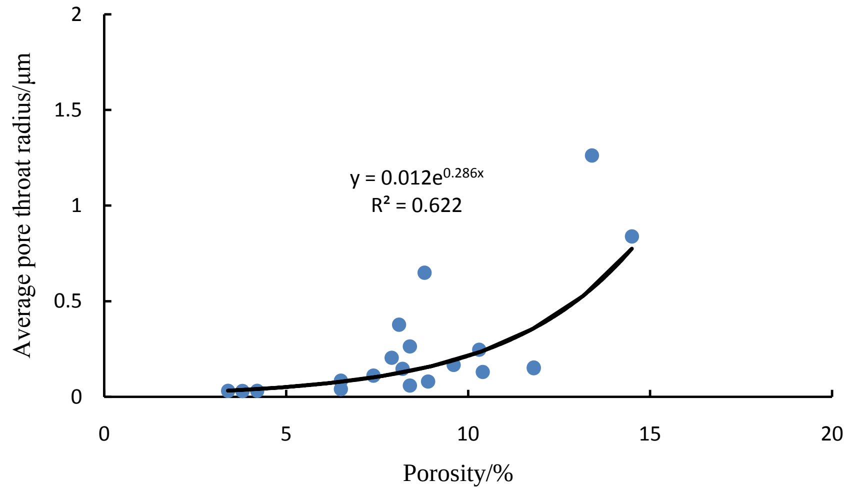

Figure 4. Correlation between porosity and average pore throat radius.

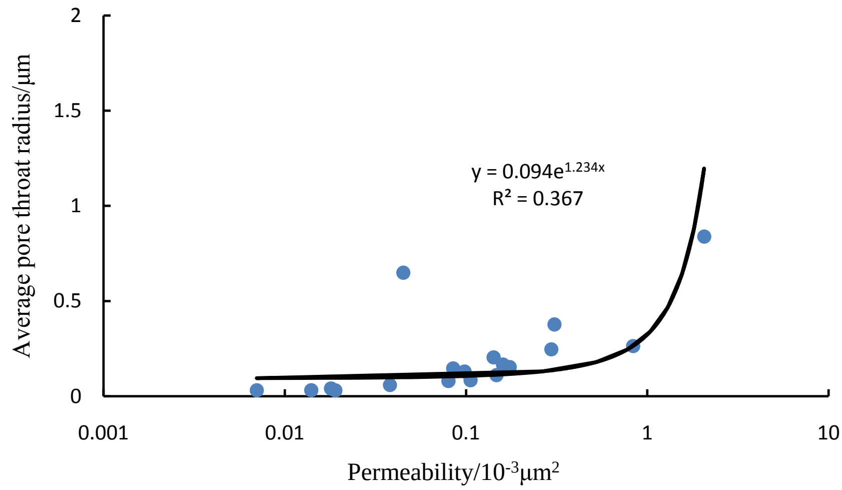

Figure 5. Correlation between permeability and average pore throat radius.

the distribution of deposition relative to reservoir is critical. The Chang 4 + 5 reservoir in the Heijiabao area has a certain scale, and each small layer shows a sand-mud interlayer, in which the reservoir is mainly located in the Chang 4 + 52 small layer, followed by the Chang 4 + 51 small layer. The Chang 4 + 5_1 reservoir and Chang 4 + 5_2 reservoir have different distributions in the Changitudinal direction. As Figure 6 shows the reservoir profile in the downstream direction, the thickness and continuity of the main reservoir of the Chang 4 + 5_2 reservoir are found to be better than that of the Chang 4 + 5_1 reservoir according to the profile. Figure 7 shows the Chang 4 + 5 reservoir profile in the vertical source direction in the study area, and according to the profile, it is found that the main reservoir is concentrated in Chang 4 + 5_2, and the thickness and continuity of Chang 4 + 5_2 reservoir are much better than that of Chang 4 + 5_1.

5.2. Chang 4 + 5_2 Reservoir Planar Distribution Characteristics

Chang 4 + 5_2 development of the main reservoir of Chang 4 + 5, oil layer continuous development, such as **Figure 8** for Chang 4 + 5_2 oil layer thickness and planar spreading and sedimentary microphase overlay map, according to the

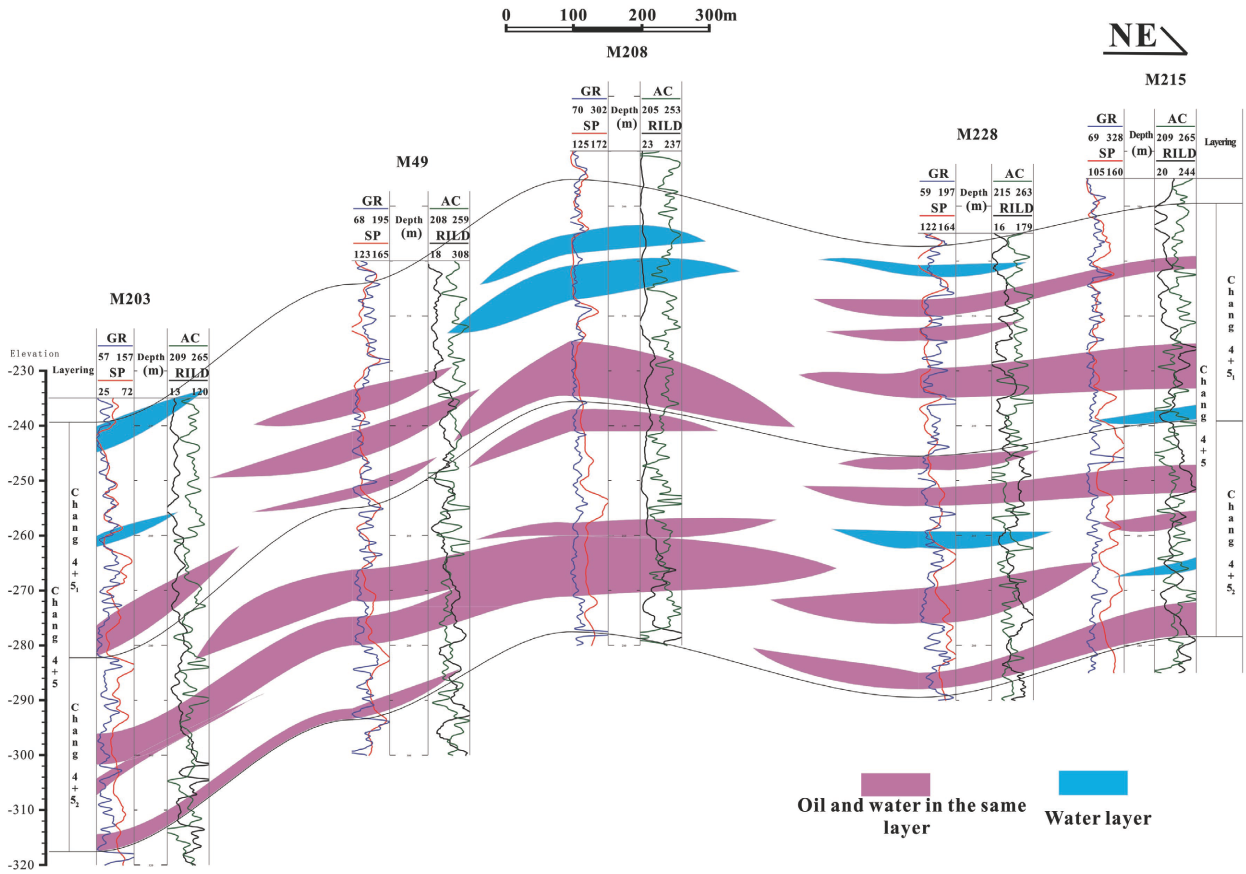

Figure 6. Well M203~well M215 continuous well reservoir section.

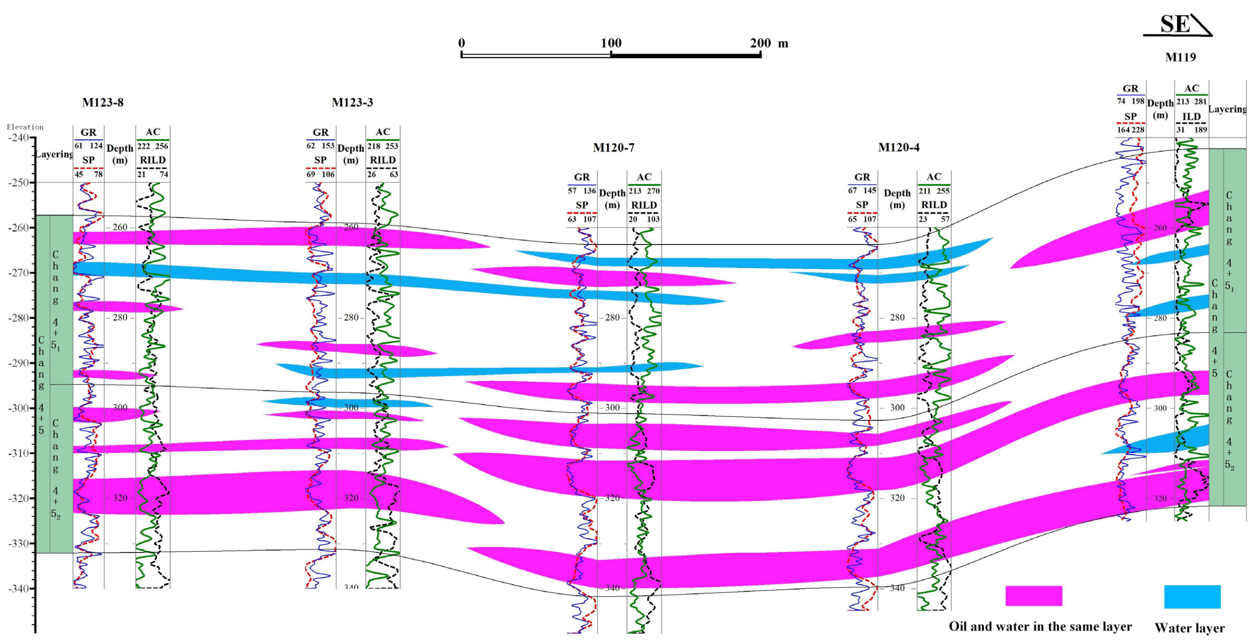

Figure 7. Well M213-8~well M119 continuous well reservoir section.

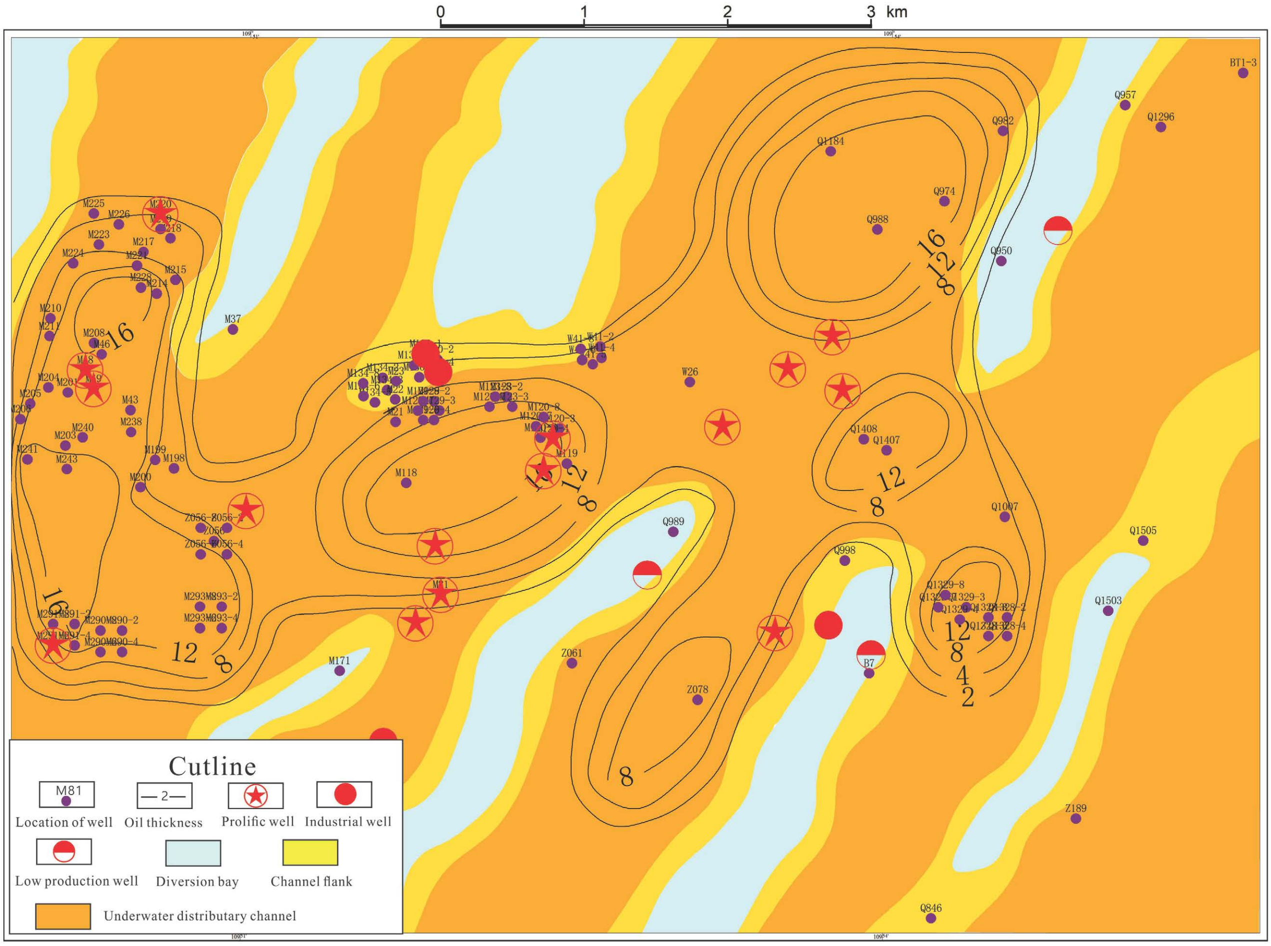

Figure 8. Chang 4 + 5_2 reservoir distribution and sedimentary phase overlay map.

planar map found Chang 4 + 5_2 oil layer thickness up to 16m, mainly located in the sand body development of submerged diversion river center, oil layer thickness main body is located in 4 - 8 m, oil layer average thickness 11.72 m, river flank transition zone oil layer. The thickness reaches the lower limit of 2 m, and the oil layer is not developed in the inter-diversion bay. Combined with the actual initial monthly production, it can be found that the high-producing wells (production greater than 30 t) are distributed in the area with the largest oil layer thickness in the study area, the oil layer thickness in the distribution area of industrial oil flow wells (production greater than 10 t) is lower than the oil layer thickness in the distribution area of high-producing wells, and the oil layer thickness in the distribution area of low-producing wells (production less than 10t) is the thinnest. Considering the relationship between oil production and sedimentary phase zone, it is found that the main body of the high-producing wells is distributed in the area with larger oil layer thickness or in the location where the sand body is developed in the center of the river channel, and the oil layer thickness of the wells that reach industrial oil flow is not large, and the main body is located in the flank of the diversion river channel, and the low-producing wells are located in the location with thin oil layer thickness, and all of them are located in the micro-phase of the inter-diversion bay, which makes them unable to produce industrial oil flow.

6. Conclusions

1) The lithology of the Chang 4 + 5 formation in the study area is fine-grained feldspathic sandstone, with an average porosity of 10.43% and an average permeability of 0.79 mD.

2) The average pore throat radius and porosity and permeability are correlated, and have a significant effect on porosity.

3) The Chang 4 + 5 main reservoir is developed in the Chang 4 + 5_2 sublevel, the sedimentary phase zone is the key factor affecting the distribution of the reservoir, and the submerged divergent river channel is the preferred zone for exploration and development.

Conflicts of Interest

The author declares no conflicts of interest.

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