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Reservoir Characteristics and Main Controlling Factors of the Flow III Section of the K Oilfield in the Weixinan Depression

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Abstract

In order to clarify the reservoir characteristics and main controlling factors of the flow three section of the K oil field in the Weixinan Depression, a study on the reservoir characteristics and main controlling factors of the flow three section of the K oil field in the Weixinan Depression has been carried out by utilizing the data of cores, casting thin sections, physical property tests and logging wells. The results show that the lithology of the reservoir in the flow three section of the study area is dominated by coarse sandstone and medium sandstone, followed by conglomerate-bearing sandstone and sand conglomerate. The porosity is mainly distributed in the range of medium-high porosity, and the permeability is mainly medium seepage, and the overall physical properties are good. The three sections of the stream in the study area mainly include four sedimentary microphases, namely, underwater diversion channel, estuarine dam, mat sand and inter-diversion bay. The underwater diversion channel has the best physical properties, characterized by coarse grains and low mud content. The medium and coarse sand content of various lithologic reservoirs is the main factor in the formation of high-quality reservoirs. Rock-forming action is an important factor affecting the physical properties of local reservoirs, comparing the compaction, cementation and dissolution between different sedimentary microphases, the underwater diverging river has the lowest rate of compaction and pore reduction, the highest rate of pore increase by dissolution, and the best physical properties. Therefore, the weakly cemented-strongly dissolved coarse sandstone phase developed in the microphase of the underwater diversion channel in section 3 of the flow in the study area is the most favorable reservoir.

Keywords

Weinan Depression, Liushagang Formation, Reservoir Characteristics, Sedimentary Microphase, Diagenesis

1. Introduction

The Weixinan Depression is one of the richest hydrocarbon producing depressions in the northern argillic zone of the Beibuwan Basin, and after more than 40 years of exploration, several oilfields and hydrocarbon-bearing formations have been discovered, which has become an important oil and gas production base in China's western South China Sea waters [1] [2]. The Xiyang slope zone is located in the northeastern part of the Weixinan Depression, and the third section of the Liushagang Formation (Liushan section) is an important exploration target system in this area. The reservoir is characterized by strong non-homogeneity and unstable lateral spreading, and with the deepening of exploration, the difficulty of exploration has gradually increased, which has constrained the exploration of this area. At present, domestic scholars have carried out relevant studies on the reservoir characteristics and main controlling factors of the Liusan section in the Weixinan Depression and neighboring areas. Previous researchers [3] [4] [5] on the reservoir of Liusan section concluded that sedimentation is the main factor affecting the physical properties of the reservoir, compaction is the main reason for the deterioration of physical properties, and the development of the reservoir is obviously controlled by the sedimentary phase. In the study of reservoir control factors in the third section of the flow, although the researchers emphasized the influence of sedimentary phase on the reservoir, there is a lack of research on the influence of different micro-phases on the reservoir and the differences in diagenetic effects between micro-phases. On the basis of the previous research, the author took the K oilfield in the Weixinan Depression as the research object, and utilized the data of rock core, cast thin section, scanning electron microscope and logging, etc. to deeply study the key roles affecting the quality of the reservoir, analyze the main controlling factors of reservoir formation, compare the influences of different sedimentary micro-phases on reservoir, and carry out the quantitative research on the rock-forming role. In order to better understand the exploration and development significance of the site this paper sets out to recognise the high quality reservoir development zone from the perspective of sedimentary microphase and lithology.

2. Regional Geological Background

The Weixinan Depression is a tertiary tectonic unit within the Beibu Gulf Basin in the northern part of the South China Sea [6]. The depression is located in the northwestern edge of the Beibuwan Basin, adjacent to the Wanshan Rise in the north and the Qixi Rise in the south, separated from the Haizhong Depression by the Weixinan Low Bulge in the southwest, and as a whole, it is a mini-shaped faulted lake basin that is broken in the north and exceeded in the south [7] [8].

The K oil field in the present study area is located in the northeastern part of the Weixinan Depression, which is a large-scale nose-like structure formed by the extension of the Qixi uplift into the B depression of the Weixinan Depression, with excellent reservoir conditions (**Figure 1**). The drilled wells reveal that the stratigraphy of the study area develops the Paleoproterozoic (Paleocene Changliu Formation, Eocene Liushagang Formation, Oligocene Weizhou Formation), Neoproterozoic, and Quaternary systems in the order of bottom-up [9]. Among them, the Liushagang Formation can be subdivided into the Liusan Section, Liusan Section and Liusan Section from bottom to top. The Liusha Harbor Formation is the target section of this study. During the depositional period, the activity rate of the boundary faults was small, and it was in the early stage of the rapid tension cracking of the lake basin, and the water body was shallow. The Liusha Harbor Formation is dominated by shallow lacustrine deposition, and coarse-grained alluvial fans and fan deltas were developed at the boundary of the depression. In the study area, the reservoir of the K oil field in the Liushan section is mainly developed in the subphase of the front edge of the fan delta, and the lithology mainly consists of sandstone, sand conglomerate and conglomerate-bearing sandstone, etc., which can be classified into four oil groups, namely, L_3 I, L_3 II, L_3 III, and L_3 IV from the bottom up [10], among which L_3I and L_3III can be divided into the upper and lower two oil groups. K oil field this area of fracture development, flow three section of the main fault block circle closure, has a large potential, so as to focus on the discussion object.

3. Basic Reservoir Characteristics

3.1. Petrological Characteristics

The depositional period of the flow three section in the study area was the early stage of the lake basin expansion, and the sedimentary water body was shallow and small in scope, so the material sources often formed a near-edge accumulation

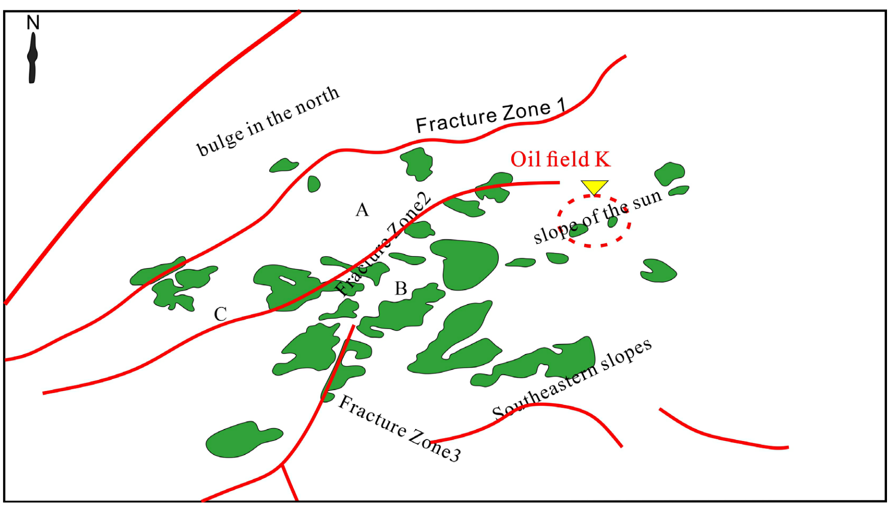


Figure 1. Regional geologic overview of the K oilfield in the flow three section of the Weixinan depression.

at the edge of the basin [11]. Through the core and wall core observation of the flow three section of the K oilfield in the Weixinan Depression, it is analyzed that the lithology of the flow three section in the study area is mainly dominated by coarse and medium sandstones, followed by fine sandstones, siltstones, conglomerate-bearing coarse sandstones, and conglomerates. Based on thin-section identification, the rock type is mainly feldspathic quartz sandstone (**Figure 2**). The quartz content ranges from 71.2% to 92.5%, with an average content of 82.2%, and the single-crystal quartz content is higher; the feldspar content ranges from 4.54% to 19.8%, with an average content of 12.5%, and is dominated by potassium feldspar; and the rock debris content ranges from 0 to 18.9%, with an average content of 5.3%, and is dominated by granite clasts and metamorphic rock clasts. Compared with feldspar and rock chips, quartz has better stability and is one of the important minerals reflecting the maturity of the composition. The flow three sections in the study area have high quartz content and moderate to good compositional maturity.

Based on the cast thin-section observation, the gravel particles of the reservoir in the third section of the K-field flow are poorly-moderately sorted, and the rounding degree is dominated by sub-prismatic-sub-rounded shape (**Figure 3(a)**). The contact mode of the particles is mainly point contact, some particles are point-line contact, and the cementation type is mainly pore type. Locally, the weak compaction between the visible particles shows point-frequent contact. In general, the three sections of the flow in the study area reflect a low degree of mechanical differentiation, mainly depositing gravelly, developed cross-laminated sandstones, all with low structural maturity and characterized by near-source, rapid accumulation.

3.2. Characterization of Storage Space

Based on the identification of microscopic thin section, it shows that the type of

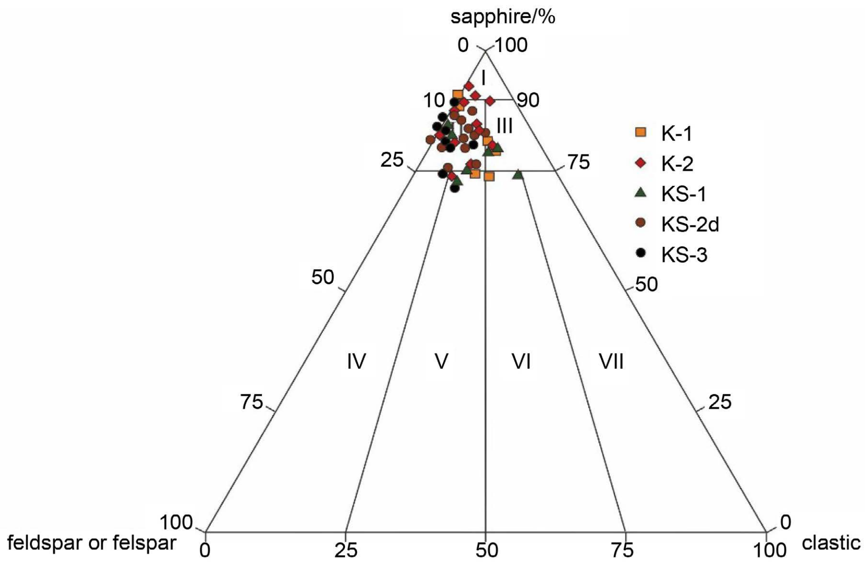


Figure 2. Triangulation of rock types in K oil field, Liu San section, Weinan depression.

reservoir space in the flow three sections of the study area is mainly pore space, with primary pore space dominating, secondary pore space following, and relatively few cracks. Primary pores are mainly intergranular pores (Figure 3(b)), and secondary pores include intergranular soluble pores, intragranular soluble pores, and cast pores (Figure 3(c), Figure 3(d)), which are mainly dominated by intergranular soluble pores. The pore edges of primary intergranular pores are characterized by regular and straight morphology, and local strong compaction leads to pore reduction, which can be seen in the rupture of brittle mineral particles to form cracks (Figure 3(e)). Overall, the study area is characterized by better pore development and connectivity.

3.3. Physical Characteristics

Statistical analysis of the measured physical data of the reservoir in the flow three section of the K oil field in the Weixinan depression shows that the porosity of the study area ranges from 4.1% to 35.1%, with an average value of 24.1% and a median value of 24.1%, of which the samples with porosity greater than 15% account for 94.6% of the total number of samples; the permeability ranges from 0.34 mD to 10,000 mD, with an average value of 1448.46 mD and a median value of 211.7 mD, of which the permeability is mainly distributed between 30 mD and 3000 mD, accounting for 63.4% of the total number of samples (Figure 4). 211.7 mD, of which the permeability is mainly distributed between 30 mD - 3000 mD, accounting for 63.4% of the total number of samples, and some samples can reach 10,000 mD (Figure 4). The grain size particles have a large influence on the physical properties of the study area, and the content of medium and coarse sand is the main factor to improve the physical properties. When the

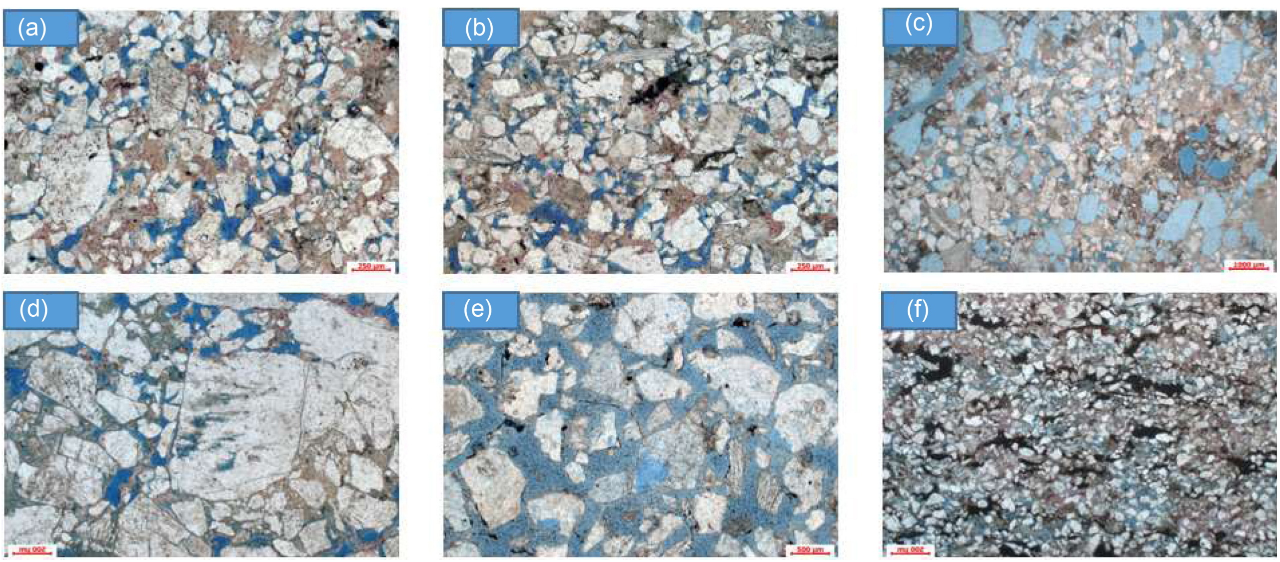


Figure 3. Characteristics of reservoir of the El_3 in K Oilfield, Weixinan Depression (casting thin section). (a) K-2, 1387.1 m, development of intergranular pores; (b) K-2, 1387.1 m, mica-filled intergranular pores; (c) K-2, 1388.41 m, cast pores produced by complete dissolution of feldspars; (d) K-2, 1405.90 m, feldspathic intragranular dissolution pores; (e) K-2, 1796.63 m, fracture formed by fracture breakage of detrital grains; (f) K-2. 1384.11 m, organic matter filled pores.

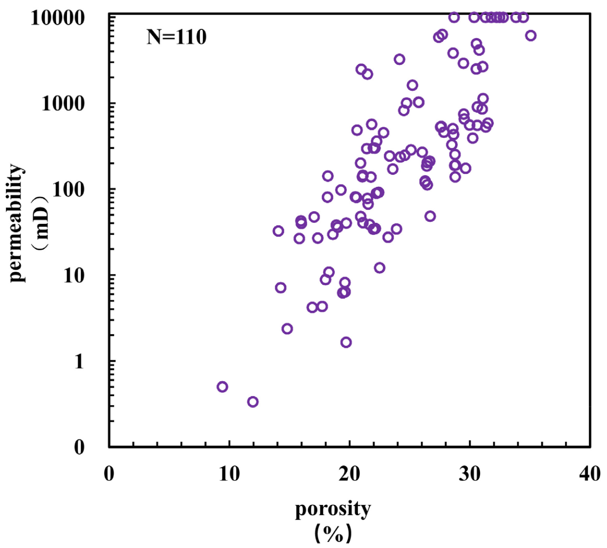


Figure 4. Porosity-permeability intersection diagram of the El_3 in K Oilfield, Weixinan Depression.

particles in the sediments are well sorted, the particle sizes are relatively consistent, forming a uniform particle grain size. The porosity of the reservoir in the study area is distributed from low porosity to high porosity, mainly distributed in the interval range of medium-high porosity; the permeability is normally distributed from extra-low seepage to extra-high seepage, with medium seepage as the dominant one, which reflects that the overall physical properties of the reservoir in the study area are relatively good.

In order to further clarify the differences in physical properties among different lithologies, the lithologies in the study area were categorized into sandstone, sandy conglomerate and sandy conglomerate on the basis of core and wall core observation, and their physical properties were compared. The results are as follows: 1) the porosity of sandstone in the study area ranges from 4.1% to 35.1%, with an average value of 25.3%, and there are few samples with low porosity, mostly greater than 15%, and the average porosity is higher than the average value of the study area; the permeability ranges from 0.05 mD to 10,000 mD, with an average value of 530.0 mD, and it is normally distributed, mainly concentrating on 50 - 500 mD. 2) The porosity of sand conglomerate Between 15.9% and 28.6%, the average value is 20.0%, of which the percentage of samples with porosity of 15% - 25% is the highest, amounting to 90.9%; the permeability ranges from 40.0 mD - 3825.0 mD, the average value is 1152.6 mD, the distribution of the permeability is irregular, and the relationship with the porosity is poor. 3) The porosity of gravelly sandstone ranges from 11.9% to 33.8%, with an average value of 23.6%, and the permeability ranges from 0.34 mD to 10,000 mD, with an average value of 851.1 mD. The results show that the sandstone has the highest porosity, and most of the samples can be up to highly porous, followed by the gravelly sandstone and sand conglomerate, which are mostly moderately porous, and the porosity shows a decreasing tendency with the increase of gravel content. The permeabilities are all dominated by medium permeability, in which the samples of sandstone and sand conglomerate larger than 1000 mD are obviously larger than sandstone, which may be related to the existence of large throats between the particles or microcracks formed by the differential compaction of minerals of different grain sizes [1].

4. Reservoir Formation Main Control Factors

4.1. Influence of Sedimentary Microphase on Reservoirs

Different sedimentary microfacies play a decisive role in the genesis, morphology and size of the sand body. The proximity to the source and the strength of hydrodynamic conditions lead to differences in the composition, sorting, rounding, and heterogeneous content of mineral grains [5]. The study area is a subphase deposition at the front edge of the fan triangle, and in order to further identify the sedimentary microphase, the author used the core, wall core and logging data.

Four sedimentary microphases, namely, submerged diversion channel, estuarine dam, mat sand, and submerged inter-channel, were identified in the study area. Taking the top 1382 m - 1391 m of well K-2 as an example, the funnel and box shapes correspond to the estuarine dam and submerged diversion channel, respectively. Physical data show that the underwater diversion channel has better reservoir physical properties, therefore, the dominant sedimentary microphase is the key to find favorable reservoirs in the plane.

In order to further explore the advantageous sedimentary microphase in the study area, on the basis of identifying the microphase by logging phase, the physical properties of the core are tested (**Figure 5(a)**), and the results confirm that the physical properties of the underwater diversion channel in the study area are the best, with the porosity ranging from 4.87% to 35.06%, and the average porosity can be up to 26.72%; the permeability ranges from 0.49 mD to 10,000 mD, and the average permeability can be up to 2082.39 mD, and the median permeability is 1361.20 mD. The average permeability can reach 2082.39 mD, and the median permeability is 1361.20 mD. The oil content level of the core is mostly oil-soaked or full of oil, and the oil and gas content is good. The microphase lithology of the underwater diversion channel in the study area is

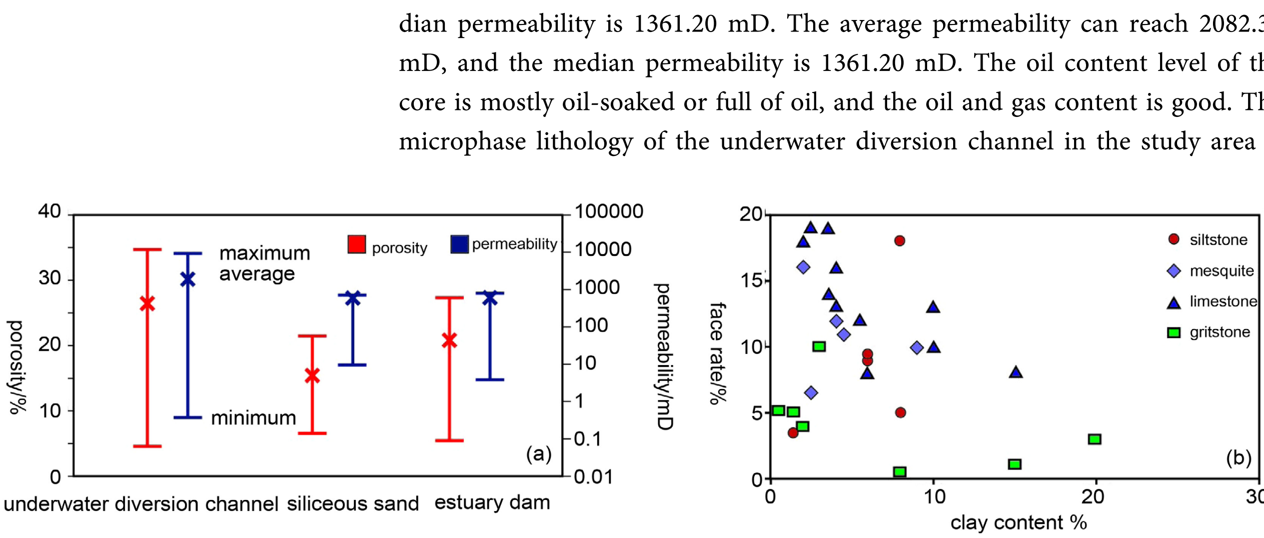


Figure 5. Reservoir characterization of different sedimentary microfacies of the El_3 in K Oilfield.

dominated by coarse sandstone and medium sandstone, followed by conglomerate-bearing sandstone and conglomerate, which are subject to strong hydrodynamic influence, and the mineral particles have large grain size, poorly sorted - medium, and rounded to sub-angular - sub-rounded shape. The second is the estuary dam and mat sand, the lithology of the estuary dam is mainly powder, fine sandstone, mud-bearing siltstone, etc., and it gradually changes into conglomerate-bearing medium and fine sandstone upward, with typical characteristics of the reverse grain sequence, the porosity ranges from 5.69% to 27.44%, the average porosity of up to 20.90%, the permeability ranges from 4.47 mD to 870.23 mD, the average permeability of up to 643.93 mD, the median permeability of 592.32 mD. Compared with the estuary dam, the physical properties of the mat sand are slightly poorer, mainly because the mat sand is mainly the sediment from the far end of the delta front edge, which is dominated by siltstone, with finer mineral grains, the porosity ranges from 6.47% - 21.44%, with an average porosity of up to 15.31%, and the permeability ranges from 9.93 mD - 721.16 mD, with an average permeability of up to 585.81 mD, with a median permeability of 352.0%, and a mean permeability of up to 4.47 mD - 870.23 mD, and a mean permeability of up to 643.93 mD. The average permeability is 585.81 mD, and the median permeability is 352.63 mD. Horizontal laminations can be seen in the core of the microphase rocks in the Gulf of Diversion, the hydrodynamic conditions are very weak, and the deposition is relatively slow, so it is mainly dominated by fine-grained sediments, and the development of primary pore space is very little, and it is difficult for the later diagenesis to form modification to the reservoir, and the physical properties are the worst.

The level of mud content is an important factor affecting the physical properties of the reservoir. Mud will not only occupy the primary pore space and throat, reducing the physical properties of the reservoir, but also inhibit the growth of carbonate cement in the early stage of diagenesis, making the reservoir more plastic and easier to be compacted; in the middle and late stages of diagenesis, mud occupies the reservoir space and inhibits the occurrence of dissolution and erosion, reducing the modification of the reservoir by constructive diagenesis [12] [13]. As the mud content increases, the facies porosity shows a decreasing trend, in which the mud content of the submerged diversion channel of the near-source accumulation is relatively high, the sorting is poor, and the mud heterogeneous base fills the pore space (**Figure 5(b)**). The higher the mud content, the poorer the sorting, which is unfavorable to fluid transport in the reservoir, and the poorer the physical properties. The submerged diversion channel at the front edge of the fan delta is characterized by coarse grains, low mud content, and good physical properties, and is the most effective reservoir development zone in the flow three section of the study area.

4.2. Influence of Sedimentary Gyrations on Reservoir Physical Properties

The depositional environment and its evolution not only affect the planar spreading of the reservoir, but also control the vertical stacking of the reservoir. Vertically, the Flow III section as a whole is a long-term water-entry cyclone, and the L_3 III and L_3 IV oil groups together form a complete mid-term cyclone. In the medium-term basal cyclone, the L_3 I and L_3 II oil groups all exhibit an ascending cyclone [14]. Through the statistics of physical property data of each oil group, it is found that the average porosity of L_3 I oil group can reach 24.8%, and the reservoir property shows better characteristics compared with L_3 II and L_3 III oil groups, and the reservoir property of L_3 I upper oil group has the most superior performance, and the average porosity can reach 26.3%. In the context of long-term water inflow, the lake level is deepening, the sediment transportation distance increases, and the lithology changes from sandstone and conglomerate-bearing sandstone to sandstone [15]. Therefore, the flow three sections in the study area as a whole show a positive rhythm of upward sedimentary grain size thinning, and the change of rock grain size may influence is an important factor in the vertical distribution of favorable reservoirs (**Figure 5(b)**). The major clastic particle compositions of the submerged diversion channel, the mat sand and the estuarine dam were related to porosity and permeability, respectively, and the results showed that medium and coarse sands are favorable factors for the formation of high-quality reservoirs (**Figure 6(b)**, **Figure 6(c)**), and porosity and permeability are positively correlated with the medium and coarse sand contents, and with the increase of the contents of the two, the physical properties of the reservoirs show a tendency to become better; whereas the increase of gravel content makes the physical properties of the reservoirs deteriorate, which is unfavorable to the formation of The increase of gravel content makes the reservoir properties worse, which is not favorable for the formation of high-quality reservoirs. In the study area, the early water body of Liusan section is shallow, and the rapid sedimentary debris particles near the edge of the basin are coarse in grain size and high in gravel content, but poorly sorted and high in muddy heterogeneous base, which makes the physical properties worse [5].

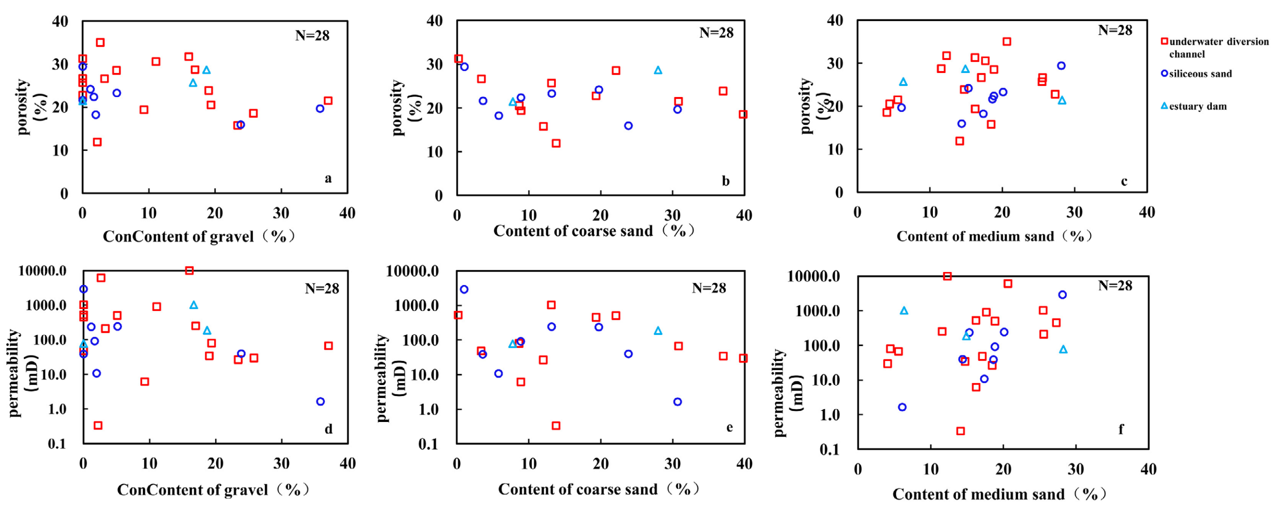


Figure 6. Plot of different sandstone contents versus reservoir physical properties.

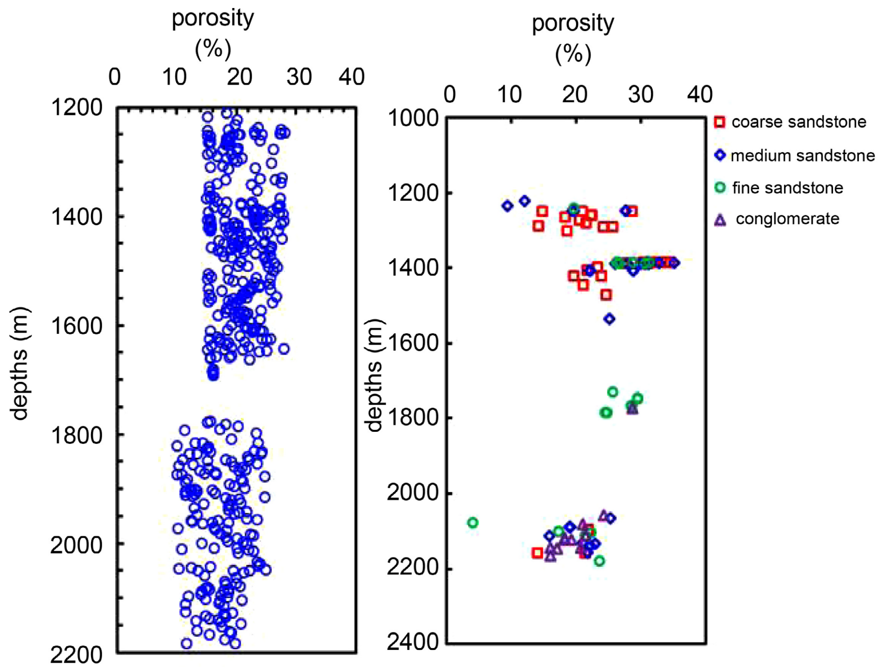
L_3 I oil group are submerged diversion channel will also show different lithological differences, as shown in **Figure 3(c)**, gravel poorly sorted, prismatic - sub-prismatic, containing a large number of fillers, for the basal type of cementation, most of the pores are filled by fillers; while the middle and coarse sandstone particles poorly sorted - medium, locally better sorted, rounded sub-prismatic - sub-rounded, mostly pore-supporting, heterogeneous basal content is relatively small [16], the remnants of the inter-granular pore development, the physical properties of the Relatively good. It is analyzed that under the control of high-frequency cyclone, the cyclic change of the lake plane makes the sedimentary lithology change, and with the change of water body, the proximal part of the front edge of the fan delta changes to the distal part of the front edge of the fan delta, and the grain size of the sand body becomes finer, and the sorting and rounding show a tendency to become better, and the content of heterogeneous bases decreases.

4.3. Effects of Diagenesis on Reservoirs

Different microphases suffer from different degrees of transformation by diagenesis, and favorable sedimentary phase zones lay a good natural foundation for the storage properties of reservoirs, however, with the increase of burial depth, diagenesis has a significant impact on the storage properties of sand bodies. Diagenesis often has both building and destructive effects on reservoirs [17].

4.3.1. Compaction

Compaction is one of the most important reasons for the reduction of reservoir physical properties throughout the sedimentary burial process of the reservoir, especially in the shallow burial stage [18]. The drilled wells reveal that the burial depth of the flow three sections in the study area ranges from 1150 m - 2100 m, and the overall burial depth is shallow. Based on the cast thin-section observation, point contact or point-line contact is dominant between particles (**Figure 3(a)**, **Figure 3(b)**), and some particles are oriented under compaction. Establishing a relationship between the burial depth and porosity of the same sedimentary microphase reservoirs in the study area, the results show that with the increase of the burial depth, the compaction effect of the flow three sections in the study area is gradually enhanced, and the porosity shows a decreasing trend, and the contact relationship of the mineral particles visible in the thin section is gradually transformed from the point contact to the point-line contact. As seen in **Figure 3(e)**, when the burial depth of K-2 well is 1388.34 m, the contact relationship between particles is point contact, and the face porosity can be up to 32.8%, and with the increase of burial depth, the compaction effect is enhanced, and when the burial depth is 1796.63 m, the contact relationship between particles is point-line contact, and the face porosity decreases to 21.5% (**Figure 7**), and it can be seen that the compaction effect ruptures the clastic particles (**Figure 3(f)**). No suture contact is seen in the thin section of the study area, and the evolution of particle contact has not yet reached the stage of compaction and



(a) (b)

Figure 7. Plot of logging data, measured data burial depth versus porosity. (a) Plot of logged data burial depth versus porosity. (b) Plot of measured data burial depth versus porosity.

dissolution. The diagenetic stage experienced by the sandstone has not reached the late diagenetic stage, and it is mainly in the early middle diagenetic stage.

4.3.2. Cementation

The colluvium of the flow three sections in the study area is mainly carbonate colluvium, dominated by calcite, with small amounts of iron calcite, dolomite, iron dolomite and rhodochrosite. The content of iron calcite ranges from 0.5% to 10.5%, with an average content of 1.4%; the content of dolomite ranges from 1.0% to 12.0%, with an average content of 0.37%; the content of iron dolomite ranges from 0.5% to 1.0%, with an average content of 0.04%; and the content of rhodochrosite ranges from 0.5% to 2.0%, with an average content of 0.19%. Observed by microscopic thin section, calcite is mostly embedded crystals or fine and medium crystal structure in the debris particles to form cement and fill the pores. The rhodochrosite was formed in the early diagenetic stage, and most of them are in microcrystalline form to fill the pores.

4.3.3. Dissolution

Dissolution action forms or improves pores and throats through the dissolution of rock components, improving the physical properties of the reservoir [15]. In the study area, the dissolution of the three sections of the flow is mainly manifested in the dissolution of unstable components such as feldspars, rock fragments and carbonates by atmospheric freshwater or organic acids, which produces secondary pores such as intergranular pores, intragranular pores and molded pores. Among them, the dissolution of feldspar is mainly dominated, and the dissolution edge left behind by dissolving feldspar partially when the fluid flows in the pore throat can be seen in the thin section, and the dissolution fluid dissolves along the direction of solubility or cracks, forming intragranular pores (**Figure 3(d)**), and when the feldspar is subjected to strong dissolution, the feldspar is dissolved away to form the casting holes (**Figure 3(c)**). In addition, the development of primary pores also allows the dissolution fluid to better modify the reservoir and improve the reservoir physical properties. In particular, the primary pore development of sedimentary microphases such as diverging interbay and mat sand is worse, and it is more difficult for the dissolution fluid to flow between the pores to form secondary dissolution holes. Therefore, the sedimentary microphase is also the key to control the intensity of dissolution in the later stage, often the higher the sand richness, the larger the mineral particles, the better the sorting and rounding of the reservoir, the stronger the dissolution effect [17].

4.3.4. Quantitative Evaluation of Rock Formation

In order to further evaluate the effect of diagenesis on the reservoir, this paper will carry out a quantitative study of diagenesis in terms of compaction pore reduction rate, cementation pore reduction rate and dissolution pore increase rate.

The empirical formula of Beard *et al.* [19] is adopted:

$$\varphi_{\text{primitive}} = 20.91 + 22.9/\text{So}$$

Calculate the original porosity of the flow three reservoirs in the study area (where $\varphi_{\text{primitive}}$ is the original porosity and So is the sorting coefficient), and based on the cast thin section, use the dot notation method to obtain the parameters of the total surface porosity compaction porosity, cementation porosity, and dissolution porosity, and to establish the relationship between the total surface porosity and the porosity:

$$y = 0.0203 \times 132 + 0.1547 \times 13 - 1.1132 \tag{1}$$

where: y is porosity, %; x is apparent face porosity, %. Using Equation (1) combined with cementation face porosity and dissolution face porosity to calculate the cementation pore reduction φ cementation and dissolution pore increase φ dissolution during the evolution of the flow three reservoirs in the study area, and combined with Equation (2) can calculate the compaction pore reduction φ compaction. In this paper, we draw on the method of Wang *et al.* [20] to calculate the intensity of diagenetic action, and according to Equation (3), Equation (4), and Equation (5), we can get the pore increase/decrease rate of each diagenetic action during the evolution of the reservoir:

$$\varphi_{\text{compaction}} = \varphi_{\text{primitive}} + \varphi_{\text{solution}} - \varphi_{\text{cementation}} - \varphi_{\text{present}} \tag{2}$$

$$P_{\text{compaction}} = (\varphi_{\text{compaction}}/\varphi_{\text{primitive}}) \times 100\% \tag{3}$$

$$P_{\text{cementation}} = (\varphi_{\text{cementation}}/\varphi_{\text{original}}) \times 100\% \tag{4}$$

$$P_{\text{dissolution}} = (\varphi_{\text{dissolution}}/\varphi_{\text{original}}) \times 100\% \tag{5}$$

where: φ present for present porosity, %; $P_{compaction}$ for compaction pore reduction rate, %; $P_{cementation}$ for cementation pore reduction rate, %; $P_{dissolution}$ for dissolution pore reduction rate, %.

Calculations show that the average compaction-reduced porosity $P_{compaction}$ of submerged diversion channel, mat sand, and estuarine dam are 82.576%, 94.232%, and 97.938%, respectively, and the compaction-reduced porosity of submerged diversion channel is the lowest. The average dissolution pore gain rate P dissolution of submerged diversion channel, mat sand, and estuarine dam were 7.501%, 2.101%, and 1.003%, respectively, and the dissolution pore gain rate of submerged diversion channel was the highest.

Based on the thin-section statistics of total pore face porosity and colluvium face porosity, and establishing the relationship can be seen that the sample points mostly fall in the pore reduction area dominated by compaction, and colluvium has a slightly weaker influence on reservoir quality (**Figure 8**), and compaction is the most dominant destructive diagenetic action in the K oilfield. And according to the results of the formula, the underwater diversion channel has the lowest compaction-reduced pore rate, the highest dissolution-enhanced pore rate, and the best physical properties (**Table 1**).

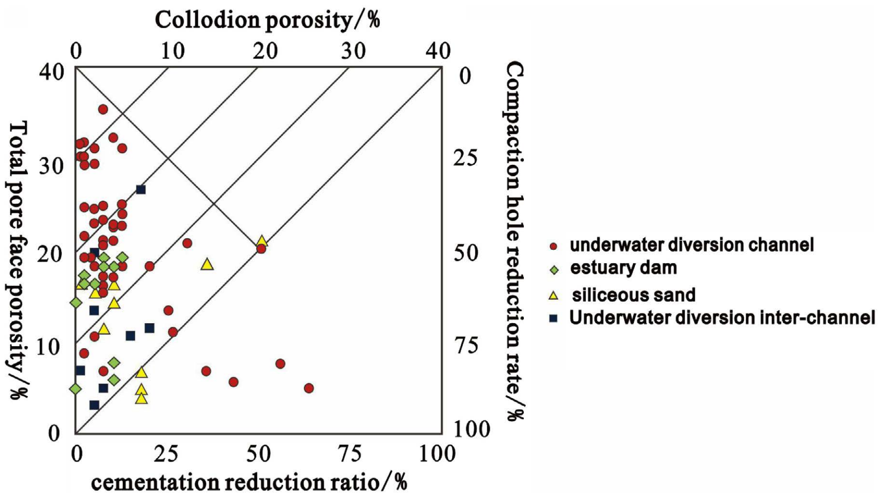


Figure 8. Intergranular volume versus cement content intersection plot.

Table 1. x Quantitative analysis of three sections of tectonic flow diagenesis.

	Compaction hole reduction rate/%			Cementation reduction ratio/%			Dissolution porosity enhancement rate/%		
	maximum	minimum	average	maximum	minimum	average	maximum	minimum	average
Underwater diversion inter-channel	100	9.638	82.576	31.419	0	1.314	50.828	0	7.501
siliceous sand	100	0.465	94.232	6.339	0	0.334	34.941	0	2.101
estuary dam	100	0.268	97.938	2.335	0	0.003	19.334	0	1.003

5. Conclusion

1) The lithology of the K oilfield in the Weixinan Depression is mainly sandstone, followed by conglomerate-bearing coarse sandstone and sand conglomerate. The rock type is mainly feldspathic quartz sandstone. The grains are pore-type cemented, and the rounding degree is mainly sub-prismatic and sub-rounded, and the sorting is moderate to good. The storage space is dominated by primary pore space, with a small amount of secondary pore space, porosity ranging from mesoporous to highly porous, permeability of medium seepage, and overall physical properties are good.

2) The depositional environment is the main reason affecting the K oil field in the Weixinan Depression. Medium and coarse sandstones are favorable factors for the formation of high-quality reservoirs, and the high content of gravel and mud is unfavorable for the formation of high-quality reservoirs. The underwater diversion channel is the most effective reservoir development zone in the flow three section of the study area, characterized by coarse grains, low mud content and good physical properties.

3) Compaction is the main pore-reducing mechanism in the study area, and dissolution improves the physical properties. The underwater diversion channel has the lowest compaction pore-reducing rate, the highest dissolution pore-enhancement rate, and the best physical properties, and the weakly cemented-strongly dissolved coarse sandstone phase developed in the subphase of the submerged diversion channel in Section 3 of the flow in the study area is the most favorable reservoir.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Li, W. (2023) Reservoir Characterization of the Flow Three Sections of the Weixinan Depression in the Beibuwan Basin. *Natural Gas Exploration and Development*, **46**, 42-49.

[2] Man, X., Hu, D., Wu, J., *et al.* (2023) Developmental Characteristics and Reservoir Formation Mode of the Lake Bottom Fan in the Eocene Fluvial Section of the Weixinan Depression, Beibuwan Basin. *Lithologic Reservoirs*, **35**, 137-144.

[3] Lou, M., Yang, X., Yao, G., *et al.* (2020) Diagenetic Phase Analysis and Dessert Reservoir Prediction of the Flow Three Reservoirs in the Weixinan Depression. *Marine Geology and Quaternary Geology*, **40**, 171-184.

[4] Xu, Y., Yang, X. and Mei, L. (2020) Characteristics and Main Controlling Factors of the Sand and Gravel Reservoir in the Flow Three Section of the Northwest Steep Slope Zone of the Weixinan Depression. *Earth Science*, **45**, 1706-1721.

[5] Qiao, Y. (2017) Sedimentary Phase Spreading and Favorable Reservoir Prediction of the I-II Oil Group in the Flow Three Section of Wushi Depression, East District, Beibuwan Basin. Master's Thesis, China University of Geosciences, Beijing.

[6] Wu, S., You, L., Zhao, Z., *et al.* (2017) Reservoir Characteristics and Favorable Re-

servoir Distribution in the Flow Three Section of the Sloping Yang Slope Zone of the Weixinan Depression. *Journal of Northeast Petroleum University*, **41**, 24-31, 122.

[7] Peng, S., Li, S., Hu, D., *et al.* (2017) Early Oligocene Low-Level Deltaic Deposits and Hydrocarbon Geologic Significance of the Sloping Yang Slope of the Weixinan Depression, Beibuwan Gulf. *Frontiers of Marine Geology*, **33**, 32-39.

[8] Liu, J., Wang, R., You, L., *et al.* (2012) Compositional Petrography and Effective Reservoirs of the Liusha Harbor in the Weixinan Depression. *Journal of Southwest Petroleum University* (*Natural Science Edition*), **34**, 175-184.

[9] Gong, L., Hu, D., Man, X., *et al.* (2022) Sedimentary Characteristics of Early Lake-Bottom Fan and Prediction of Favorable Reservoirs in the High Level Domain of the Flow Section of the Weixinan Depression. *China Offshore Oil and Gas*, **34**, 54-64.

[10] Sun, X., Fang, X., Chen, K., *et al.* (2019) Sedimentary Microphase Study of the Fan Delta in the Context of Complex Fault Blocks and Lithology—A Case Study of the Weizhou A Oilfield. *China Science and Technology Information*, No. 6, 97-98.

[11] Sun, L., Yu, X., Li, S., *et al.* (2017) Sedimentary Characteristics of the Water-Entrained Fan Delta of the Eocene Liusan Section in the Eastern Part of the Wushi Depression, Beibuwan Basin. *China Geology*, **44**, 485-498.

[12] Liu, X. (2021) Sedimentary Phases and Reservoir Characteristics of Shasi Section in Niuxintuo Area, LiaoXi Depression. Master's Thesis, China University of Petroleum, Beijing.

[13] Ma, X., Yin, T. and Wang, X. (2009) Sedimentary Microphase Study of the Fan-Delta Front of the Qiketai Formation in Le3 Block. *Xinjiang Oil and Gas*, **5**, 10-14, 27.

[14] Li, M., Dong, G. and Qi, Z. (2015) Sedimentary Phases of the Weizhou 10-3 Oil Field in the Weixinan Depression and the Flow Three Sections in the Surrounding Area. *Journal of Sedimentology*, **33**, 314-325.

[15] Zhang, B. (2021) Sedimentation and Diagenesis in a Faulted Basin under Volcanic Influence. Master's Thesis, China University of Mining and Technology, Xuzhou.

[16] Gao, L., Zhang, M., Yan, H., *et al.* (2017) Reservoir Characteristics and Controlling Factors of the Weizhou 10-A Oilfield and the Flow Three Section of the Surrounding Area in the Weixinan Depression. *China Mining Industry*, **26**, 156-163, 168.

[17] Jiang, P. (2014) Comprehensive Evaluation of Complex Reservoirs in Liushagang Formation, Weixinan Depression. Ph.D. Thesis, China University of Geosciences, Wuhan.

[18] Cao, Y. (2019) Main Controlling Factors of High-Quality Reservoirs in Dongying Formation of CFD6-4 Oilfield in Bozhong Depression. Master's Thesis, China University of Petroleum (East China), Qingdao.

[19] Beard, D.C. and Weyl, P.K. (1973) Influence of Texture on Porosity and Permeability of Unconsolidated Sand. *AAPG Bulletin*, **57**, 349-369. https://doi.org/10.1306/819A4272-16C5-11D7-8645000102C1865D

[20] Wang, J., Cao, Y., Liu, K., *et al.* (2017) Identification of Sedimentary-Diagenetic Facies and Reservoir Porosity and Permeability Prediction: An Example from the Eocene Beach-Barsandstone in the Dongying Depression, China. *Marine and Petroleum Geology*, **82**, 69-84. https://doi.org/10.1016/j.marpetgeo.2017.02.004