Reservoir characteristics and physical property controlling factors of Kexia Formation in WEH Oilfield, Junggar Basin

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Abstract. The Kexia Formation reservoir in WEH oilfield is located at the bottom of the Triassic, which is mainly characterized as delta plain and front margin deposits. Through a comprehensive analysis of rock flake identification, scanning electron microscopy and physical properties, the petrological characteristics and the physical properties and physical property control factors of the reservoir were studied in detail. The results showed that the reservoir rock of Kexia Formation is consisted of medium-fine-grained lithic sandstone, glutenite and conglomerate, and the reservoir pore types of the reservoir space are mainly divided into intergranular pores, intergranular dissolved pores and intra-granular dissolved pores. The mercury intrusion data indicated that the reservoir throat of the Kexia Formation is featured as a medium-small pore thin throat, and the average porosity of the reservoir physical property is 17.78%, and the average permeability is 5.2mD, which suggested that it is a medium deviation reservoir with medium-low porosity and low permeability. The physical properties of the reservoir are essentially subject to the actions of sedimentation and diagenesis. The reservoir development is benefited by the distributary channel, river mouth bar and subaquatic distributary channel sedimentary environment in the delta plain and front. And the actions of compaction and cementation works as the major causes for the low permeability of reservoir, while the action of alteration serves as the basic sources of clay minerals.

1. Introduction
As early as in the beginning of 90s last century, the WEH oilfield in the Junggar Basin has been put into development, of which the major block to be developed was fell down to the Wu 5th well area, after that Kexia Formation oil deposit of Triassic Period was found in the Wu 33rd well area. With an in-depth study on the characteristics and the influential factors of the Kexia formation reservoir, the reservoir harvested a detailed description in terms of its oil deposit, through which the distribution of the oil left currently can be fully understood, in order to provide to a geological basis for the forecast of high-quality reservoir and for the formulation of high-efficient development programs in advanced phase [1].

WEH oilfield is a naturally favorable block of oil and gas accumulation, ascribed to its geographical location in the Northeast direction of Karamay City and the south of Hala Alat Mountain, and adjacent to the Devil City Scenic Area in northeast, to its endowed development with Yadan landform by...
Cretaceous wind erosion, as well as to its regional structure standing in the upper part of the Urho fault nose structure in the Wu-Xia fracture zone on the northwestern margin of the Junggar Basin. The well drilling has disclosed the Cretaceous Tugulu Group with a top-down development (K1tg), and the Jurassic formations including Qigu Formation (J3q), Toutunhe Formation (J2t), Xishanyao Formation (J2x), Sangonghe Formation (J1s), and Badaowan Group (J1b), and the Triassic formations including Baijiantan Formation (T3b), Keshang Formation (T2k2), Kexia Formation (T2k1), and Baikouquan Formation (T1b), and the Permian Formations including Urho Formation (P2w), Xiazijie Formation (P2x), and Fengcheng Formation (P1f). Of these formations, the formations of Jurassic show an unconformable contact with the formations of Triassic, and the formations of Triassic are also in unconformity contact with the formations of Permian. Moreover, the Baijiantan Formation and Keshang Formation, both located at the high position in the northeast structure, are subject to denudation.

The northwestern margin of the Junggar Basin has experienced three regional tectonic movements, of which the tectonic movement at the end of the Permian period formed the basic pattern of large uplifts, depressions and large fault zones in the basin; for example, it is in this period that the basic geographical contour of Ke-Wu fault zone which was shaped. The second tectonic movement is the one occurring at the end of the Triassic period. Inherited the last tectonic movement, this tectonic movement, with a reduced intensity and extent, formed nose-shaped anticline structures and reverse faults, such as the Wu-Xia fault nose structural belt that was shaped in this period; besides, this period is also a period when a massive amount of oil and gas were migrated and accumulated. Starting from the late Cretaceous period, the tectonic movement in this area is mainly manifested by an uplift and erosion of the basin and the formation of normal faults in small scales. The Urho anticline is considered as the primary direction for the migration and transportation and the gathering place for oil and gas. To blame the higher uplifts and the fault development, the top of the anticline has been denuded in a severe manner, leading to a decrease in the oil and gas accumulation. The fault is a bridge connecting the oil source of Permian and the Triassic trap, and the channel of importance for the vertical migration of oil and gas. The regional cap lock is the Baijiantan Formation of Upper Triassic Series, while the mudstone compartment between the glutenite of Middle-Lower Triassic Series is a partial cap lock [2]. The core oil-generative assemblage in the Wu-Xia area is the Fengcheng Formation and the Lower Urho Formation of Permian Series, while the main oil-bearing strata of the Upper Triassic Series comes down to the Kexia Formation, with a stratum exceeding 100m. And this is the key geographic segment that is studied in this article.

2. Characteristics of the Reservoir

2.1. Petrological characteristics

According to the results of core observation and indoor rock slice identification, it is suggested that the reservoir rocks of the Kexia Formation in the WEH oilfield of the Junggar Basin are constituted of medium-fine-grained lithic sandstones, unequal-grained sandstones, glutenite, and conglomerate. The maturation of the reservoir composition is relatively low, and the sandstone composition includes 0~31% of quartz, with an average of 16.54%; the feldspar is 1%~28%, with an average of 14.92%; the cuttings content is 47%~95%, with an average of 68.54%. In the debris, the primary ingredient is tuff cuttings, with a content of 33%~84% and an average of 54.15%, followed by fine rock fragments and a small amount of andesite, slate and quartzite cuttings. The rock of the conglomerate is mainly composed by tuff, with a content of 51%~78% and an average content of 64.86%, followed by sandstone and andesite cuttings, and a small amount of fine rock and granite cuttings and so forth. The sandy conglomerate contains the sandy components of 11~27%, with an average of 19.7%, while its major ingredient is the tuff cuttings. The grinding of glutenite particles is dominated by sub-circles and secondarily dominated by sub-shapes, so as to sort poor quality and medium quality; and the contact modes for the particles is mainly operated by line contacts, and assisted by line-point contacts. The main type of cementation is press insertion, and the secondary type is press insertion-porosity [3].
2.2. Types of reservoir space

2.2.1. Types of pores. Based on the identification results from the clastic rock casting slices of the No.11 core well and scanning electron microscopy, it is suggested that the pore type of the Kexia Formation in the WEH oilfield was dominated by residual intergranular pores, followed by intra-granular dissolved pores, and a small number of primary intergranular pores, as well as a very small number of micro-cracks and kaolinite inter-crystalline pores. The average face rate was .02%, and the coordination number of pore throats ranged from 0 to 2, where the remaining intergranular pores accounted for 48% of the total pores, and the primary intergranular pores accounted for 11% of the total pores. Accordingly, the major type of the pore combination in the reservoir is considered to be the combination of residual intergranular pores and intra-granular dissolved pores, with a small proportion of the combination of residual intergranular pores-primary intergranular pores, which is rated as a relatively poor pore combination type.

2.2.2. Characteristics of pore structure. Through a statistical process and collation on the data of the 25 mercury intrusion samples and the parameters of pore throats of the 6 wells in the Kexia Formation, the mercury intrusion curves (Figure 1) and the pore structures (Table 1) were separated into 4 categories. Of the categories, the I category of pore structure is featured with a coarser skewness, where the curve presented a platform section with a small slope, the particle sorting is preferential to medium-poor quality, the discharge pressure is relatively low, the value usually fluctuating between 0.01 ~ 0.14 MPa, the median pressure ranges from 0.06 ~ 1.79 MPa, the maximum pore throat radius is between 5.15~113.71μm, and the maximum mercury-input saturation ranges from 89.45%~96.2%; all these natures contribute the reservoir of this type to being equipped with outstanding physical properties, and most of the reservoir is inherent with a porosity of 17.4%~27.8% and a permeability of generally greater than 100mD, regarded as a favorable reservoir in the Kexia Formation within the research district.

![Figure 1. Typical mercury injection curves of Triassic Kexia Formation in WEH Oilfield.](image)

| Pore structure classification | skewness | Porosity /% | Permeability /mD | Displacement pressure /MPa | Median pressure /MPa | Maximum pore throat radius /μm | Maximum mercury saturation /% | Reservoir performance |
|-----------------------------|----------|-------------|-----------------|---------------------------|---------------------|-------------------------------|-------------------------------|----------------------|
| I                           | positive | 17.4~27.8   | >100            | 0.01~0.14                 | 0.06~1.79           | 5.15~113.71                  | 89.45~96.2                   | excellent            |
| II                          | negative | 11.1~18.8   | 0.081~3.04      | 0.52~3.11                 | 4.43~15.87          | 0.24~1.41                    | 59.32~90.81                  | good                 |
| III                         | negative | 9.9~19.3    | 0.04~20.1       | 0.6~1.48                  | 5.22~17.5           | 0.5~1.22                     | 39.36~51.16                 | general              |
| IV                          | negative | 7.3~15.3    | 0.034~0.148     | 1.21~4.3                  | 11.67~19.31         | 0.17~0.61                    | 36.94~53.24                 | poor                 |

Table 1. Pore division of Triassic Kexia Formation in WEH Oilfield.

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In the II category, the pore structure shows a finer skewness, where the particle sorting is of medium-poor quality, the discharge pressure is high, usually ranging between 0.52～3.11MPa, the median pressure lies between 4.43～15.87MPa, the maximum radius of pore throat fluctuates between 0.24～1.41μm, and the maximum mercury-input saturation ranges from 59.32%～90.81%, and thus it is concluded that reservoirs in this category is natured with comparatively poor physical properties, and more of them are of 11.1%～18.8% in porosity and usually of 0.081～3.04mD in permeability; consequently, they are rated as relatively good reservoirs in the Kexia Formation within the research district. When it comes to the III class of pore structure, the skewness is at finer side, the particle sorting is of extreme poorness, the discharge pressure is comparatively high, ranging between 0.6～1.48MPa, the median pressure lies between 5.22～17.5 MPa, the maximum radius of pore throat ranges between 0.5～1.22μm, and its maximum mercury-input saturation is relatively low, as 39.36%～51.16%, indicating that its storage performance is poor; more of these reservoirs has a porosity fluctuating between 9.9%～19.3%, and a large difference in permeability, distributed over the interval of 0.04 to 20.1mD. As far as the pore structure in the IV class, they have a comparatively worse particle sorting, and their discharge pressures ranges between 1.21～4.3MPa, the maximum radius of throat channels lies between 0.17～0.61μm, and the porosity is dropped down to 7.3%～15.3%, and the permeability is smaller than 0.148mD, and thus these reservoirs are commented as a reservoir class of utmost low quality.

2.3. Physical properties of reservoir

It is the two basic parameters, namely, the porosity and permeability that are used to appraise the superiority and inferiority of the reservoir physical properties and to divide the reservoir categories. Through an analysis of the actually measured pore infiltration data of 90 samples from 6 wells in the Kexia Formation in the study area, it is shown that the reservoir porosity of the Kexia Formation in this area ranged between 10.2%～27.8%, with an average value of 17.698% and mainly distributed in the interval of 14%～18% (Figure 2a); the permeability fluctuated between 0.042～4864mD, and the mean value was 5.1988mD, basically falling in the distribution interval between 0.10～10.00mD (Figure 2b). From the statistical analysis, it is can obtained that the porosity of the siltstone was 10.2%～24.4%, with the mean value of 16.02%, and the permeability lied between 0.042～61.1 mD, with the average value of 2.92 mD; the porosity of the sandstone fluctuated between 15.9%～27.8% and the average value was 21.02%, and the permeability ranged between 0.079～4860 mD, with the average value of 917.38 mD; in terms of the conglomerate, the porosity falls into the scope between 11.4%～20.8%, with the average value of 16.13%, and the permeability lied in the scope of 0.25 3~91.2 mD, with the average value of 10.4 mD. In overall, these values indicated the characteristics natured in the reservoir of medium-low porosity and low permeability.

Figure 2. Reservoir property distribution and correlation of the Kexia Formation.

The results of porosity and permeability interaction (Figure 2c) suggested that the overall correlation of the porosity and permeability of the Kexia Formation was at a comparatively high level, and R2=0.61,
which indicated that the permeation ability of the reservoir was mainly under the constrains from pores and throats, while the quality of physical properties and the change of oil bearing is directly controlled by the pores. Of them, the fine sandstone-the gravel coarse sandstone showed the best porosity-permeability correlation, while the glutenite-small conglomerate and siltstone are natured with a relatively poor correlation between the porosity and permeability, from which it was indicated that the glutenite was characterized by strong anisotropism and comparatively poor pore structure.

3. Analysis of control factors to reservoir development

3.1. Sedimentation action

The original sedimentary environment determines the rock component types, the change of component contents, the particle structure of debris, and the location and morphology of the reservoir distributions of the clastic reservoir, which furthermore imposed an impact on the inherent physical properties of the reservoirs eventually [1]. In the article, the focus is come down to a discussion of the effects of particle structure and lithology of the clastic rock and the sedimentary micro-facies on the porosity and permeability characteristics and oil deposit levels of the reservoirs, under the control by sedimentation action.

3.1.1. Particle structure of debris. Based on the analyzed data of the particle size and physical properties of 54 samples from 6 wells, it is suggested a significant influence that was casted by the debris

![Figure 3. Relationship between sedimentary particle texture and physical properties of Triassic Kexia Formation in WEH Oilfield](image-url)
particle structure of the Kexia Formation reservoirs in the WEH oilfield of Junggar Basin on the changes in the porosity and permeability of the reservoirs, and a wide distribution of the sample lithology covering from siltstone to medium conglomerate. From the relationship between pore permeability and average particle size, it can be concluded that the physical properties of the reservoirs attached a positive correlation to the average particle size within a certain range ($4^{-3}_φ$), while the pore permeability was abruptly reduced when the average particle diameter was larger than $3_φ$. In the view of the relation between the pore permeability and the standard deviation, the physical properties of reservoirs was negatively correlated with the standard deviation, and the sorting of the samples were at a lower level overall.

In this study, it is deemed that the rock types produced a certain controlling effect on the reservoirs’ physical properties (Figure 3), consistent with the law that the physical properties are changed with the change in particle size. The fine sandstone-coarse sandstone was of moderate particle size, its sorting and rounding were both relatively good, and the structure maturity was at a higher level; the rock of this type is born with a low content of cements, a weaker cementation, and is concurrently developed with karstification, thus contributing to a good pore permeability. Although small conglomerate, glutenite, and the like are possibly exposed to the karstification action, the content of heterogeneous base in them are usually high, and these rocks are matured with poor sorting and rounding, strong heterogeneity, and comparatively worse physical properties. With a fine particle size, the siltstone is born with a relatively high content of cements, and its physical properties are dominated by compaction and cementation; thus, the siltstone is featured with relatively poor physical properties [4].

3.1.2. Sedimentary facies. The influence of sedimentation on the reservoir physical properties are mainly embodied in the obvious differences in the reservoir physical properties on the different sedimentary facies belts [5]. The reservoirs of the Kexia Formation in the study area primarily belongs to delta plains and delta front sediments, which can be further subdivided into distributary channels, distributary forks, crevasse splay, as well as river mouth bar, subaqueous distributary channels and sheet sands. The statistics of pore permeability data of reservoirs categorized into different micro-facies suggested that the control of micro-facies on the distribution of reservoir physical properties was of significance. The favorable reservoirs are mainly separated as distributary channels, river mouth bar and subaqueous distributary channels; the mean values of their porosity were 20.89%, 22.15%, and 20.22%, respectively, and the average values of their permeability were 58.418mD, 157.813mD, and 48.182mD, respectively. The lithology of the favorable reservoirs is consisted of glutenite and sandstone. Additionally, these reservoirs were matured with a relatively strong hydrodynamic environment, relatively large thickness of the sand bodies, better sorting and rounding, a comparatively high degree of the structural maturity, and a better pore permeability.

| Sub-facies          | Micro-facies       | Main lithology                     | Porosity (%) | Permeability (mD) | Sand body thickness | Oily         |
|---------------------|--------------------|------------------------------------|--------------|-------------------|---------------------|-------------|
| Delta plain         | Distributary channel | Glutenite sandstone               | 16.52-26.48  | 20.89             | 1.135-583.877       | 58.418 Medium-thick | Medium - better |
|                     | Distributary fork   | Siltstone                          | 15.50-20.77  | 18.53             | 0.579-18.962        | 7.071 Thinner  | Poor          |
|                     | Crevasse splay      | Siltstone, fine sandstone          | 16.07-23.53  | 20.23             | 0.842-117.665       | 29.827 Medium-thin | Medium- poor   |
| Delta front         | River mouth bar     | Glutenite - sandstone              | 17.38-27.33  | 22.15             | 2.100-1086.692      | 157.813 Thick  | Good          |
|                     | Subaqueous distributary channel | Glutenite - sandstone      | 15.29-28.77  | 20.22             | 0.501-1516.899      | 48.182 Medium-thick | Good          |
| Sheet sand          | Fine sandstone      |                                   | 14.87-23.27  | 18.83             | 0.381-99.378        | 11.902 Medium-thin | Medium- poor   |
3.2. Diagenesis
By means of analysis on the slices, scanning electron microscopy and X-ray diffraction, and combined with the studies concerning the rules in the aspects of diagenesis, tectonic evolution and oil and gas display, it is indicated that the reservoirs in the Kexia Formation in the WEH oilfield of the Junggar Basin have been undertaken with a series transformation by diagenesis such as mechanical compaction, cementation and karstification. Of these diagenesis actions, the compaction and cementation led to a decrease in the physical properties of the reservoirs, and the karstification can impose a certain effect of construction reformation on the reservoirs, while the tectonic activities controlled the reginal accumulation types of gas and oil and played a certain positive role in improving the pore permeability [6-9].

3.2.1. Compaction. From the rules that the porosity and the apparent density of rocks are changing with the depth variation, it can be known that the reservoirs in the WEH oilfield have been clearly impacted by the compaction. Moreover, it was found from the statistical data of microscopic specimens that the reservoirs of the Kexia Formation mainly develop lithic sandstones; the content of plastic heterogeneous reaches to high level. The spaces between the particles were mainly filled with clay minerals. The compressive strength of these reservoirs was also at a lower level. And the debris particles were primarily linked by line contact, while they were supplemented by point contacts. Thus, the primary intergranular pores of the reservoirs would be completely depleted under an intense compaction. [10] Regarding to the sections where the carbonates cementation was forceful in the early stage, the occurrence of compaction harvested a suppression, for most of the intergranular pores were filled with cements, and the contacts between the particles were made by points; the dissolution of calcite in the later stage generally grouped with residual primary pores to form mixed pores, which imposed an ameliorating effect on the reservoirs. [1].

| Well name | Sample depth /m | Number of samples | Smectite % | illite/smectite mixed mineral % | Illite % | Kaolinite % | Chlorite % | Illite/smectite mixed ratio % |
|-----------|----------------|------------------|------------|---------------------------------|----------|-------------|------------|-------------------------------|
| WD3384    | 985.4-1001.01  | 5                | 26.8       | 12.4                            | 44.4     | 16.4        | 20         |                               |
| W001      | 1089.48-1090.51| 2                | 25.5       | 9.5                             | 52.5     | 12.5        | 40         |                               |
| W002      | 857.16-893.04  | 3                | 39.7       | 14.3                            | 30.7     | 15.3        | 53.3       |                               |
| W003      | 900.21-1039.91 | 4                | 53.5       | 17.5                            | 20       | 9           | 70         |                               |
| W33       | 859.72-930.22  | 5                | 60         | 8.8                             | 21.2     | 10          | 60         |                               |

3.2.2. Cementation. With the statistical analysis of rock slices, scanning electron microscopy and X-ray diffraction data of 156 samples from 11 wells in the study area, the results presented that the main interstitial materials filling the Kexia Formation reservoirs of Triassic Series in the WEH oilfield were muddy heterogeneous, with content ranging between 1%~25% and an average value of 5%, which were evenly distributed among the particles; in addition, the presence of uneven hydro-mica and hydro-biotite were also reflected in these data. The content of cements fluctuated between 0~3%, 0.4% in average, and most of the ingredients were calcite and siderite and few of siliceous substances; of them, the calcite cements were evenly distributed and the edge phenomenon of metasomatic debris particles was exhibited clearly. The clay minerals were mainly composed by illite and smectite mixed layers, followed by kaolinite, illite and chlorite. Among them, the average mass fraction of the illite and
Smectite mixed layers reached to 41.1%, and these layers were presented as irregular and honeycomb-like aggregates under the scanning electron microscope, which were generally wrapped in the form of a film on the surface of the crumb particles. For the kaolinite, its average content was 33.76% and most part of it was worm-like aggregate that filled in the intergranular pores. The illite was tested an average content of 12.5%; generally, the illite was wrapped in the form of filaments on the surface of debris particles, while some part of it was in the form of directional sheet-like aggregates, filling in the intergranular pores. The chlorite had an average content of 12.64%, and most of them were in shape of leaf and their surfaces were presented as fluff spheres, which grew on crumb particles, filled in the intergranular pores, and dissolve pores.

3.2.3. Alteration. From an observation on the slices, it was found that a large number of feldspars showed the muddy phenomena (kaolinite and a part of sericitization), which belongs to a typical alteration with medium- and low-temperature hydrothermal liquid, often distributed in the upper part of the alteration zone. In the process of alteration, the minerals are decomposed and the basic components such as calcium and iron are strongly leached, thus to yield rocks that are composed of kaolinite, sericite and quartz. Categorized into the layered silicate minerals, the clay materials are commonly visible in slices, and the alteration serves as the primary source of the clay minerals.

4. Conclusion

(1) The main rock types in the Kexia Formation reservoirs in the WEH oilfield are medium-fine-grained lithic sandstone, unequal lithic sandstone, glutenite and conglomerate, of which the content of debris is high. The interstitial material is dominated by argillaceous heterogeneous. The cement minerals are mainly composed by calcites and clay minerals, with a dense cementation. The rounding of the granules of the reservoir rock is primarily presented as sub-rounded and as sub prism for secondary presence, with a sorting of poor-medium quality. The contact methods between the particles are dominated by line contact, while the point contact works as an auxiliary method. The main cementation type of the reservoirs is press-embedding, and the secondary type is press embedding with pores fitting.

(2) The dominated types of storage spaces in the Kexia Formation, WEH oilfield are intergranular pores, intergranular dissolved pores and intra-granular dissolved pores. On the basis of the date of mercury intrusion samples and the characteristic parameters of the pore throats, the mercury intrusion curves and its corresponding reservoir pore structures were sorted out into four classes.

(3) The porosity of the Kexia Formation reservoirs in the WEH oilfield ranges between 10.2% and 27.8%, and 17.698% in average, and the main distribution falls into the interval between 14% and 18%. The permeability of these reservoirs fluctuates from 0.042 to 4864mD, with an average value of 5.1988mD, and most of the values are distributed in the section between 0.10 and 10.00mD. The results of porosity and permeability intersection indicates a good overall correlation between the porosity and permeability of the Kexia Formation; generally, the Kexia Formation are performed by medium deviant reservoir characteristics with medium-low porosity and low permeability.

(4) The physical properties of the Kexia Formation reservoirs in the WEH oilfield are chiefly subject to the actions of sedimentation and diagenesis. The physical properties of the reservoirs share a positive correlation with the average particle radius, and a negative correlation with the standard deviation, indicating that the overall sorting of the samples is relatively poor. The distributary channel, river mouth bar, and subaquatic distributary channel sedimentary environment control the development of favorable reservoirs. And the effects of compaction and cementation work as the major causes for the low permeability of the reservoirs. Here, the components of the cements are dominated by calcite, while the clay mineral cements are mainly constituted by illite and smectite mixed layers. In addition, the alteration is considered the main source for the clay minerals.

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References

[1] Zhou Junliang, Hu Yong, Li Chao, et al. Characteristics and controlling factors of fan delta facies low permeability reservoirs in Bohai A oilfield, the Bohai Bay Basin [J]. Oil & Gas Geology, 2017, 38(1) : 71–78.

[2] LU Dongliang. Study on rational development model of Wu5 and Wu16 well areas in Wuerhe Oilfield [D]. Southwest Petroleum University. 2005.

[3] MEI Linde, DENG Mingyi, YANG Yuyao, et al. Urho 33 well area the T2k1 reservoir sensitivity experiments [J]. Petrochemical Industry Application, 2013, 32(1) : 45–48.

[4] YUAN B C, XIAO W H, WEI H Y, et al. Characteristics and controlling factors of glutenite reservoir of Cretaceous Xiagou Formation in Ya’erxia area, Jiuquan Basin. Lithologic Reservoirs, 2018, 30(3) : 61–70.

[5] LU Na. Reservoir characteristics and control factors of the Es3 of Changlu Oilfield in Huanghua depression [J]. China Mining Magazine, 2018, 27(S1) : 119–124.

[6] DONG Dawei, LI Jiyan, WANG Xiaolei, et al. Reservoir characteristics and controlling factors of red bed of Kongdian Formation in eastern Dongying Depression, Bohai Bay Basin [J]. Journal of China University of Petroleum(Edition of NaturalScience), 2017, 41(5) : 20–29.

[7] PANG X J, DAI L M, WANG Q B, et al. Characteristics and controlling factors of low permeability reservoirs of the third member of Dongying Formation in northwestern margin of Bozhong Sag [J]. Lithologic Reservoirs, 2017, 29(5) : 76–88.

[8] Gao Chonglong, Ji Youliang, Jin Jun, et al. Characteristics and controlling factors on Physical Properties of Deep Buried Favorable Reservoirs of the Qingshuihe Formation in Muosuowan Area, Junggar Basin [J]. Journal of Jilin University (EarthScience Edition), 2017, 47(4) :990–1006.

[9] Yang Guiqian, Du Shehuan, Liang Shuang, et al. Reservoir characteristics and controlling factors of the Jurassic Badaowan Formation in Zhongguai Uplift, Junggar Basin [J]. Natural Gas Geoscience, 2017, 28(11) : 1689–1698.

[10] SHI H L, YANG K M, WANG T, et al. Characteristics and controlling factors of tight sandstone and shale reservoirs of the fifth member of Xujiahe Formation in the Western Sichuan Depression. Lithologic Reservoirs, 2017, 29(4) : 38–46.