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New Study on Reservoir Characteristics of the Macroscopic Heterogeneity-Example of BZ25-1S

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Abstract: *The heterogeneity of the reservoir refers to the basic properties of the reservoir (lithology, physical property, electric property and oiliness) in three dimensional space on the distribution of heterogeneity. Based on statistics of core and well log data, paramenters of variation coefficient and differential are calculated to carry out the study on heterogeneity of layer, interlayer and areal heterogeneity of Lower Member of Minghuazhen Formation in BZ25-1S area. The sand sets of BZ25-1S reservoir are mainly of distributary channel sand bodiesin delta plain, and the layer heterogeneity is medium. There are many barriers developed, and layer heterogeneity is relatively strong. In the plane,the reservoir heterogeneity in the distributary channel is strong, and it is weak in the overbank sand. It is considered that Lower Member of Minghuazhen Formation in BZ25-1S area is of strong heterogeneity.*

Key words: *BZ25-1S, Lower Member of Minghuazhen Formation，heterogeneity，Individual Sand Body.*

I. Introduction

BZ25-1S oilfield is located in Bohai Bay Basin, which is located in the east of China Bohai Sea and its coastal areas. It is China's largest rift petroliferous basin which mainly extends NNE direction.BZ25-1S district is located in Bonan low uplift West plunging end, boundaries of Bozhong depression (source) and the Yellow River Mouth Sag, whose basic proven oil-bearing area (composite) achieves 58.1km2（fig1）. It is Bohai Sea large Neogene conventional heavy oil field (Lu Yi., 2009). The main production layer is Lower Member of Minghuazhen Formation, which belongs to the structural reservoir with the complex lithology of the reservoir. The reservoir is characterized by good trap type, close range and medium depth. Objective layer thickness of the layer is about 200m, which is divided into six reservoirs. The source direction is southwest. The main oil bearing strata in this area are IV, V, VI oil group total 27 small beds, and the data of 138 wells is more comprehensive, which are the main research object.

With the development of the research, the fine geological conditions, such as sedimentary microfacies, reservoir characteristics and so on, are not clear, which play a decisive role in the development and exploitation of oil field: 1. In the plane, the porosity, permeability and oil saturation of the formation change with the changes of the lithofacies and sedimentary facies, and the change is rapid.2. In the vertical direction, the distribution of oil and water is irregular and complex. The relationship between the injection and the collection of small wells is not clear, and so on. It will bring some difficulties to the further development of oil field.

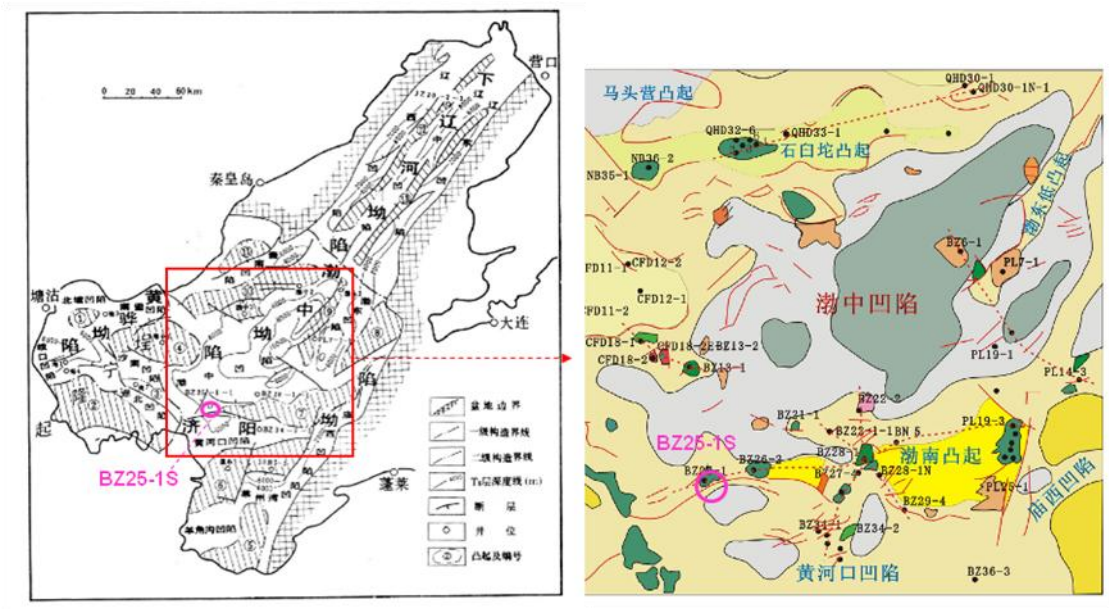

Fig.1 Location map of BZ25-1S oil field

In previous studies of heterogeneity, the interpretation of porosity and permeability is only conducted to the oil group or sand group level, while the innovation of this research lies in the first research on the heterogeneity of the single sand body level. In view of this, there must be a suitable fit of porosity and permeability. In previous work, we have fine division and correlation of BZ25-1S oilfield in the study area, to establish the single sand body and sequence stratigraphic framework and unit time study plane sedimentary microfacies, meticulous depiction of single sand body space distribution characteristics, using density curve to 0.125m for the minimum depth unit fitting porosity and permeability formula, in full respect on the basis of original data to determine the porosity, permeability, and found that interpretation of porosity, permeability and original interpretation in low permeability and permeability of sand in basically the same, but in high permeability sand have certain difference. Based on this study, the heterogeneity of reservoir sand bodies in the study area, interlayer and plane is studied.

1 Internal Heterogeneity

Reservoir heterogeneity refers to a single sand scale vertically to the storage layer properties changes, including vertical to the permeability, grain size of rhythm, interlayer distribution uneven. Reservoir heterogeneity directly controls and effects key factors of a single sand layers in vertical to flooded thickness size and drive oil efficiency(Xiao Ling, 2006)

1.1 Grain Size Rhythm and Rhythm of Permeability

（1）Type of Rhythm

A large number of domestic and foreign experiments and water injection development practices show that the positive rhythm reservoir and the anti rhythm reservoir are very different from the water injection effect, the latter of the water flooding recovery is 10% ~ 20% (Hu Wangshui, 2010). IV, VI, and V focus groups are divided into four categories: positive and negative, anti - and homogeneous and homogeneous, and the compound is a complex, which consists of four sub categories: positive, complex, and positive.

（2）The Rhythm of Statistics

Through the study of 27 small layers of 138 wells in the study area found that different rates of VI，V ， IV oil group are as Table 1, granularity rhythm and permeability rhythm correspondence between good and granularity rhythm and permeability rhythm were mainly consists of positive rhythm, complex rhythm and reverse rhythm times, homogeneous rhythm rarely. Therefore, vertical spread and development effect of water injection is poor.

Table1 The percentage statistics of granularity rhythm and penetration rhythm of IV，V，VI oil formation

Reservoir	Rhythm Type	Positive Rhythm	Counter Rhythm	Homogeneous Rhythm	Compound Rhythm				Percentage of Compound Rhythm	Percentage of Positive Rhythm and Compound Positive Rhythm
					Complex Positive Rhythm	Positive and Negative Rhythm	Negative and Positive Rhythm	Complex Negative Rhythm		
VI Oil Group	Granularity Rhythm	56.52	22.55	2.72	10.33	1.63	66.85	1.63	18.21	66.85
	Permeability Rhythm	49.18	19.57	4.35	15.49	2.17	64.67	3.26	26.9	64.67
V Oil Group	Granularity Rhythm	60.2	17.6	3.6	10.7	0.8	70.9	0.8	18.7	70.9
	Permeability Rhythm	50.8	16.5	6.3	15.4	1.9	66.2	1.9	26.4	66.2
VI Oil Group	Granularity Rhythm	53.18	15.61	2.89	17.34	0.58	70.52	2.89	28.32	70.52
	Permeability Rhythm	39.88	15.61	6.36	21.97	3.47	61.85	4.62	38.15	61.85
Total	Granularity Rhythm	57.35	19.23	3.09	11.82	1.1	69.17	1.55	20.33	69.17
	Permeability Rhythm	48.07	17.57	5.52	16.69	2.32	64.75	2.98	28.84	64.75

1.2 Characterization of Interlayer

In the process of development, the high resistance of the fluid flow can be played by the inner layer of the interlayer, and the oil displacement efficiency is very high (Li Yuanhao et al. 2010).

（1） Type，Characteristic and Identification Method of Interlayer

The curve of core dissection is a sensitive tool for GR, RD, RS, etc.. Through the comprehensive analysis of all the well logging data, the following 3 types of interlayer are summarized. 1. Mud layer，whose identification method is mainly based on GR, with RS, RMLL, RD, DEN, AC, CN and so on. Because of the mud layer, it can be distinguished as the standard to distinguish the mud quality into A whose feature is obvious, the return rate of GR is relatively small, while B is not obvious, GR return rate is relatively small, which is not easy to identify two sub categories.2. Calcareous interlayer，whose characteristics of this kind of sandwich are high calcium content, strong randomness distribution, and the frequency is relatively small. The micro lateral resistivity is significantly high, while the acoustic time difference is significantly low. Identification method is based on RD, RS, AC, supplemented by RMLL, GR, etc., which is more easily identified. 3. Physical layer，whose characteristics of this kind of interlayer are high mud content and complex nature. The curves of each curve are between the clay layer and the interlayer. The frequency is not high. The identification method is based on GR curve, with RS, RMLL, RD, DEN, AC, CN, etc..

（2） Parameters of Sandwich Distribution

It is not comprehensive and accurate to reflect the characteristics of the interlayer distribution only by the number and thickbness, and this study introduces a more comprehensive and reliable characterization of the parameters such as the distribution frequency and the distribution density of the sandwich. The distribution frequency and distribution density of the sandwich layer are more and more developed, the heterogeneity is stronger.

The types，thickness, frequency and percentage of the density of the sandwich layer of all the 101 wells are calculated and statistically studied, as shown in Figure 2:

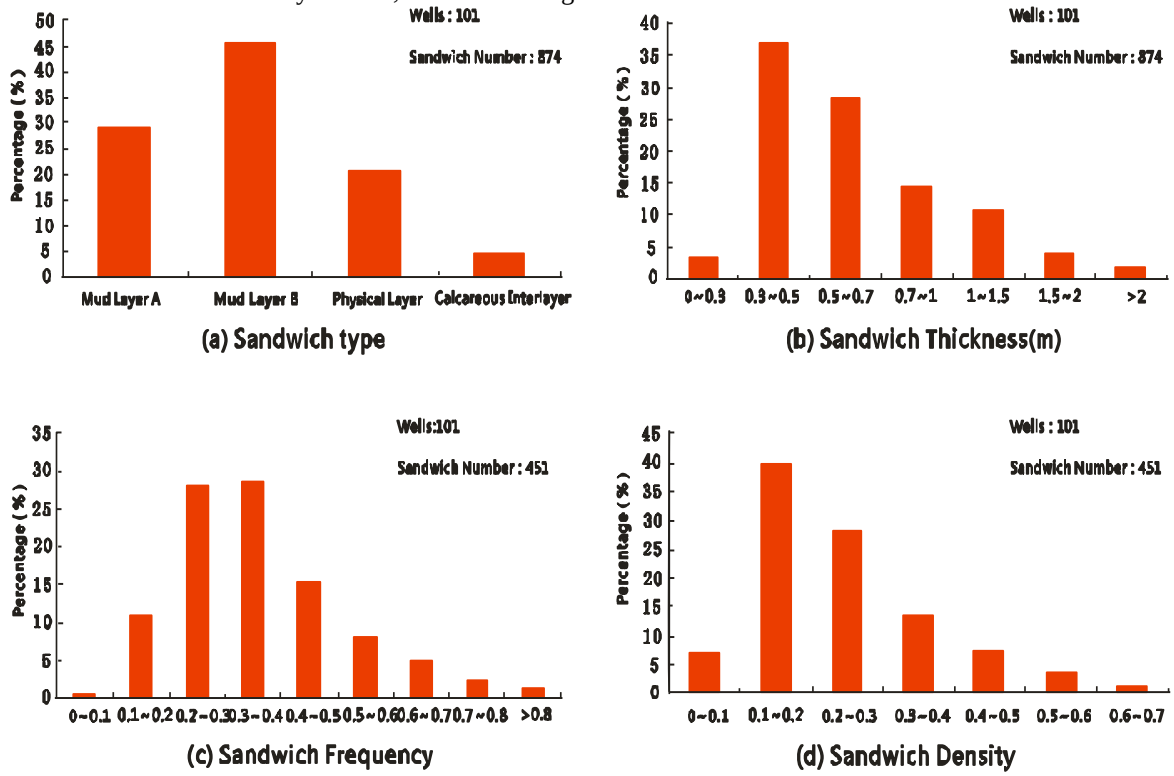

Fig2. Type，thinkness，frequency，density of dissection of BZ25-1S oil field of Lower Member of Minghuazhen Formation

The interlayer type is mainly in the clay layer (74.6%), a small amount of material and few calcareous interlayer. The thickness of the interlayer is very large, and the main distribution is 0.3～0.7m (65.1%), the average value is 0.717m. The frequency of the sandwich is 0.1～0.5, the proportion reaches 83.37%, the average value is 0.36. The density of the interlayer is 0.1～ 0.4, the proportion is 81.15%, the average value is 0.24. The development degree of the interlayer is general, which reflects the medium heterogeneity. The plane distribution is shown in figure 4.

1.3 The permeability heterogeneity of reservoir

The change and difference of permeability in reservoir is the key parameter to study the heterogeneity of reservoir.

Through the statistics of all the heterogeneity parameters of 27 layers of 138 reservoirs in the study area（table 2）, the average values of the variation coefficients of almost all the wells in the study area are more than 0.5, and the average values of 19 layers variation coefficients are more than 0.7， which belongs heterogeneous to serious heterogeneous range; the onrush coefficient of average value was greater than 2, among which 13 layers is greater than 3, belonging to the non homogeneous to highly heterogeneous range. It is found that the coefficient of variation and onrush coefficient of two parameters characterizing the consistency effect is strong and can be as a characterization of non homogeneous parameters, but range parameters characterizing the effect is poor, here is only for auxiliary reference.

Table2 The statistical table of different microfacies types of parameters of reservoir layer heterogeneity

The Number of Sand Layer/Wells	Vertical Thickness Effective Sandstone/m	Average Porosity/%	Average Permeability/×10-3μm2	Coefficient of Variation	Onrush Coefficient	Range	Measurement Thickness of Oil and Water Layer/m	Measurement Thickness of Oil Layer/m
Main Channel	107	5.2	33.6	2988	0.65	162.0	3.1	2.9
River A	221	3.3	30.4	2493	0.76	381.6	2.9	2.8
River B	252	2.8	28.2	2085	0.79	647.8	2.9	2.8
Overflow Sand Body	101	1.7	25.6	480	0.70	236.6	2.1	1.5
Overflow Sand A	64	1.6	24.3	410	0.76	288.2	2.4	2.2
Overflow Sand B	33	1.6	23.7	351	0.87	453.3	3.4	6.0
Natural Levee	34	1.7	27.8	1115	0.73	272.4	1.3	1.4
Crevasse Splay	4	1.3	27.7	492	0.43	10.8	1.4	0.9

Among all the sedimentary microfacies sand body of Lower Member of Minghuazhen Formation, distributary channel, overflow shore sand, natural levee, crevasse splay etc. are reflected in the strong heterogeneity, shows that the hydrodynamic conditions in the study area is very unstable. The composition of the diversion channel is single, the sorting is relatively good, the grain size is relatively uniform, so the heterogeneity is weaker than that of the sand body. The better the river development, the weaker the heterogeneity, the better the development of the sand body in the sand body, the weaker the heterogeneity.

II. Characterization of heterogeneity of reservoir sand bodies

Interlayer heterogeneity refers to the regularity of the interaction between the layers of the vertical and the sand bodies of different environments, as well as the interlayer of the argillaceous rocks in the section on development and distribution. It is a general study of the interaction of sand and mudstone in the reservoir, which belongs to the reservoir description. The interlayer heterogeneity is a general study on the interaction between the sand and mudstone in the same sedimentary unit (Mao Zhiqiang, 2003). The heterogeneity of the interlayer has an important influence on the distribution of oil and water (Zhang Na, 2007).

2.1 Stratification Coefficient and Sandstone Density

Stratification coefficient refers to a certain interval of the sand layer, which is always expressed by the average drilling rate. The higher the stratification coefficient, the stronger the interlayer heterogeneity. Sandstone density refers to total thickness of sandstone section and stratum thickness ratio, also known as sand ratio. The sand body density is higher, which indicates that the longitudinal connectivity of sand body is better.

The level of the single sand body is achieved by the stratification, so the overall level of the hierarchical coefficient is small, the average value is only 1.19. From the IV oil group to the VI oil group, the coefficient of stratification increases from 1.125 to 1.207 to 1.244, and the sand density decreases from 0.389 to 0.378 to 0.349. Among them IV1, IV8.1, V1.2, IV1, V6, VI1, VI2, and VI3, have a large stratification coefficient, which shows strong heterogeneity. The density of IV5.2, IV8.2, V1.1, and V3 is relatively large, which indicates that the sand bodies of these small layers are well connected.（fig 3）

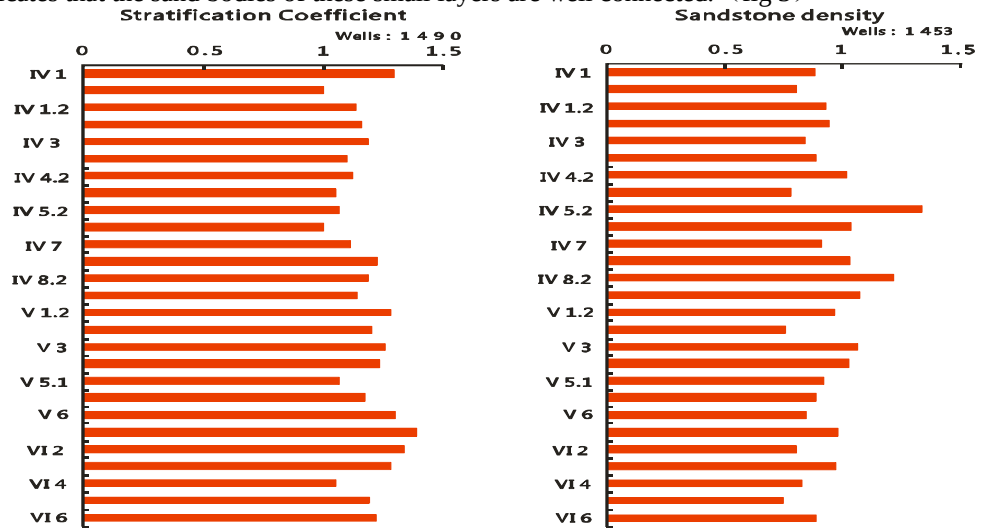

Fig.3 The statistical graph of stratification coefficient density sandstone of each layer of IV，V，VI oil formation

2.2 Interlayer

In the process of the deposition of BZ25-1S reservoir, the interaction between the sand and mudstone in the reservoir is changed due to the change of hydrodynamic conditions and the rapid migration of the river. Based on core observation and logging interpretation, BZ25-1S oil field of Lower Member of Minghuazhen Formation commonly exist large thickness mudstone interlayer and extremely low permeability layer. By well and layer identification and through the region of the connected wells profile analysis, research layer of the study area is identified six relatively stable layers, which is IV1 bottom ～ IV2 bottom, IV3 bottom ～ IV4.2 bottom，IV5.2 bottom ～ IV7 bottom，V1.1 bottom ～ V2 bottom， V4 bottom ～ V5.2，VI2 bottom ～ VI2 bottom in turn. The key oil group is divided into 7 stages of development，as in table 2.

It is found that IV1 bottom ～ IV2 bottom, V1.1 bottom ～ V2 bottom and VI2 bottom ～ VI4 bottom three layers are more development, bigger thickness, while vertical permeability is the worst, and sealing isolation ability is strong (Dali Yue et al., 2005). More, the number of spacer layer thickness is large, reflecting that BZ25-1S oil field of Lower Member of Minghuazhen Formation has strong interlayer heterogeneity.

Table2 The statistical table of each insulating layer thickness of BZ25-1S oil field of IV，V，VI oil formation

Barrier Layer	0-5m		5-8m		8-10m		10-12m		>15m		Percentage	Distribution Characteristic
	Wells	Percentage（%）	Wells	Percentage（%）	Wells	Percentage（%）	Wells	Percentage（%）	Wells	Percentage（%）		
IV1 bottom ～ IV2 bottom	0	0	2	1.44	6	4.32	9	6.47	25	17.99	69.78	Stable
IV3 bottom ～ IV4.2 bottom	6	4.32	21	15.11	22	15.83	89	64.03	1	0.72	0	Relatively Stable
IV5.2 bottom ～ IV7 bottom	18	12.95	15	10.79	29	20.86	77	55.4	0	0	0	Relatively Stable
V1.1 bottom ～ V2 bottom	4	3.13	10	7.81	13	10.16	17	13.28	49	35	27.34	Stable
V4 bottom ～ V5.2 bottom	10	8.4	13	70.92	16	13.45	18	15.13	62	0	0	Relatively Stable
VI2 bottom ～ VI4 bottom	1	1.25	5	6.25	8	10	5	6.25	18	43	53.75	Stable

III. Reservoir Sand Body Plane Heterogeneity

Reservoir plane heterogeneity is defined by the geometric shape, scale, continuity and the change of porosity and permeability of the reservoir. It has a direct impact on the volume and water displacement efficiency (Angela Baby, 2014).

3.1 Thickness and Characteristics of Plane Distribution of Sandstone and Effective Sandstone

Geometric shape, scale and continuity of sand bodies are controlled by sedimentary facies. By means of facies control sandstone and effective sandstone thickness contour map, the sand body of river channel is developed, and the thickness of sandstone and effective sandstone is larger, and the thickness of natural levee and overflow sand sand body is obviously less than that of channel sand body. Geometry of BZ25-1S reservoir sand bodies mainly band, with a small amount of potato shaped. The diversion channel is a ribbon, and the overflow sand and natural levee are potato shaped. When the channel sand body deposition, the main stream of the main channel is moving frequently, and the phase change rapidly, resulting in the change of the distribution of sand body in the study area.

3.2 Plane Distribution Feature of Effective Porosity and Permeability

The effective porosity of the reservoir in the BZ25-1S area is 29.49% ～ 24.68%, the average is 27.48%. It changes large on the plane whose permeability variation of the reservoir is 540.42 ～ 5794.71 * 10-3um2, and the average is 2842.53 * 10-3um2. In the same direction, the sand body is connected with the same phase belt, and the physical property changes slowly. The continuity of the sand body is poor, the connectivity is poor, and the change of the property is changed. In the study area, the distribution of reservoir hole and high permeability zone is in agreement with the main channel sand body. In the direction parallel to the river, the change of the hole and the seepage is small. In the vertical direction of the river, the hole and the seepage are gradually reduced by the center of the river. In the development of sand body in the diversion channel, water injection can obtain high yield because of good reservoir physical properties, which is easy to form water

injection channel. In natural levee and other micro phase development, sand body connectivity is poor, reservoir physical property is poor, the low level of reservoir space, the remaining oil is relatively concentrated.

3.3 Permeability Plane Heterogeneity

According to the statistics, it is concluded that the average permeability, coefficient of variation onrush coefficient and range of 10 main rivers, 13 River A, 17 River B. Among them the average permeability of the main river is 8500.62， the coefficient of variation is 1.67, onrush coefficient is 5.08, and range is 3319.38. The average permeability of River A is 3645.59，coefficient of variation is 1.25, onrush coefficient is 3.5, and range is 349.89. The average permeability of River B is 1294.09, the variation coefficient is 1.22, onrush coefficient is 3.39, and range is 439.82. The average permeability of overflow sand coast is 804.76 and coefficient of variation is 1.18, onrush coefficient is 2.74 and the range is 125.18.（table 3）

After analysis, the heterogeneity of main channel, River A, River B, overflow sand is weakened in turn.

Table3 The statistical table of different microfacies types of parameters of reservoir plane heterogeneity

	Permeability	Coefficient of Variation	Onrush Coefficient	Range
Main River	8500.62	1.67	5.08	3319.38
River A	3645.59	1.25	3.50	349.89
River B	1294.09	1.22	3.39	439.82
Overflow sand	804.76	1.18	2.74	125.18

IV. Conclusion

(1)The reservoir in BZ25-1S oilfield overall performances strong reservoir heterogeneity. The layer of every sand group shows moderate heterogeneity. Among rhythm and complex rhythm is rhythm accounted for a high percentage. The effect of the thickness and the development of water injection is poor. Interlayer number and thickness is larger, with strong interlayer heterogeneity. In the plane, the distribution and physical properties of the sand bodies of the river and the reservoir sand bodies change large, and the plane heterogeneity is outstanding. Waterflooding should be selected in the distributary channel and overbank sand microfacies development area.

（2）In each of the micro facies of the reservoir in BZ25-1S oil field of Lower Member of Minghuazhen Formation, the distribution of the channel and the overflow sand show strong heterogeneity, which indicates that the dynamic condition of the water in the deposition process is very unstable.

（3）In the level of a single sand body heterogeneity study, porosity and permeability and not with the sand as the smallest unit, but to 0.125 m thickness of strata as the smallest unit, income heterogeneity characterization parameters (coefficient of variation onrush coefficient and range) and not strictly applicable traditional heterogeneity study comes to the conclusion that the evaluation standards of parameters, especially the range parameters are changed greatly.

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