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Study on Reservoir Characteristics of the Heterogeneity of Wang 9 Well Area in Wangji Oilfield

Li Jiaona, Chang Pengsong, Zhou Di
Northeast Petroleum University, Daqing, Heilongjiang, China, 163318

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[1]. Based on the comprehensive utilization of drilling geology, logging, thin section analysis data testing a newly drilled oil well and production performance data, combined with detailed core observation and description, Wang 9 well area of reservoir geological characteristics in Wangji oilfield of Henan are studied. In this area mainly developed mud and properties of sandwich, statistical development dissection analysis showed that the interlayer region layer is basically stablly distributes, but the variation of thickness is large. According to the representations of the development of interlayers, interlayer distribution frequency and interlayer distribution density, distribution of in-layer interlayer is complex. The analysis of particle，thin section，property shows that objective to reservoir physical property belongs to Medium porosity and medium permeability reservoir and High porosity and permeability reservoir，but there are some differences between each layer, distribution of high porosity and permeability of basic and sedimentary microfacies can provide good correspondence. When we establish the heterogeneity of the reservoir evaluation parameters, study the heterogeneity of inner layer, interlayer and plane，we find that the majority of horizon shows medium - strong heterogeneity.

Key words: *Wang 9 well area， He 3 Formation，heterogeneity，Individual Sand Body*

WangJi oil field is located in the easternmost part of the north slope zone of BiYang sag of Nanxiang basin, the exploration area is 100 km2, with a content source, sedimentary system development and the characteristics of fault development. Wang group oilfield fault development, according to the distribution of fault could be divided into east wang group, wang group oilfield Chai Zhuang area, Bi 242 area and west wang group four blocks, each block is consists of a number of small fault blocks. Wang group oilfield is a nose-like structure [2] which is complicated by the fault plunging towards south east,and its location is in the northeast of north slope zone of BiYang sag, the main oil-bearing horizon is walnut orchard group nuclear three [3], the latest research shows that wang group oil source direction is mainly composed of two parts [4], the northern wang group delta and the eastern Hou Zhuang braided river delta.

I. THE INTRAFORMATIONAL HETEROGENEITY

Intraformational heterogeneity refers to the scale of a single sand layer inside the vertical changes of reservoir properties, including the development of the interlayer,the plane distribution features,layer permeability permeability heterogeneity degree and the intraformational heterogeneity of different sedimentary microfacies characteristics. Intraformational heterogeneity is a key factor[5] which directly controls and influences the layer vertical waterflooded thickness size and oil displacement efficiency of a single sand layer.

1.1 Development of intraformational interlayer

intraformational interlayer has a high resistance of no permeability or extremely low permeability on the flowing fluid,also has a great influence on oil displacement efficiency in the process of development [6].According to the characteristics of the interlayer lithology, the interlayer in the study area is divided into argillaceous interlayer and physical properties.Argillaceous interlayer mainly includes mudstone, shale, silty mudstone, argillaceous siltstone and part of siltstone, its factor is related with lacustrine sedimentary and abandoned underwater distributary channel, migration,and its characteristic is micro electrode resistance significantly lower, microelectrode separation is zero or very small, natural gamma value is relative higher; Physical intercalation includes argillaceous, opaque, silty mud support and cementation of conglomerate or conglomeratic sandstone, most are stranded at the bottom of the river sediment and river channel sandstone of high content of silty mud sediment, and its characteristics is natural gamma ray value is relative high, and microelectrode resistance value is higher,but the small acoustic time, spontaneous potential amplitude is low.

Obvious interlayer distribution is directly controlled by sedimentary microfacies. Since the Ⅳ, Ⅴ oil group of He San period of Wang 9 wellblock is in far source wang group delta front, due to differences in different parts of the sedimentary conditions, often makes the different location of the work area within the sand layer upon layer of interlayer distribution presents different intercalation distribution patterns.

1.2 Internal sand body heterogeneity

The change of reservoir porosity and permeability in addition to related to sedimentary condition, also related to the formation rock after the change. Sedimentary conditions change, leading to the granularity of sand body, sedimentary structure, rhythmic in vertical tend to have very big difference, which directly affects the intraformational heterogeneity of reservoir.

(1) Permeability rhythm type

Permeability rhythm is the rhythm which formed by the size on the vertical permeability change, usually in a single sand layer upon layer within the highest permeability relatively homogeneous section of the location and its change rule to determine the permeability in vertical rhythm type. According to the core physical property data in the study area, this area within the layer permeability rhythm type can be divided into positive rhythm, reverse rhythm, homogeneous rhythm and compound rhythm four types, and the study area mainly contains positive rhythm, homogeneous rhythm and compound rhythm.

(2) permeability heterogeneity degree of interlayer

According to the permeability heterogeneity parameters evaluation criteria evaluate reservoir layer upon layer heterogeneity within (table 1). Table 2 for the Wang 9 wellblock and Bi 276 wellblock He San period Ⅳ, Ⅴ oil group each small layer permeability variation coefficient, dash coefficient of permeability and permeability differential statistics, from the evaluation results, the heterogeneity of each small layer of Ⅳ, Ⅴ oil group is given priority to medium - strong, only a handful of wellheterogeneity degree is weak. Intraformational heterogeneity will lead to serious contradiction within the development process middle, and then affect the development effect.

Table.1 The reservoir permeability heterogeneity parameters evaluation standard

V_k	T_k	J_k	The degree of heterogeneity
V_k＜0.5	T_k＜2	Jk＜20	Homogeneous model,weak
0.5-0.7	2-3	20-50	A uniform type,medium
V_k＞0.7	T_k＞3	Jk＞50	Heterogeneous type,strong

Table.2 Each layers' inner heterogeneity parameters statistics of H3IV，V oil group in Wang 9 well area and Bi 276 well area

Small layers	Porosity （%）	Permeability （10-3μm2）	Coefficient of variation		Dash coefficient		Level poor	
			Distribution range	Mean	Distribution range	Mean	Distribution range	Mean
H3Ⅳ5^1	19.92	249.9	0.28-1.40	0.67	1.10-4.45	2.27	1.17-1413	112.13
H3Ⅳ5^2	18.74	144.0	0.15-1.40	0.66	1.23-5.04	2.24	1.70-1220	69.40
H3Ⅳ5^3	19.53	126.8	0.26-1.25	0.71	1.26-3.48	2.24	2.54-262.9 8	101.31
H3Ⅳ5^4	21.36	333.1	0.11-2.76	0.61	1.13-5.79	2.10	1.48-1311. 22	89.59
H3Ⅳ5^5	18.16	145.4	0.14-1.15	0.52	1.17-4.97	1.97	1.64-830.7 3	34.00
H3Ⅳ6^1	18.72	164.2	0.15-1.04	0.63	1.20-4.13	2.30	1.65-338	63.65
H3Ⅳ6^2	19.15	168.3	0.46-0.86	0.75	1.93-3.13	2.48	12.16-191. 62	71.86
H3Ⅳ6^3	18.34	167.5	0.26-1.02	0.65	1.32-2.81	2.16	2.24-831	142.83
H3Ⅳ6^4	24.60	606.6	0.31-1.41	0.58	1.38-5.94	2.18	3.56-1953	169.78
H3Ⅳ7^1	19.44	191.7	0.06-1.95	0.53	1.13-6.00	2.12	1.23-1472	60.98
H3Ⅳ7^2	20.17	241.1	0.09-1.39	0.52	1.09-5.29	1.98	1.28-772	46.96
H3Ⅴ4^1	21.24	277.8	0.18-0.90	0.51	1.34-3.30	1.93	1.77-330.5	29.80
H3Ⅴ4^2	19.25	225.6	0.04-1.23	0.62	1.04-5.05	2.20	1.13-420	49.53
H3Ⅴ4^3	14.36	36.8	0.35-0.77	0.55	1.58-2.73	1.96	2.86-82.85	32.13
H3Ⅴ5^1	18.27	171.5	0.23-1.51	0.68	1.36-4.87	2.39	1.98-1066	130.49
H3Ⅴ5^2	21.68	342.5	0.14-1.22	0.65	1.18-4.00	2.28	1.6-1637.6 1	235.74

Within the H3 Ⅳ oil group of objective interval, within the scope of work area of approximate consistent and sedimentary environment mainly underwater distributary channel of small layer, such as H3Ⅳ5^5、H3Ⅳ6^4、H3Ⅳ7^1、H3Ⅳ7^2small layers, give priority to medium - weak heterogeneity, evaluation of weak heterogeneity of 33.33% ~ 54.28%, and the heterogeneity of medium accounted for 22.86% ~ 51.67%, the proportion of strong heterogeneity in 15% ~ 22.86%; Different sedimentary environment to underwater distributary channel, underwater overflow shore sand body reservoir - front sheet sand mix into the H3Ⅳ5^1、

H3Ⅳ5^2、H3Ⅳ6^1 small layers of H3Ⅳ give priority to with medium - strong heterogeneity, evaluation of weak heterogeneity of 26.53% ~ 32.91%, and the heterogeneity of medium accounted for 24.05% ~ 31.25%, the proportion of strong heterogeneity in 37.5% ~ 46.94%. H3Ⅴ oil group, H3Ⅴ4^1 small layer heterogeneity is weak - medium is given priority to, accounting for 90%; H3Ⅴ4^2、H3Ⅴ5^1、H3Ⅴ5^2 small layer heterogeneity is stronger, give priority to medium - strong, basically have accounted for more than 70%. From the coefficient of variation of the floor plan shows are distributed in high low and white, high value area approximation of the distribution characteristics of strip or flake, basically has a good corresponding relation with the sedimentary facies belt. Coefficient of permeability to penetrate the evaluation results similarly, differential evaluation results will have some differences, but still can be used as a guide.

(3) different sedimentary microfacies of intraformational heterogeneity characteristics

Sedimentary microfacies not only determines the type of reservoir heterogeneity, but also determines the heterogeneity degree of sand body inside. From the statistics, different sedimentary microfacies sandbodies of intraformational heterogeneity of H3 Ⅳ, Ⅴ oil group of Wang 9 wellblock exists obvious difference (table 3). the mean value of permeability variation coefficient of the underwater overflow shore sand is 0.42,which belongs to the weak heterogeneity, underwater distributary channel sandbody, frontal sheet sand and turbidite sand bodies are between 0.58-0.66, belong to medium heterogeneity; Underwater overflow shore sand permeability variation coefficient of average of 1.68, belongs to the weak heterogeneity, other various microfacies types of average coefficient of permeability dash between 2.13-2.15, belong to medium heterogeneity; permeability differential of underwater distributary channel of is 49.06, belongs to the medium heterogeneity, other various microfacies are bigger than 50, belongs to the strong heterogeneity. Overflow from the evaluation results of each index, water shore sand body basically belongs to the weak - medium heterogeneity, underwater distributary channel, frontal sheet sand body and turbidite sand bodies are mainly medium heterogeneity, turbidite sand body heterogeneity degree strongest.

Table.3 Different sedimentary microfacies sand body's inner heterogeneity parameters statistics of H3IV，V oil group in Wang 9 well area

Microfacies types	Rhythm type	V_k	T_k	J_k
Underwater distributary channel sand body	Positive rhythm	0.04-2.76/0.58	1.04-6.0/2.13	1.13-1953/91.45
Underwater shore sand body	The rhythm, compound rhythm	0.12-1.28/0.42	1.16-3.35/1.68	1.68-462/49.06
The front sheet sand body	The rhythm, compound rhythm	0.1-1.51/0.61	1.09-5.26/2.14	1.28-1220/67.94
Turbidite sand body	BaoMa sequence and homogeneous rhythm	0.23-1.25/0.66	1.26-3.48/2.15	1.98-831/102.43

The parameters of evaluation results is slightly different, but the overall objective interval in reservoir heterogeneity degree is more complicated. Underwater overflow shore sand body has better homogeneous

degree, underwater distributary channel sand body-front sheet sand-turbidite sand body heterogeneity degree is gradually enhanced. Permeability variation coefficient, dash coefficient and the differential has the approximate consistent result on each miscrofacies, three parameters could be used as heterogeneity evaluation effective index.

II. INTERLAMINATION HETEROGENEITY

Interlamination heterogeneity mainly refers to the vertical differences between each layer,which is the general study [7] of sand-shale interactive oil-bearing series on the same sedimentary unit,and has an important effect on oil/water system [8] distribution. Including the cyclicity of layer group, the small interlayer permeability heterogeneity, interlayer and the distribution of interlayer. Interlayer heterogeneity is the vertical distribution of oil and gas, the condition of water between the upper and the root cause of the remaining oil distribution in different. The research mainly through studying the physical properties differences to describe the interlamination heterogeneous characteristics. Looking from the vertical, the small layers' sandstone thickness, porosity, permeability all have significant differences, which reflects the strong interlayer heterogeneity.

2.1 Differences of interlamination physical parameters

Porosity is between 10.03% ~ 36.02%, the average porosity of over 14.36%, most of the strata porosity is more than 18.16% on average. On the longitudinal,in the $H3Ⅳ5^1$—$H3Ⅳ7^2$ and $H3Ⅴ4^1$—$H3Ⅴ5^2$, the difference between each small layer porosity value is larger, the drilled well points is much,distributes widely,such as $H3Ⅳ5^4$,$H3Ⅳ6^4$ and $H3Ⅳ7^1$.But in the top and bottom of the large-scale channel,the porosity value is little low because of the shaliness, such as $H3Ⅳ5^5$,$H3Ⅳ6^4$ and $H3Ⅳ7^2$. The porosity value of the middle is the highest,which indicates there is some certain correlation between sedimentary microfacies and reservoir porosity.

The difference of the average permeability of each small layer vertical distribution is bigger, the overall permeability is low, the average permeability in $124\sim559\times10^{-3}\mu m^2$, but relatively high permeability section has a certain regularity, overall keeping a line with the cyclicity of thick channel sand body development. Objective interval permeability in this area belongs to medium permeability, minority is high permeability. Single sand layer permeability rhythm is various, which gives priority to the positive rhythm, homogeneous rhythm and compound rhythm.

2.2 Sandstone density

Sandstone density refers the ratio of the total thickness of sandstone and the total thickness of strata, the bigger sandstone density ratio, the greater the sand body develop. By the statistics, the sandstone density of $H3Ⅳ5^4$、$H3Ⅳ6^4$、$H3Ⅳ7^1$ and $H3Ⅴ5^2$ small layers is equal to 0.50, which drills more well in sandstone, reflecting sandstone development degree of the small layers is good; $H3Ⅳ5^3$ and $H3Ⅳ6^3$ small layers sandstone density is less than 0.24, drilling less well in sandstone, sandstone nearly doesn't develop.

2.3 The permeability heterogeneity degree of interlayer sand

In addition to the entire district is given priority to with lacustrine mudstone, more distributed small sand sheet or turbidite sand body of $H3Ⅳ5^3$、$H3Ⅳ6^2$、$H3Ⅳ6^3$ and $H3Ⅴ4^3$ small layers, from the point of variation coefficient, the interlayer heterogeneity of all small layers sandstone is strong; Dash coefficient shows that $H3Ⅳ5^5$ and $H3Ⅳ6^1$ small layer is weak heterogeneity, $H3Ⅳ5^2$ is medium heterogeneity, other small layers are strong heterogeneity; Permeability differential display heterogeneity of weak - medium. Overall, the reservoir heterogeneity between layers is more serious.

III. PLANE HETEROGENEITY

Sand body plane heterogeneity refers to the sand body geometry, size and continuity of the sandbody , and porosity and permeability sand body spatial distribution, and the spatial distribution of heterogeneity caused by porosity and permeability distribution. It directly affects the swept volume and the water displacement efficiency [9].

3.1 Sand body extension method and geometry

(1) The sandstone thickness plane changes

The reservoir of Ⅳ and Ⅴ oil reservoir group of Wang 9 wellblock and Bi 276 wellblock is the typical far source delta front deposition, mainly controlled by the northwest or northern source, sand body development of each small layer gives priority to the underwater distributary channel deposition, to the northwestern evolves into the branch channel to the secondary branch channel sand body, front and interchannel is mainly sand sheet sedimentary, on the whole the sandsone successively becomes thick from the northwest to the southeast.

(2) The sand body extension

In northwest and main source approximation most single sand layer in section vertical longitudinal contrast pinchout sand body by the north to the south. Main source in northwest and approximate parallel horizontal contrast section, most of the single sand layer on the transverse section extends far, sand body lateral connectivity is better, to east or southeast pinchout sand body on the side.

(3) The sand body geometry

Sand body geometry is relative to the size of the sand body. Sand body geometry in this area mainly include sheet sand body, potatoes-shape sand body, banded sand body and irregular sand body four types, in the underwater distributary channel development horizon, where the strong hydrodynamic conditions, sediment source supply,exsisting plenty of potatoe-shape and irregular shape sand body, such as H3Ⅳ6^4 and H3Ⅳ7^1 small layers; Part of the delta front sand sheet horizon is given priority to with sheet sand body, such as most of the horizon of front-end of underwater distributary channel sand body; Hydrodynamic condition sharps, underwater distributary channel in the banded extension horizon for ribbon sand body, such as the H3Ⅳ5^5Ⅴ、H3Ⅳ6^1、H3Ⅴ4^1、H3Ⅴ4^2 small layers.

3.2 Sand body plane change characteristics of porosity and permeability

Planar distribution of reservoir permeability and sedimentary and microfacies has good consistency. Small layers of thick sand body development in northwest or northern area is basically the combination of underwater distributary channel sand body and underwater overflow shore sand body, to the central and southwest plane phase change frequently, due to the different methods of hydrodynamic condition and sedimentary different facies belt, the differences between porosity and permeability is very big. With internal reservoir property in the same phase also exists certain differences, in the the mainstream line ofunderwater distributary channel and the interchange of the multiple branching river,the physical properties of the sand body is relatively high,in the river edge, underwater shore sand body and front sheet sand body, the physical property gradually become worse.

IV. CONCLUSION

(1) As a whole,the reservoir of He San period of Wang 9 wellblock is medium - strong heterogeneity reservoir.And each small layer of Ⅳ and Ⅴ oil group of this area has the heterogeneity of medium - strong,

only a few wellblock the heterogeneity degree is weak. In the each small layer, the sandstone thickness, porosity, permeability and interlayer thickness esist big difference, reflecting the strong interlayer heterogeneity.

(2) In the intraformational heterogeneity of each microfacies of He San period of Wang 9 wellblock, underwater overflow shore sand body basically belongs to the weak - medium heterogeneity, underwater distributary channel, frontal sheet sand body and turbidite sand bodies are mainly medium heterogeneity, turbidite sand body heterogeneity degree is the strongest.

(3) Obviously interlayer distribution is directly controlled by sedimentary microfacies, due to differences of the sedimentary conditions in different parts, often makes intraformational interlayer distribution of the different location sand body of the work area present different intercalation distribution patterns.

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