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The Research on the Super Heavy Oil Reservoir Characteristics of Du 84 Block in Liaohe Oilfield

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Abstract
The reservoir characteristics of super heavy oil directly determine the development effects of heavy oil thermal recovery. The development process of super heavy oil reservoir in Du 84 block contains the production test of steam huff and puff-the industrialization of steam huff and puff-the production test of SAGD-the industrialization of SAGD. The researches on the reservoir characteristics carried out at the early stage of the reservoir development have partly guiding significance for the reservoir development and deployment. As the development progress, we need describe the reservoir characteristics of super heavy oil once more in order to guide the deployment of thermal well network. This article makes a detailed and reliable description of reservoir characteristics of super heavy oil and provides fundamental data support for the next dynamic regulation by doing a statistical analysis of the characteristics of sand body distribution, petrology, physical property and aeolotropy of the Guantao formation and the Xinglongtai reservoir[1,2].

Key words: Super heavy oil; Du 84 block; Reservoir characteristics; Guantao formation; Xinglongtai reservoir

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INTRODUCTION
The reservoir characteristics of super heavy oil directly determine the development effects of heavy oil thermal recovery. The development process of super heavy oil reservoir in Du 84 block contains the production test of steam huff and puff-the industrialization of steam huff and puff-the production test of SAGD-the industrialization of SAGD. The researches on the reservoir characteristics carried out at the early stage of the reservoir development have partly guiding significance for the reservoir development and deployment. As the development progress, we need describe the reservoir characteristics of super heavy oil once more in order to guide the deployment of thermal well network[3,4]. This article makes a detailed and reliable description of reservoir characteristics of super heavy oil and provides fundamental data support for the next dynamic regulation by doing a statistical analysis of the characteristics of sand body distribution, petrology, physical property and aeolotropy of the Guantao formation and the Xinglongtai reservoir[5].

1. THE CHARACTERISTICS OF SAND BODY DISTRIBUTION OF SUPER HEAVY OIL
The sand body distribution of the Xinglongtai reservoir is controlled by some factors, such as the palaeostructure condition, the palaeogeographic condition, the river swing strength and the hydrodynamic force strength and so forth. There are some differences between the horizontal distribution and the longitudinal distribution.

The Xing-VI formation sedimentary facies is a sublacustrine fan sedimentary. Facies change of channel sand body is fast. The characteristics of sand body

distribution at present are east-thick, west-thin, south-thick and north-thin, because its roof layer had been denuded inordinately within the whole area when the Earth crust was uplifted at the end of the Xing-VI formation. The main direction of sand body distribution is northwest-southeast. The maximum thickness of sand body after denudation is 250 m, the minimum one is 7 m, generally between 100-200 m. The sandstone thickness of the eastern of Du 84 well field, Du 813 block and Du 32 fault block in general is between 100-270 m; the sandstone thickness of the western of Du 212 well field is between 50-120m; the sandstone thickness of the eastern of Du 212 well field is the smallest one, generally less than 50 m.

The Xing-V~I formation sedimentary facies is a basin expansion deposition and its stratigraphic distribution characteristics is a southeast–northwest overlapping deposition. The provenance is from northeast, northern and western. The western one is less important one, because it only controls the deposition near Du 212 block and its detrital supply capacity is worse than the northern one and the northeast one. So it shapes the Xing-V~I sand body distribution characteristics, which is east-thick, west-thin, north-thick and south-thin. The sandstone thickness of Du 32 well field is generally between 80-180 m; the sandstone thickness of the eastern and southern of Du 212 well field as well as that of the northern of Du 84 well field is generally between 80-110m; the sandstone thickness of the southern of Du 813, the eastern and southwest of Du 212 and the middle part of Du 84 well field is generally between 60-80 m; the sandstone thickness of the northwest of Du 212, the smallest one, is between 30-60 m.

In Du 84 block and Du 229 block, the sandstone thickness of the Guantao oil layer continuously distributing both in longitudinal and planimetric, is 150-170 m.

2. THE PETROLOGY CHARACTERISTICS OF RESERVOIR

2.1 The Reservoir Lithology

The reservoir lithology of the Xinglongtai oil layer: According to the fractional analysis, the reservoir lithologic character of the Xinglongtai oil layer mainly includes anisometric sandstone, conglomeratic anisometric sandstone, medium sandstone, fine sandstone, glutenite and conglomerate[6]. The Xing-VI formation mainly consists of lithic sandstone, and the gravel concentration is 42.4%, and the sandstone mainly consists of anisometric sandstone. The lithology of each block in the plane has a certain change that it gradually becomes thicker from south to north and from east to west. The reservoir lithologic character of Du 84-Du 212 block, Du 229 and Shu1-6-12 block mainly includes glutenite, conglomerate, pebbled sandstone, anisometric sandstone, medium sandstone and fine sandstone. The reservoir lithologic character of Du 813 and Du 80 block mainly includes conglomeratic anisometric sandstone, anisometric sandstone, medium sandstone and fine sandstone.

The reservoir lithology of The Guantao oil layer: the Guantao formation, which is the production of the wetland alluvial fan facies and deposited with a long process of depositional breaking and sunken deplanation, is mainly composed of coarse fragments. The fractional analysis data shows that the reservoir lithology of the Guantao oil layer of Du 84 block and Du 239 block mainly includes medium-farewell rock and anisometric sandstone while the rest includes conglomerate, conglomeratic sandstone and fine sandstone. But the particle distribution of each well has a certain difference with the others.

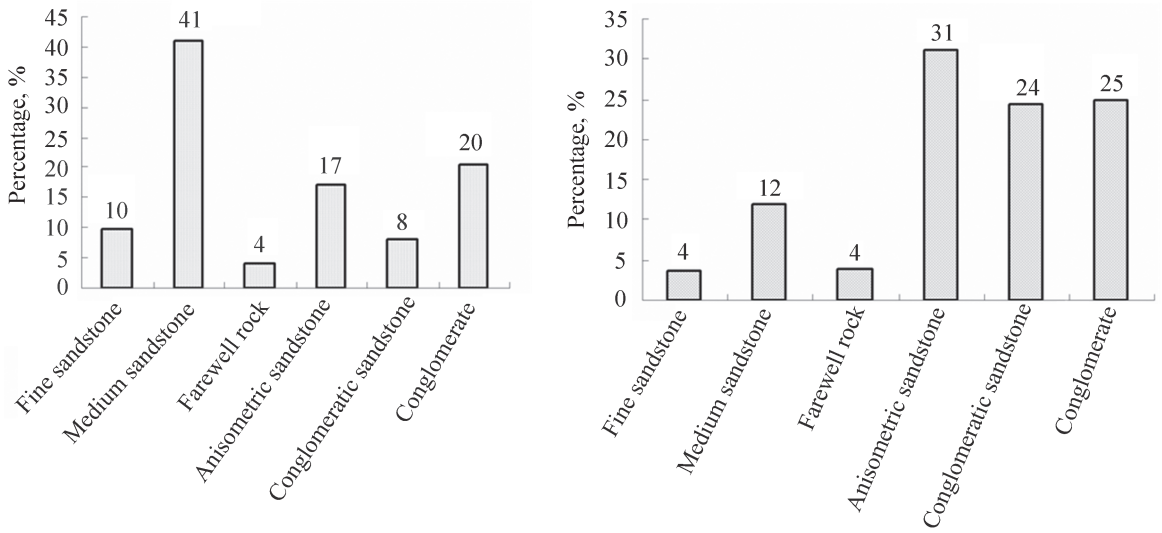

Figure 1
Histogram of the Guantao Reservoir Lithology

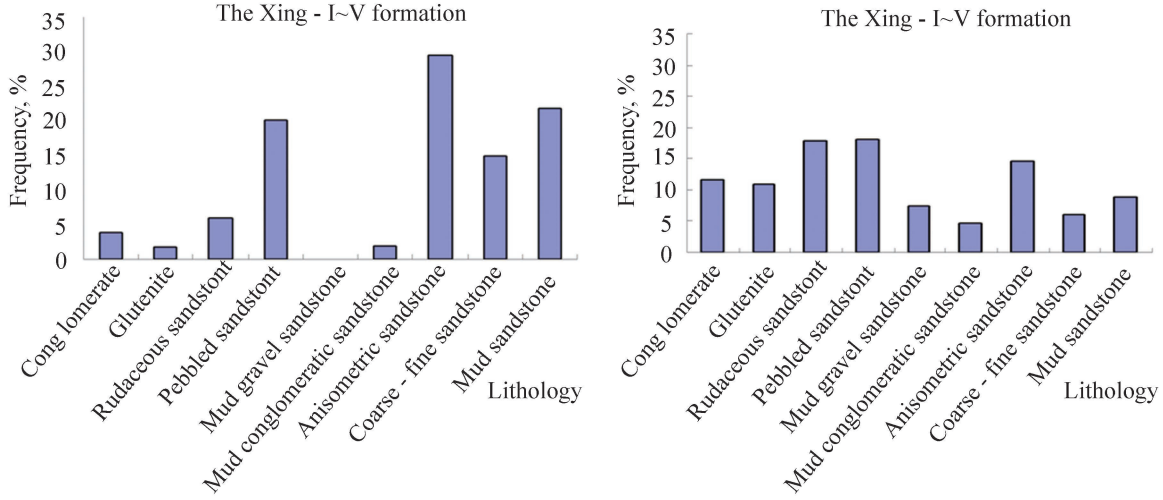

Figure 2
Histogram of the Xinglongtai Reservoir Lithology

2.2 The Mineral Composition and Structure of the Reservoir Rock

The Xing-VI formation reservoir rock is mainly composed of feldspathic lithic farewell rock. The rock composition consists of quartz (37%), feldspar (27%), debris (29.8%) and matrix (6.2% on average). Debris component is made from intermediate extrusive rock, acid extrusive rock, granite, quartzite, mudstone and silica rock, etc. The median grain diameter is 0.44 mm. The grading factor is 2.7. Its characteristics are coarse clastic and assorted. The granule, poorly rounded, is mainly subrounded-subangular. Its argillaceous cementation types are in the majority pore style and basement style[7]. The rock compositional maturity and textural maturity are low.

The Xing-I~V formation reservoir rock is mainly composed of feldspathic litharenite and lithic sandstone. The rock composition consists of quartz (37%−42%, 39.3% on average), feldspar (30%), debris (26%−31%, 21.3% on average) and matrix (9.4% on average). Debris component is complex and made from some kinds of igneous rock, such as granite, granodiorite, diorite, rhyolite, andesite, and so forth. The median grain diameter is 0.35 mm. The grading factor is 1.8. Compared with Xing-VI, It has finer debris and it is better sorted. The granule, poorly rounded, is mainly subrounded-subangular. The types of its argillaceous cementation, loose textured, are pore style and contact style. The rock compositional maturity and textural maturity are low.

The Guantao formation reservoir rock is mainly composed of arcose. The rock composition consists of quartz (41.6%), feldspar (33.3%), debris (19.2%) and matrix (5.9% on average). The median grain diameter is 0.42 mm. The granule, poorly rounded, is mainly subrounded-subangular. The particles are connected by point contact. Its argillaceous cementation types are in the majority pore style and contact style.

3. THE PHYSICAL PROPERTY CHARACTERISTICS OF RESERVOIR

The statistics of core physical property analysis show that the physical property of super heavy oil reservoir in Shu 1 formation has a low-high tendency from bottom to top. It is mainly affected by the sedimentary environment and the late diagenesis. The whole reservoir, highly porous and highly permeability, has the advantages for super heavy oil development.

Table 1
Statistics of Core Physical Property Analysis

Formation	Φ%	km^2	sh%
Ng	36.3	5.54	5.9
Xing-I～V	32.6	2.37	9.4
Xing-VI	27	1.92	6.2

From the point of log interpretation results, porosity and permeability plane distribution has certain regularity.

The Xing-VI formation: Generally, the porosity values are 15%-27% while the permeability values are 0.5-2.3 μm^2. In Du 84 well field and the northeast of Du 229, the higher porosity values are 20%-27% while the permeability values are 1.0-2.3 μm^2. In Du 212 well field, Du 813 block and Du 80, the porosity values are in general 15%-20% while the permeability value are 0.5-1.0 μm^2.

The Xing-I~V formation: the porosity is controlled by sedimentary facies belt and 20%-30% of the area, banding distributed in the plane, is mainly concentrated in distributary channel development zone. The porosity values of the inter distributary channel and the frontal lice are 15%-20%. Corresponding with the regularity of porosity distribution, the high permeability values distribution area also have a good relationship with the distribution of sedimentary facies belt. The poroperm values of the western and southeast of Du 84 well field,

the middle part of Du 212 well field and the northeast of Du 229 block are the highest. Generally, the porosity values are 20%-30% while the permeability values are 1.2-2.5 μm^2. The poroperm values of the western and eastern of Du 212 well field, the northeast of Du 84 block, Du 813 block and Du 80 block are lower. Generally, the porosity values are 15%-20% while the permeability values are 0.5-1.2 μm^2.

The Guantao oil layer reservoir, which has poor lithology and loosen rock texture, is a low maturity reservoir. The reservoir is better because its pores are mainly the Intergranular pores. The analysis of 127 samples of the coring wells in Guantao reservoir shows that the average porosity is 36.3%, and the average permeability is 5.539 μm^2 and the average shale content is 5.9%. So it belongs to the extra high porosity-extra high permeability reservoir (Table 2).

Overall, the super heavy oil reservoir of Shu 1 area is high porosity-high permeability reservoir and the condition of reservoir physical property is better.

Table 2
Statistics of the Guantao Reservoir Physical Property

Sandstone group	2	3	4	5	Average
Active porosity, %/block	37.0/32	36.7/32	36.5/29	35.2/34	36.3
Horizontal permeability, μm^2/block	5.261/28	5.187/26	7.124/13	5.403/27	5.539
Shale content, %/block	6.0/44	6.4/65	5.8/41	5.7/45	5.9
Carbonate content, %/block	0.48/9	0.38/13	0.22/11	0.13/10	0.25

4. THE RESERVOIR HETEROGENEITY

The parameters commonly used for the evaluation of reservoir heterogeneity level include: Permeability variation coefficient (V_k), dash coefficient (S_k) and differential (N_k).

4.1 The Xinglongtai Reservoir

According to the evaluation standard of the enterprise, the in layer heterogeneity parameters of Du 229 block is poor, homogeneous and the differential is small. Because each reservoir group on the longitudinal homogeneous degree is higher but the ratio of horizontal permeability and vertical permeability is bigger, so the horizontal permeability is higher than the vertical permeability. Longitudinally, the in layer heterogeneity type is from homogeneous to heterogeneous. The differential, increases from top to bottom, is bigger than that of Du 229 block. So the in layer heterogeneity is bigger than that of Du 229 block. The in layer heterogeneity from Du 813 to Du 212 is even stronger so that basically the type is from homogeneous to heterogeneous and the differential is higher.

The in layer heterogeneity of the Xinglongtai oil layer reservoir is serious and heterogeneous. The coefficient of anisotropy is 1.73-3.33 (2.27 on average), the coefficient of variation is 0.58-0.86 (0.73 on average), the differential is 127-204 (164.8 on average) times. The Xing-I~V formation reservoir is proximal fan delta deposit, and the in layer heterogeneity of the reservoir is greatly affected by the sedimentary facies belt. Due to the frequently channel swing and the fast phase change, there come a difference among the sedimentary facies belts in longitudinal and a large difference in permeability between layer and layer. The Xing-VI formation is underwater gravity flow deposit and the lithological change is big and the interlayer permeability difference is obvious and the heterogeneity is accordingly enhanced.

The areal heterogeneity: Because different sedimentary microfacies are in different sedimentary locations with different hydrodynamic conditions, different sand body lithology, structures and textures, so the corresponding heterogeneity is also different. The braided channel facies heterogeneity of the Xing-VI formation is the weakest, followed by the channel lateral margin microfacies and the interchannel lice is the most serious. Among the Xing-II~V formation, distributary mouth bar microfacies sand body heterogeneity is the weakest, and it is uniform-evenly style. The heterogeneity coefficient is 1.15-1.4 (1.26 on average) and the variation coefficient is 0.4-0.8 (0.44 on average) and the differential generally is 70-123 (88.9 on average) times. Followed one is the distributary channel sand body and it is relatively homogeneous style, and the heterogeneous coefficient is 1.35-1.64 (1.44 on average), and the variation coefficient is 0.5-0.62 (0.52 on average), and the differential is 130-150 (142.3 on average) times. The third one is the interdistributary shoal microfacies sand body and it is uniform-unevenly style and the heterogeneous coefficient is 1.47-2.2 (1.68 on average), and the variation coefficient is 0.48-0.72 (0.59 on average), and the differential is 66-220 (151.3 on average) times. The interdistributary lice microfacies sand body heterogeneity is the strongest and it is unevenly style, and the heterogeneous coefficient is 1.3-2.15 (1.73 on average), and the variation coefficient is 0.43-1.3 (0.74 on average), and the differential is 91-166 (142 on average) times.

4.2 The Guantao Reservoir

According to the results of the Guantao formation system frozen coring well core analysis data statistics: the total variation coefficient of the Guantao formation is 0.47, and the dash coefficient is 1.7, and the differential is 15 (Table 3). According to the evaluation standard of the enterprise, the Guantao formation heterogeneity is medium-weak.

The ratio of the intraformational vertical permeability and horizontal permeability is the important parameter that could reflect the characteristics of the intraformational heterogeneity. The core analysis results of the Guantao formation show that the ratio of the vertical permeability and the horizontal permeability is generally 0.7-0.9 (0.77 on average) and the heterogeneity is weak.

Table 3
Statistics of the Guantao Oil Layer Heterogeneity Parameter

Formation name	Horizontal permeability 10^{-3} μm^2			Anisotropy parameter			Anisotropy	Sample quantity	Note
	Max.	Min.	Avg.	V_k	S_k	N_k			
1 sandstone group	4,305	338	2,010	0.8	2.2	8	Medium	3	Water layer
2 sandstone group	9,002	385	5,479	0.5	1.8	23	Medium-weak	27	Oil layer
3 sandstone group	8,685	681	5,117	0.4	1.7	12	Medium-weak	32	Oil layer
4 sandstone group	9,783	2060	7,037	0.4	1.4	5	Weak	29	Oil layer
5 sandstone group	9,165	507	5,463	0.6	1.6	18	Medium-weak	34	Oil layer
Group 2~5	9,783	385	5,724	0.47	1.7	15	Medium-weak	125	Oil layer

CONCLUSION

(a) According to the analysis of reservoir characteristics, the Guantao formation, affected by reservoir heterogeneity, is good for SAGD development, and the steam chamber will be much plumper, and the recovery ratio will be higher than that of the Xinglongtai reservoir.

(b) The particularity of the Xinglongtai reservoir heterogeneity directly determines the difficulty of SAGD development. So using the combination of straight and flat is the best way for SAGD development.

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