Study on reservoir classification and influencing factors of sandstone reservoirs

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Abstract: An oil field reservoir belongs to a large river-delta sedimentary system in the northern part of the Songliao Basin. The depositional environment of the reservoir has changed significantly in different periods, and the nature of the reservoir is segmented in the vertical direction, so that different types of oil layers are developed in different areas and sections. There are many sandstone layers, and the oil-bearing well section is more than 500 meters long, consisting of mutual layers of sandstone and mudstone, in which the thickness of single sand layer is only a few meters to less than 1 meter, with obvious multi-rotation nature. With the continuous development of the oil field, the oil field has entered the late stage of high water content development, and the comprehensive water content of the oil field has reached over 90%, making it more difficult to stabilize the production of the oil field. In order to further extend the stable production period of the field and achieve the goal of "oil stabilization and water control", while doing a good job of efficient development of the main oil reservoir, the development of non-main oil reservoirs with poor pore permeability, fragmented distribution, complex reservoir properties and serious non-homogeneity is increased, and various development methods such as water drive, poly drive and ternary composite drive are used comprehensively. As the difference of reservoir properties determines the difference of oil recovery methods and oil recovery costs, for the convenience of oilfield decision making and management, oil reservoirs are divided into main and non-main reservoirs, usually the reservoir with good physical properties, high oil saturation, low oil recovery costs and high development benefits are called main reservoirs, also known as class I oil reservoirs, and other reservoirs are called non-main reservoirs.

Keywords: Oil formation classification; classification criteria; single factor; cumulative probability; classification limits.

1. Classification by oil formation criteria of oil fields

The formation classification criteria for this field are shown in Table 1, and the effective thickness was used as the main basis for the classification, and the formation types were classified qualitatively for the core extraction wells. According to the classification results, the corresponding statistics of the oil formation characteristics according to the class I oil formation, class II oil formation and class III oil formation were conducted, and we obtained the following characteristics of different types of oil formations.

Table 1 Classification criteria for oil formations in Daqing Sa Zhong Development Zone

Classification of oil layers		Single sand body		Basic characteristics of the oil formation: Effective thickness (m)	Penetration rate ($10^{-3}\mu m^2$)	Size	Suitable for injection of poly molecular weight	Suitable well spacing for triple recovery
Class I oil layer		River sand	Flood plain phase river sand, high bend diversion river sand	$H_{有}$ ≥4.0	≥800	The oil layer is developed over a large area in patches with a width greater than 1000 m.	Ultra High	200 ~ 250 m
Class II oil layer		River sand	Low-bending diversion channel sand, submerged branching channel sand	$H_{有}$ ≥1.0 m	≥100	The oil layer is developed in patches with a width greater than 200m.	Medium-high	150 ~ 175 m
		Framed non-riverine sand body H with ≥ 1.0m oil layer assisted by perfect						
Class III oil layer	Sub-Class I	Non-River	Thin layer of sand inside the surface	$H_{有}$ <1.0 m	<100	Generally broken mat-like, scattered, small area, two-phase mixed interlaced distribution.	Low	100 ~ 125 m
	Sub-class II		Off-Surface Reservoirs	0	0			

1.1 Characteristics of class I oil formation

Class I oil formation is the floodplain braided river or curved flow point dam sand body and deltaic diversion plain large high bend diversion river sand deposits, sand body drilling encounter rate is generally greater than 60%, single layer thickness is above 4 meters, effective permeability is above 0.8μm^2, total oil formation drilling encounter rate is greater than 90%, the proportion of off-surface drilling encounter rate to total oil formation drilling encounter rate is generally less than 10%, the original oil-bearing saturation is above 70%. The type of sand body is mainly river sand and lumpy deltaic sand body. The oil formation is developed in large areas and the width is generally greater than 1000m.

1.2 Characteristics of Class II oil formation

class II oil layer is the delta diversion plain small and medium-sized diversion channel sedimentary sand body or submerged diversion channel sand development area of more than 20% of the delta within the front edge of the sedimentary sand body deposits, the thickness of a single layer is generally 1-2m, the effective permeability is mostly greater than 0.1μm^2, the total drilling encounter rate of the oil formation is generally greater than 80%, the ratio of off-surface drilling encounter rate to the total drilling encounter rate of the oil formation is generally less than 30%, and the original oil-bearing saturation is greater than 50%.

1.3 Characteristics of class III oil formation

Class III oil formation is the oil layer and off-surface reservoir with effective permeability less than 1m, which belongs to the thin mat-like sand deposit outside the front edge of the delta, with effective permeability generally less than 0.1μm^2. It usually scattered distribution, small area, mixed and staggered distribution of two phases. The third type of oil layer is a poor reservoir different from the first and second type of oil layer, and is the object of adjustment of the original well network after blocking the thick oil layer, mainly the thin poor oil layer of the original well network without shooting holes, and the narrow river sand body which cannot be controlled by the well distance of about 200m. They are mainly characterized by poor oil formation development and connectivity, low mobilization and weak water absorption. For this kind of intra-surface thin differential layer and extra-surface reservoir, its physical properties are poor, the number of layers is large, the remaining oil is highly dispersed, the production capacity is low after three times of densified well placement, the water content is high, and the adjustment is very difficult.

2. Single-factor classification

The parameters that can characterize the geological features of different oil reservoirs are selected and the selected parameters are classified as a single factor. When establishing specific classification limits for the selected parameters, if only the sample points, i.e., the evaluation indexes, are classified, it cannot truly reflect the overall distribution pattern of these sample points, so we use the cumulative probability method to classify them. The cumulative probabilities of different sample points can not only reflect the real spread of data points in the sample, but also can quantitatively classify and summarize the sample points with different cumulative probabilities.

The cumulative probability is the percentage of each value in the sample and the value less than or equal to that value in the sample. It can show the correspondence between different sample points and their cumulative probabilities, reflect the size of the influence of different sample points on the whole, and clearly reflect the trend of the distribution of sample points in the whole. The values of different sample points are represented by horizontal coordinates, and the percentage of cumulative probability is represented by vertical coordinates, so that a cumulative probability graph is built. At the same time, the points with roughly linear trend are connected into a straight line, and most points are on the straight line when connecting, but some points are not on the straight line, so that straight line segments with different slopes can be made, so that the cumulative probability points with the same slope, i.e., with linear relationship, can be classified into one category, and eventually different cumulative probability points can be classified into different categories.

The specific parameters selected are: degree of recovery, sandstone thickness, effective thickness, porosity, air permeability, wash thickness, original oil-bearing saturation, current oil-bearing saturation, and oil drive efficiency of the wash layer.

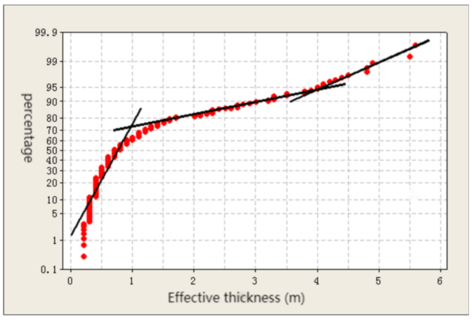

Figure 1 Permeability accumulation curve

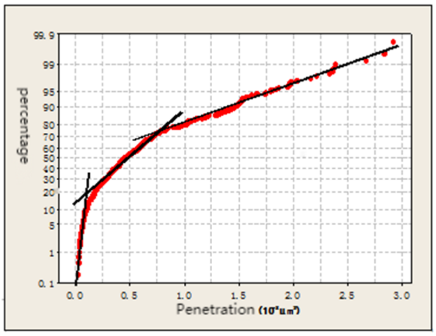

Figure 2 Effective thickness accumulation curve

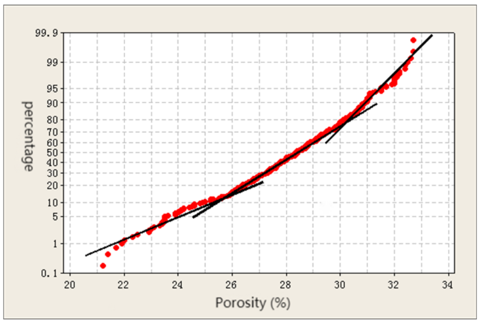

Figure 3 Washing thickness accumulation curve

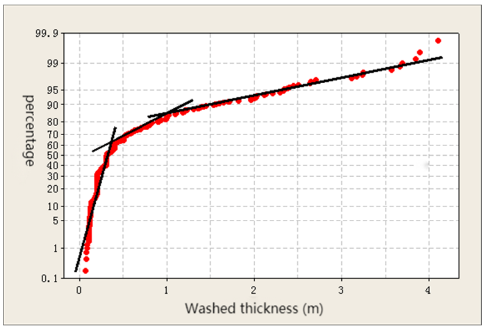

Figure 4 Porosity accumulation curve

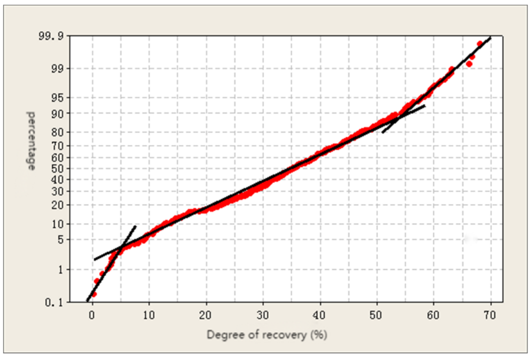

Figure 5 Cumulative curve of extraction degree

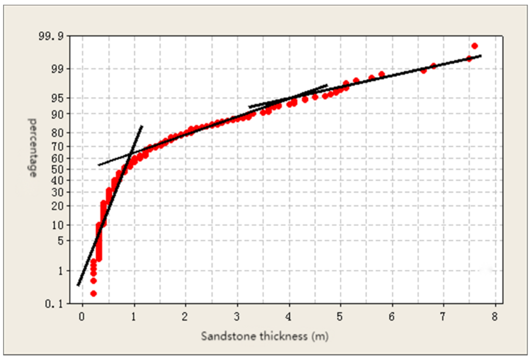

Figure 6 Sandstone thickness accumulation curve

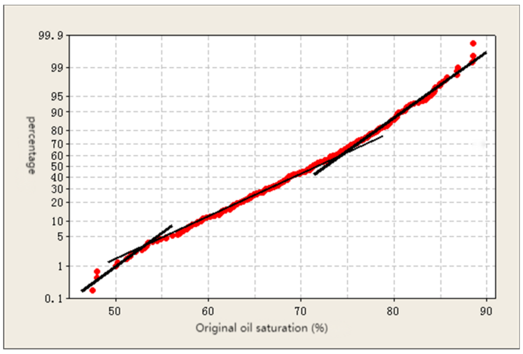

Figure 7 Cumulative curve of original contained saturation

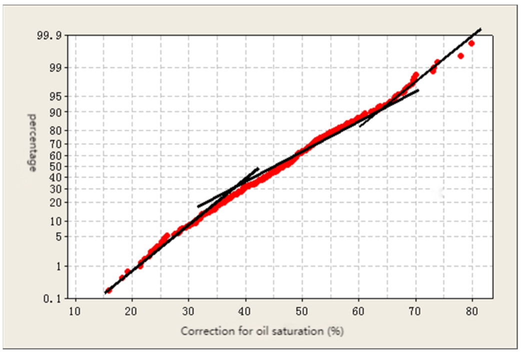

Figure 8 Cumulative curve of current oil content saturation

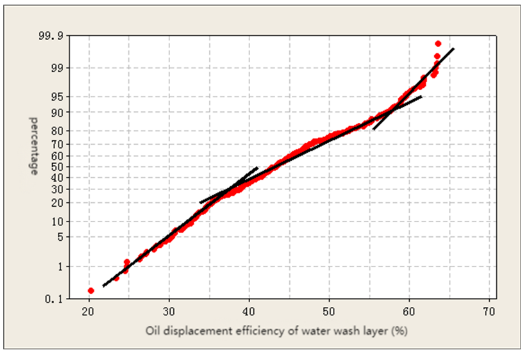

Figure 9 Cumulative curve of oil drive efficiency in washed layer

Table 2 Single-factor classification boundaries

Parameters	I	II	III
Air permeability (10^{-3}/μm^2)	> 0.8	0.1~0.8	< 0.1
Effective thickness (m)	> 4	1~4	< 1
Porosity (%)	> 30	26~30	< 26
Extraction level (%)	> 54	5~54	< 5
Thickness of sandstone (m)	> 4	1~4	< 1
Washing thickness (m)	> 1	0.4~1	< 0.4
Original contains saturation (%)	> 75	54~75	< 54
Currently contains saturation (%)	> 64	39~64	< 39
Water-washed layer oil drive efficiency (%)	> 58	38~58	< 38

3. Conclusion

Firstly, according to the overall oil formation classification standard of the field, the effective thickness was used as the main division basis to qualitatively classify the formation types in the coring wells, and based on the classification results, the different characteristics of the class I, class II and class III formations were counted separately. Then, the parameters that can characterize the geological features of different oil formations were selected, and the selected parameters were classified as a single factor. In establishing specific classification limits for the selected parameters, we used the cumulative probability method to classify them. The cumulative probabilities of different sample points not only truly reflect the spreading of data points in the sample, but also can quantitatively classify and generalize the sample points with different cumulative probabilities. We qualitatively consider that the cumulative probability points with linear relationship on the cumulative probability graph are classified into one category, and eventually different cumulative probability points can be classified into different categories. After completing the classification, the classification results were compared and analyzed. Through the comparison and analysis, we found that the single-factor classification results are prone to crossover, therefore, we are required to evaluate the degree of influence of each parameter and determine the oil formation type through comprehensive analysis in the development process.

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