Study on Reservoir Heterogeneity in Block S

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Abstract. Based on core analysis and testing and logging interpretation data, this paper studies the interlayer heterogeneity and plane heterogeneity of the reservoir, and establishes a set of evaluations for calculating the interlayer and plane heterogeneity of Fuyang oil layer. Standard, draw contour maps of 5 parameters and 12 main force layers. The results showed that 77% of the small layers with interlayer heterogeneity showed strong heterogeneity, and 23% showed moderate heterogeneity or homogeneity. 80% of the plane heterogeneity of the small layer is strong heterogeneity, and 20% is strong heterogeneity.

1. Introduction
Reservoir heterogeneity refers to the uneven changes in spatial distribution and internal properties of oil and gas reservoirs due to the influence of sedimentary environment, diagenesis, and tectonic processes during the formation process. Such changes are called reservoir heterogeneity. Reservoir heterogeneity plays a vital role in the accumulation, production, distribution and formation of oil and gas reservoirs. At the same time, it controls the seepage characteristics of oil, gas and water, determines the quality of the reservoir, and influences the quality of the reservoir. It is one of the main factors for the length of time for high and stable production of oilfields and the level of ultimate recovery. Therefore, understanding the heterogeneity of reservoirs is an important prerequisite for good oilfield development, and is of great significance in petroleum exploration and development. In recent years, many scholars have studied the heterogeneity of reservoirs from different angles, and proposed a variety of classification schemes for the heterogeneity of reservoirs. Generally, reservoir heterogeneity is divided into macro heterogeneity and micro heterogeneity. Reservoir heterogeneity research is based on core analysis and testing and logging interpretation data. From the perspective of macro-heterogeneity, it analyzes the characteristics of intra-layer, inter-layer, and planar heterogeneity and its influence on remaining oil distribution. The oilfield has laid the foundation for increasing reserves and production and adjusting the development plan.

Block S is a third-class block in Fuyang. In recent years, oil wells have gradually seen water, and the injection of each layer of water wells is uneven. In view of the conflicts between layers and planes caused by different reservoir heterogeneities in the process of oilfield development. For the 178 oil and water wells in the block S, Fuyu and Yangdachengzi have a total of 73 layers, the interlayer heterogeneity and plane heterogeneity are studied layer by layer, and the heterogeneity of each layer in Fuyang is further studied. Qualitative and quantitative understanding of qualitative nature provides strong data support for dynamic analysis and adjustment of measures.

2. Research on interlayer heterogeneity of block reservoirs
Interlayer heterogeneity refers to the difference between sand bodies, including the cyclicity of the
strata, the degree of heterogeneity of permeability between sand layers, the distribution of interlayers, and the characteristics of interlayer fractures. The study of interlayer heterogeneity is the basis for dividing the development strata and determining the mining technology. At the same time, the interlayer heterogeneity is an important reason for interlayer interference and water flooding differences in the water injection development process.

2.1. Inter-layer difference analysis of heterogeneity parameters

Layers with different heterogeneity have obvious differences in the porosity, permeability, oil saturation, level difference, penetration coefficient, heterogeneity coefficient, and coefficient of variation. Therefore, the vertical parameter histograms of each sublayer from FI1-1 to FIII5-2 and YI1-1 to YII7-2 are drawn for these 7 heterogeneity parameters. Through the analysis of the difference and the same characteristics of the vertical changes of each layer, it can better guide the later development and adjustment, which is conducive to improving the recovery rate.

According to the difference of quantitative parameters, the degree of heterogeneity of each sublayer is evaluated. According to the evaluation criteria, the difference in heterogeneity between each sublayer is obtained. Most of the sublayers are expressed as Strong heterogeneity, a small part of it is medium heterogeneity or homogeneity. The evaluation results: The Fuyu oil layer is homogeneous with 1 layer, 7 layers with medium heterogeneity, and 27 layers with strong heterogeneity. The Yangdachengzi oil layer has 3 homogeneous layers, 6 medium-heterogeneous layers, and 29 strongly heterogeneous layers. A total of 4 layers are homogeneous, 13 layers are medium heterogeneity, and 56 layers are strong heterogeneity.

2.2. Dynamic applications

The results of interlayer heterogeneity assist the water absorption profile data. The water absorption profile data is often used in dynamic analysis to analyze the water absorption of each layer of the well, and then determine the injection plan, stop the well layer with high oil pressure, and rotate the injection thin and poor layers to relieve the high pressure layer pressure. For wells with no water absorption profile measured, the results of interlayer heterogeneity can be used to assist the water absorption profile data to determine the water absorption difference of each layer.

Taking the layered water well A as an example, when the physical properties and oil content of the three layers are similar, the heterogeneity of the YI72 layer is stronger than that of the YII31 and YII41 layers. The water absorption profile shows that the water absorption of the latter two layers is much greater than YI72, therefore, during the water injection adjustment, if the YI72 layer is to absorb water, a single card is required. There are 36 water injection wells in Block S and 16 wells with water injection profiles, which are consistent with the results of the interlayer heterogeneity study in 8 wells.

3. Research on the heterogeneity of the block reservoir plane

Plane heterogeneity refers to the geometric shape, anisotropic continuity, connectivity of a single oil layer sand body, as well as the planar change and directionality of the permeability and porosity of the sand body. The plane heterogeneity has a great influence on the well pattern layout, the plane sweep efficiency of the injected water and the plane distribution of the remaining oil. The study of planar heterogeneity is beneficial to changing the displacement mode during the displacement process of low-permeability reservoirs, thereby effectively improving the vertical displacement efficiency and sweep efficiency of water injection.

3.1. Plotting the plane contour map

The plane contour map can visually show the optimal position in the same layer for a certain parameter. This paper uses five basic parameters: 1-sandstone thickness, 2-sand-to-ground ratio, 3-porosity, 4-permeability, 5-oil saturation to characterize the planar heterogeneity of each small layer. The thickness of sandstone is the thickness of the second-class sandstone, and the sand-to-ground ratio is the ratio of the thickness of the sandstone to the thickness of the formation.
Using GPR.MAP software to automatically stratify, automatically extract reservoir attribute values and calculate the calculation of heterogeneous parameters based on logging curves. Since perforation is put into production mainly in the main oil layer, the Fuyang oil layer is finally controlled under the control of the facies boundary. The contour map of each parameter on the plane of each main oil layer is drawn to provide an intuitive plane distribution of these 5 parameters.

3.2. Evaluation of Heterogeneous Comprehensive Index

Since there are many parameters that affect planar heterogeneity, the law of change and the degree of influence are different, so the comprehensive heterogeneity index is introduced to comprehensively characterize the parameters of the heterogeneity of the reservoir[1][2]. The entropy method is used to calculate its size. The concept of entropy originates from thermodynamics. The value of entropy is actually a measure of system uncertainty. Entropy has extreme value. When the system is in various states with equal probability, its entropy value is the largest. Therefore, the entropy method can be used for the evaluation of uncertain parameters. According to the algorithm characteristics of the entropy weight method, it can be seen that the closer the level value of the parameter, the larger the entropy value, the smaller the weight value, and the contribution of this parameter to the entire system is correspondingly smaller; on the contrary, the level value difference of the parameter is more significant, the smaller its entropy value, the larger its weight, and the contribution of this parameter to the whole system (reservoir heterogeneity) is correspondingly larger[3][4][5].

In terms of quantitatively evaluating the degree of heterogeneity, it need to select appropriate parameters, and to establish appropriate evaluation criteria. The evaluation criteria in the reference literature, set 0.4, 0.55, and 0.7 as different the limit value of qualitative degree. The smaller the value of I, the stronger the degree of heterogeneity, the larger the value of I, the smaller the degree of heterogeneity.

According to the quantitative evaluation criteria, the 73 layers of Fuyang were comprehensively evaluated for planar heterogeneity, and the results: the 58 layers of reservoirs are all strongly heterogeneous, and 15 layers are of strong heterogeneity.

3.3. Dynamic application

The planar heterogeneity results determine the planar high-permeability zone and assist in the analysis of the reasons for the high production or high water cut of oil wells. In the statistics of the block S, there are currently 8 oil wells with daily oil production greater than 1.5t, 4 oil wells are in the high...
4.Permeability zone; 21 high water-cut wells are in the high permeability zone. Due to the lack of liquid production profile, it is initially judged by combining the development of oil layers and the production data of oil and water wells. The result is that the oil wells in the high permeability zone have good efficiency, high production, and high water content.

Taking Well B as an example, in September 2015, large-scale fracturing of the FI52-FI61 layer and the FI142 layer, the current water content is 23.4%, the daily oil production is 4.06t, and the fracturing effect is good. From the FI61 plane heterogeneity coefficient equivalent map, Well B is in the dominant area, the adjacent water well a near the high water-cut well is Well b, and the dominant direction of water flooding points to b; adjacent Oil well C has high water content, and the dominant direction of water flooding points to C. Therefore, the fracture length is controlled at 600m, so that Well B can effectively communicate with adjacent water wells but not press through, so that the well will increase production after fracturing. It shows that the oil well has high water content and is in a position of high permeability, so the possibility of water breakthrough after fracturing in nearby oil wells is greatly reduced.

4.Conclusion
(1) The interlayer heterogeneity and plane heterogeneity of Fuyang oil layer have established a set of evaluation standards in both qualitative and quantitative aspects. In the quantitative calculation part of the 73 small layers of Fuyang, 56 small layers with strong interlayer heterogeneity, accounting for 77% of the total number of layers, and 17 small layers with moderate heterogeneity or homogeneity, accounting for the total 23% of the number of floors. Planar Heterogeneity Strong heterogeneity is 58 small layers, accounting for 80% of the total number of layers, and strong heterogeneity is 15%, accounting for 20% of the total number of layers. It shows that the overall heterogeneity of the block is relatively strong.

(2) The results of this paper can assist in the analysis of dynamic wells and help find the plane high permeability zone.

(3) In terms of interlayer heterogeneity, for wells whose results do not match the water absorption profile, seek out the reasons for the inconsistency, and combine dynamic production conditions to further improve the research work;In terms of planar heterogeneity, the 12 main force layers are analyzed in this paper. It is necessary to further match the main fluid-producing layers of oil wells in the high-permeability zone with the layers of the small-layer high-permeability zone, and combine the dynamic data to further determine the dominant direction of waterflooding in each layer; For oil wells in non-hyperpermeable zones, in addition to physical properties and oil-bearing properties, what else can affect high production.

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