Reservoir Classification and Evaluation Method Based on Storage-permeate and Degree of Heterogeneity

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Abstract. La-Sa-Xing oilfield is the maximum continental multi-layered sandstone reservoir in China, which has already entered the ultra-high water-cut development stage. Three major contradictions are more prominent and residual oil is highly scattered, the traditional qualitative reservoir evaluation method is hard to meet the demand of current reservoir production and development. According to the requirement of production situation and technology development at ultra-high water-cut stage, combining fine reservoir geological characteristics and development efficiency, a new reservoir evaluation method is established by using multi-parameter product method, multi-parameter bound analysis, etc. The method proposed is set up with storage-permeate assessment parameter and dominant sand-body distribution degree as assessment parameters. It establishes the relationship between static geology and dynamic production and reveals a certain oil-layer potential. The introduction of dominant sand-body distribution degree emphasizes the reservoir plane heterogeneous characters, it can quantitatively characterize the matching relationship between reservoir and well pattern; the reservoir classification based on the above two aspects providing reliable basis for designing water flood, polymer flood and ASP flood development plan.

1. Introduction
The purpose of reservoir evaluation is to establish a suitable reservoir classification and evaluation method through the analysis of the actual geological conditions of the reservoir, so as to provide a reliable and important basis on the exploration and development of oil and gas fields. As the largest continental multi-layer sandstone reservoir in China, Daqing oilfield has stepped into ultra-high water-cut stage, various types of reservoir remaining oil are highly scattered which are quite different in the same type. The traditional qualitative reservoir evaluation method is hard to meet the demand of current reservoir production and development. A new comprehensive quantitative evaluation method is need to set for the development requirement of ultra-high water-cut water flood, polymer flood and ASP flood reservoir, so as to implement the remaining oil potential and lay the foundation for the establishment of development countermeasures[1-6].

2. New Method of Reservoir Evaluation
In the same reservoir, effective thickness, oil saturation, porosity and permeability are the main factors controlling storage-permeate. Taking the influence of different types of sand bodies on the reservoir into comprehensive consideration, the classified reserves abundance which can represents the reserve scale of the reservoir and the effective permeability which can reflects the permeability of the reservoir are introduced as the main evaluation contents, with the multi-parameter product method
selected to convert multiple variable indexes into a comprehensive index, so as to construct the storage-permeate assessment parameter.

Considering the contribution of different types of sand bodies to reservoir, unit reserves can be expressed as:

$$N_T = N_{CH} + N_Z + N_F + N_B$$  \hspace{1cm} (1)

$N_T$ — total petroleum geological reserves, $10^4$ t;  
$N_{CH}$ — geological reserves of channel sand body, $10^4$ t;  
$N_Z$ — geological reserves of sheet sand in the table, $10^4$ t;  
$N_F$ — geological reserves of non-main sheet sand in the table, $10^4$ t;  
$N_B$ — off-table reservoir geological reserves, $10^4$ t.

Let the area covered by different types of sand bodies be $A_i$. According to the volumetric reserves formula, unit reserves can be written as:

$$N_{i} = 0.01 \rho / B_{oi} \sum (A_i h \phi S_o)$$ \hspace{1cm} (2)

$i$—channel sand body, main sand body, non-main sand body and off-sheet sand body  
$A$—oil bearing area, km$^2$;  
$h$—effective thickness, m;  
$\phi$—effective porosity, %;  
$S_o$—oil saturation, %;  
$\rho$—surface oil density, g/cm$^3$;  
$B_{oi}$—volume coefficient.

Then reserves abundance $I_0$ can be written as:

$$I_0 = \frac{0.01 \rho / B_{oi} \sum (A_i h \phi S_o)_{i}}{\sum A_i}$$  \hspace{1cm} (3)

In the formula, $0.01 \rho / B_{oi}$, a constant value, is omitted with no influence on the quantitative classification and evaluation. According to the statistical results of drilling encounter rate and sedimentary area of sand bodies in different types of reservoirs, the values of them are similar. The drilling encounter rate of sand bodies of sedimentary units $D_r$ can represent the sedimentary area $A$ of sand bodies.

Based on the above understanding, classified reserves abundance $I$ can be expressed as:

$$I = \sum (D_r h \phi S_o)$$ \hspace{1cm} (4)

Combined with the recognition of the geological characteristics of different types of reservoirs, the storage-permeate assessment parameter $P_1$ is constructed with the following formula:

$$P_1 = IK$$ \hspace{1cm} (5)

$K$ — permeability, D

By introducing equation (4) into the above equation, the storage-permeate assessment parameter $P_1$ can be written as:

$$P_1 = \sum (D_r h \phi S_o K)$$  \hspace{1cm} (6)

The La-Sa-Xing oilfield PI3 layers is evaluated by the use of reservoir parameters. According to the evaluation results (Fig.1), the evaluation results of storage-permeate use of reservoir parameters parameter shows a good in west but bad in east, and good in north but bad in south condition, which reflects the reservoir's oil-producing capacity difference directly with the consistent understanding of the development dynamic materials.
3. Establishment of Dominant Sand-body Distribution Degree

Planar heterogeneity is one of the main contradictions of sandstone oil fields in ultra-high water-cut stage, which has a great influence on the development effect. This study introduced the dominant sand-body distribution degree for reservoir plane heterogeneity, which provides the main contribution on sand-body connectivity, with different meanings in different reservoir types. It classifies the dominant sand-body of A type as channel sand, B type as channel and the main sheet sand, C type as effective connecting sand bodies, which indicates the concentration and dispersion degree of sand body in plane. The dominant sand body degree has an effect on the well pattern control degree of high-quality reserves (Fig. 2).

The multidirectional connectivity ratio in the dominant sand body can represent the degree of distribution of the dominant sand body ($P_2$):

$$P_2 = \frac{E_Y}{E_T}$$

$E_Y$—number of multiple connected directions in the body of dominant sand body;
$E_T$—number of total directions.
The study on the distribution degree of dominant sand bodies in different sedimentary units in area B of Saertu oilfield shows that the dominant sand bodies in scattered distribution pattern are distributed in the form of branches or potatoes, with a width of 50-100m, and the well spacing is difficult to control at present. The concentrated dominant sand body distributed in sheets with a width of several hundred meters can better be controlled by pattern arrangement and is more suitable for the tertiary oil recovery well pattern deployment (Fig. 3).

4. Establishment of Evaluation Classification

Based on the fine anatomy of typical blocks and the combination of dynamic and static data, the boundaries of reservoir types of each sedimentary unit were defined to establish a new reservoir evaluation standard, and the reservoir types were divided into three categories. Class A reservoir is the main production reservoir with highest storage-permeate and least plane heterogeneity, which is beneficial to development and adjustment. Class B reservoir is economically available with higher storage-permeate and less planar heterogeneity. Class C reservoir is a potential recoverable reservoir with poor permeability and strong planar heterogeneity.

In comparison with the water injection profile results of injection wells (Fig. 4), it shows that there is a certain correlation between storage-permeate assessment parameter and water absorption, the variation trend of which is consistent, indicating that the new evaluation standard is closely related to development and production and can reflect certain actual production characteristics.

5. Conclusion

The storage-permeate assessment parameter is composed of the reserve abundance which represents the reserve scale and the effective permeability which reflects the storage-permeate. This parameter establishes the relationship between static geology and dynamic production and reveals a certain oil-layer potential. The dominant sand-body distribution degree emphasizes the reservoir plane heterogeneous characters. On the premise of certain storage-permeate, it has an effect on the well
pattern control degree of high-quality reserves. It can quantitatively characterize the matching relationship between reservoir and well pattern. The evaluation results of this method are highly consistent with the production dynamic data, which can directly reflect the actual production situation, provide reliable basis for the reservoir residual potential implementation and the development strategy arrangement, and guide the fine measures to dig potential and the adjustment of the stratified well pattern.

6. Reference

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