The Comprehensive Evaluation Study on the Availability of low permeability reservoir

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Abstract: Reserves of low permeability reservoirs have great development potentiality. Carrying out the evaluation of reserves and optimizing the high yield region to develop, which have a guiding role for the effective use of this type of oil reservoir. This type of reserves is low and extra-low permeability tight sandstone reservoir, which has the characteristics of "low quality, poor sand body, poor physical property" and "low productivity, rapid decline, short effective development period. According to the special reserves of low permeability reservoirs, the reserves classification and reservoir characteristics and capacity were combined, using cluster analysis to optimize the reserves evaluation parameters. The final evaluation parameters were determined, and the correlation coefficient method, factor analysis method and step analytic method were introduced, a comprehensive evaluation system was established, the low permeability reservoir reserves were divided into 4 categories, and suggestions on development were given.

1. Reserves Classification Evaluation Parameters Optimization

In reservoir evaluation, in order to evaluate the quality of the reserves, effective thickness, porosity, permeability, oil reserves abundance, strength, fluidity, drilling of main sand body number and production intensity are usually considered as evaluation parameters to classify and evaluate reservoir [1-3].

In order to evaluate the correlation between the common parameters and the quality of reserves, the statistical analysis of the evaluation was carried out, and the correlation matrix of each evaluation parameter was established according to the cluster analysis (Table 1). According to the correlation coefficient of cluster analysis, the correlation between reserves abundance and effective thickness, drilling of main sand body number is very good, the correlation coefficients is above 0.9, the permeability and fluidity can reflect the reservoir seepage ability[4-7]. The comprehensive evaluation parameters of the effective thickness, oil saturation, effective porosity, mobility, drilling, production intensity of main sand body number were determined.

Table 1 Correlation matrix of evaluation indexes

Evaluation parameters	Correlation between parameters							
	Reserve abundance	Effective thickness	Oil saturation	Effective porosity	Permeability	Fluidity	Number of main sand body	Production intensity
Reserve abundance	1	0.988	0.618	0.737	0.506	0.094	0.9	0.535
Effective thickness	0.988	1	0.569	0.661	0.425	0.049	0.877	0.54
Oil saturation	0.618	0.569	1	0.574	0.448	0.18	0.537	0.298
Effective porosity	0.737	0.661	0.574	1	0.749	0.195	0.697	0.336
Permeability	0.506	0.425	0.448	0.749	1	0.404	0.469	0.208
Fluidity	0.094	0.049	0.18	0.195	0.404	1	-0.03	0.139
Number of main sand body	0.9	0.877	0.537	0.697	0.469	-0.03	1	0.478
Production intensity	0.535	0.54	0.298	0.336	0.208	0.139	0.478	1

In the 6 evaluation indicators, there are 2 parameters reflecting the reservoir distribution characteristics: the effective thickness and drilling the main sand body; there are 2 parameters evaluating reservoir physical property and oil-bearing property: effective porosity and oil saturation; there is a parameter evaluating seepage capacity of fluid: fluidity; there is a parameter evaluating reservoir productivity: production intensity (Table 2).

Table 2 Statistical table of comprehensive evaluation index

No.	Index category	I	II	III	IV	Evaluation category
1	effective thickness /m	≥10	10~5	5~2	≤2	Reflect the distribution characteristics of the reservoir
2	Number of main sand body / individual	>4	4~3	3~1	≤1	
3	Effective porosity/%	≥15	15~14	14~13	≤13	Reflect the physical properties and the oil content of the reservoir
4	Oil saturation /%	≥55	55~50	50~45	≤45	
5	Fluidity /$10^{-3}\mu m^2$/mPa.S	≥0.35	0.35~0.2	0.2~0.1	≤0.1	Reflect the reservoir seepage ability
6	Production intensity /t/d·m	≥0.6	0.6~0.3	0.3~0.1	≤0.1	Reflect the situation of reservoir capacity

2. Reserves Evaluation Method Optimization

In order to determine the weight value of each evaluation parameter, the correlation coefficient method, principal component factor analysis method and step analytic method were selected to calculate the weight value of the 6 indexes of comprehensive evaluation classification.

2.1 Correlation Coefficient Method

According to the correlation coefficient theory, for a certain data set can be used to set the weight of a correlation coefficient [8]. Therefore, the weight values of different evaluation parameters can be calculated by the correlation coefficient method:

$$W_i = \frac{\sum_{j=1}^{m} r_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{m} r_{ij}} \tag{1}$$

$$L_{ij} = \sum C_i C_j \frac{(\sum C_i)(\sum C_j)}{m} \tag{2}$$

$$r_{ij} = \frac{L_{ij}}{\sqrt{L_{ii}L_{jj}}} \tag{3}$$

Among them i=1, 2…, m; j=1, 2…, n;

W_i—Weight value;

r_{ij}—Evaluation factor I and correlation coefficient of j;

C_i、C_j—Measured data for the two evaluation factors, respectively.

According to the above formula calculated the weight value can be seen in Table 3.

Table 3 Comprehensive evaluation index weight table calculated by correlation coefficient method

Evaluation index weight	Effective thickness	Oil saturation	Effective porosity	Fluidity	Number of main sand body	Production intensity
Wi	0.196	0.171	0.185	0.109	0.192	0.147

2.2 Principal Component Factor Analysis Method

Principal component factor analysis method can eliminate the influence of different parameters dimension, which can effectively overcome the human disturbance in the process of analysis and evaluation.

Each evaluation parameter data matrix can be evaluated by the actual data of the evaluation block:

$$X_{nm} = \begin{bmatrix} X_{11} & \cdots & X_{1m} \\ \vdots & \vdots & \vdots \\ X_{n1} & \cdots & X_{nm} \end{bmatrix} \tag{4}$$

Calculation of low permeability reservoir, the relative weights are obtained, and the actual value is obtained after normalization treatment (Table 4).

Table 4 Each parameter score coefficient table calculated by principal factor analysis method

Comprehensive evaluation index	Main factor		Absolute value of principal component		Relative weight	Normalized weight
	1	2	1	2		
Effective thickness	0.417	-0.101	0.417	0.101	0.3705	0.19
Oil saturation	0.005	0.384	0.005	0.384	0.255	0.13
Effective thickness	0.032	0.383	0.032	0.383	0.2747	0.14
Fluidity	-0.221	0.516	0.221	0.516	0.4995	0.25
Number of main sand body	0.394	-0.076	0.394	0.076	0.3371	0.17
Production intensity	0.302	-0.065	0.302	0.065	0.2633	0.13
Total			1.372	1.525	2	

2.3 Step Analytic Method

Step analytic method can be used to compare the importance of multiple evaluation parameters on the same level [11]. Through the establishment of the hierarchical structure of reserves evaluation, the factors, objectives, measures and solutions are determined. 1-9 scale method was used to determine the importance of different parameters (Table 5), to calculate the combination weights of the various factors (Table 6).

Table 5 the scale of the paired comparison method

a_{ij}	Compared between two indicators	Interpretation
1	Equally important	Indicators I and j are equally important / have advantages
3	Slightly important	Indicators I slightly more important than the J /have the advantage
5	More important	Indicators J than I more important / have the advantage
7	Very important	Indicators I than j obvious important / have the advantage
9	Absolutely important	Indicators I than j is absolutely important / have the advantage
2、4、6、8	Between two adjacent importance degree	

Table 6 comprehensive evaluation index weight table

Evaluation index weight	Effective thickness	Oil saturation	Effective porosity	Fluidity	Number of main sand body	Production intensity
Wi	0.15	0.12	0.21	0.16	0.21	0.16

3. Classification Evaluation of Reserves in Low Permeability Reservoirs

In order to improve the accuracy of the evaluation results, the comprehensive weight value of each unit is calculated by using the comprehensive score weight analysis method. According to the above three methods to calculate the weight of the classification index (Table 7).

Table 7 Evaluation parameters statistical table

Calculation method	Effective thickness	Oil saturation	Effective porosity	Fluidity	Number of main sand body	Production intensity
Correlation coefficient method	0.20	0.17	0.19	0.11	0.19	0.15
Principal component factor analysis method	0.19	0.13	0.14	0.25	0.17	0.13
Step analytic method	0.15	0.12	0.21	0.16	0.21	0.16
Average	0.18	0.14	0.18	0.17	0.19	0.15

By using the individual evaluation scores were multiplied by the weight coefficient of this class, the individual weigh scores were calculated, the all individual weigh value in each unit will be added, that is, each unit's comprehensive evaluation score.

According to the distribution interval of the comprehensive value, the reserve calculation unit is divided into four categories, class I: comprehensive score >60, class II: comprehensive score 60~40, class III: comprehensive score 40~25, class IV: comprehensive score <25.

4. Conclusion

(1) The evaluation characterization parameters of reserves of low permeability reservoirs was optimized through the cluster analysis, the effective thickness, oil saturation, effective porosity, mobility, drilling, oil production intensity of main sand body number was determined.

(2) The weight of the evaluation parameters is quantified by correlation coefficient method, factor analysis method and step analytic method, a comprehensive evaluation system was established

(3) Reserves classification evaluation was done by comprehensive evaluation system of reserves in low permeability oil reservoir, the low permeability reservoir reserves were divided into 4 categories, and the development modes of different types of reserves were determined.

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