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Application of Principal Component Analysis in Reservoir Evaluation

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Abstract: - Reservoir heterogeneity is an important basis of exploration and development strategy, so a comprehensive reservoir evaluation can lay a reliable geological foundation of the formulation and adjustment of the development plan considering the influence of different parameters on the reservoir properties, cluster analysis is adopted to reasonably optimize the geologic and development parameters that can reflect the reservoir property. By using the comprehensive quantitative classification method of principal component analysis, we can determine the weight of each influencing factor, and then calculate the comprehensive evaluation index. At last, we can determine the classification boundary according to the cumulative- probability distribution curve, and finally complete the comprehensive classification evaluation of reservoirs.

Keywords: - reservoir evaluation, principal component analysis, quantity, weight

I. INTRODUCTION

The difference of hydrodynamic condition and sedimentary environment leads to the existence of reservoir heterogeneity and different degree of difference between the oil field, sandstone, small layers and the single sand body. These differences are essential basis of exploration and development strategy. Therefore, making the reservoir evaluation can lay a reliable geological foundation of the formulation and adjustment of the development plan, dynamic analysis, reservoir engineering study, and reservoir numerical simulation[1]. Before we usually choose single factor classification method, but the evaluation results are often not very clear and easy to appear contradictory when the parameter is large. Only by making a comprehensive evaluation of the reservoir can we improve the success rate of drilling and overcome the uncertainty of a single factor classification method.

II. THE PRINCIPLE OF COMPREHENSIVE RESERVOIR EVALUATION

When making comprehensive reservoir evaluation, we can either use qualitative evaluation or quantitative evaluation, but the qualitative evaluation has the following defects：①more evaluation parameters, hard to evaluate ②contradictory evaluation results. Therefore, in the oilfield, we usually choose comprehensive reservoir evaluation method, and the method is as follows:

$$REI = \sum_{i=1}^{n} a_i X_i \tag{1}$$

In which: *REI*—comprehensive reservoir evaluation index;

X_i —reservoir evaluation parameters;

a_i —the weights of reservoir evaluation parameters;

n —the number of reservoir evaluation parameters;

We can see from formula (1), X_i is known parameter, a_i is unknown. If we can calculate a_i, then the comprehensive evaluation index *REI* will be worked out[2].

III. THE METHOD OF COMPREHENSIVE RESERVOIR EVALUATION

3.1 The optimization method of reservoir parameters

When making a comprehensive evaluation of reservoir or different blocks, we should select those representatives, comparability and practical parameters on the basis of the influence of individual parameters on the reservoir characteristics and the relationship between various parameters. The method of cluster analysis is utilized to choose the parameters. Its basic principle is tantamount to obey the affinity-disaffinity relationship of the object in nature or causes, and take some kind of statistics as the classification basis, thus making quantitative classification of the object[3]. It not only considers all the factors, but also is not subject to the structure of the existing classification. Group the correlation variables, eliminate one of the parameters, and then filter out some of the parameters, finally reasonably optimizes the geologic and development parameters which can reflect the reservoir property, realizing the comprehensive evaluation of reservoir or different blocks.

3.2 Principal component analyses -the method to determine "the weighing values"

Principal component analysis is a type of multivariate analysis method. These variables are not always independent of each other, thus bringing certain difficulty to the comprehensive analysis. In order to reach the goal of simplifying analysis, we often take the more number of variables as a linear combination, merging them into several major new variables- principal component, thus the number of less principal components can on behalf of the change of the main information of geological variables. This can not only greatly streamline the data, but also reproduce their inner genetic relationships and the correlation between the original data. It contains the calculation of the mean, covariance, the weight coefficient, the correlation coefficient matrix and its characteristic value and characteristic vector.

Suppose there are N samples, each sample is observed P indexes, then it can be represented as the follows:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1p} \\ x_{21} & x_{22} & \cdots & x_{2p} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{np} \end{bmatrix} \qquad (2)$$

The formula above can be considered as p-dimensional normal distribution random variables.

For the p-dimensional normal distribution random variable $X=(x_1, x_2,\ldots, x_p)^T$, the distribution of the sample points in the p-dimensional space is a p-dimensional ellipsoid. Principal component analysis is to make use of the orthogonal transformation to let the sample points have the maximum variance in the F_1 direction, the second largest in the F_2 direction, which is perpendicular to F_1, the third largest in the F_3 direction, which is perpendicular to F_1 and F_2, until work out F_{p-1}, finally work out F_p, which is perpendicular to F_1, F_2, F_3,… and F_{p-1}.

3.3 Principle of the cumulative- probability distribution curve

The taxonomic significance of the cumulative probability distribution curve is: The more similar the geological characteristics are, the greater the slope of the straight line is, otherwise, the smaller the slope is, so these parameters of different distribution characteristics can form different slope of the straight line segment. Different slope of the straight line segment reflects different reservoir properties, so we can make the reservoir classification according to the slope of the straight line segment.

The curve of the same slope can be divided into one category, for example, as is shown in Fig 1, it can be divided into three categories, A, B and C (Fig 1).

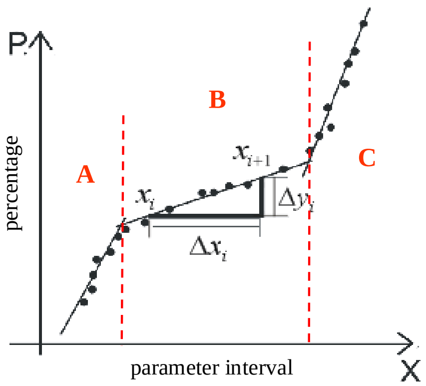

Fig 1 the cumulative probability curve

IV. APPLICATION EXAMPLE

According to the actual data of the producing well of development blocks of the eighth oil recovery factory in Daqing oil fields, adopting the method of cluster analysis to optimize the geological parameters of Putaohua reservoir, using the limitation Data Transfer Methods, with the correlation coefficient on behalf of the clustering distance, adopting the shortest distance clustering method, the following results are obtained after operation (Table 1, Fig 2).

Table 1 the clustering results

T	I	J	distance
1	crude oil density	porosity	0.01831
2	porosity	effective thickness	0.06892
3	static formation pressure	effective thickness	0.13717
4	sedimentary type	reservoir thickness	0.25786
5	original oil saturation	effective thickness	0.37703
6	combination of oil-water	effective thickness	0.42293
7	reservoir thickness	reserve abundance	0.44492
8	permeability	reserve abundance	0.50066
9	effective thickness	area	0.57665
10	reserve abundance	area	0.65168
11	oil viscosity	area	0.68499

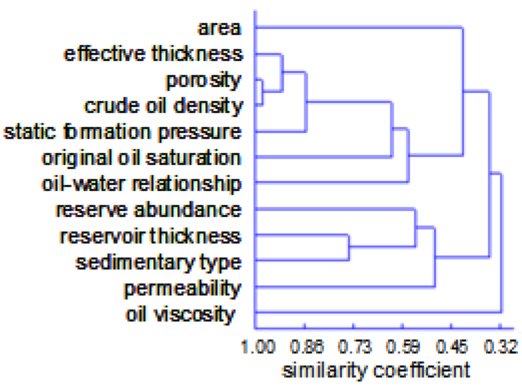

Fig 2 the spectrum diagram of clustering results of the geological parameter of Putaohua reservoir

As can be seen from Fig 2, the correlation coefficient of porosity and crude oil density is the largest, porosity and effective thickness take second place, so eliminate the crude oil density. Compare effective thickness with initial formation pressure, eliminate the initial formation pressure. Compare reservoir thickness with sedimentary type, eliminate the reservoir thickness, and so on. At last, we select six geological parameters in combination with the geological significance of each parameter, they are effective thickness, porosity, permeability, original oil saturation, sedimentary type and combination of oil-water relationship, we will use them to make the comprehensive reservoir evaluation of Putaohau blocks.

Adopting the principal component analysis method to make sure the comprehensive evaluation index, establishing the chart of the cumulative probability curve (Fig 3), and finally we make the evaluation of Putaohua reservoir according to its classifications.

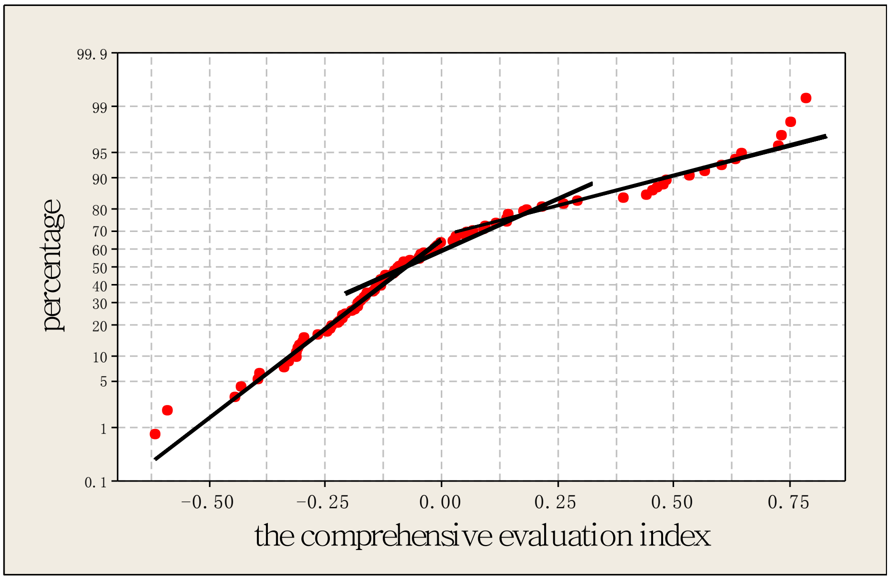

Fig 3 the cumulative probability curve of the principal component analysis

The average permeability, effective thickness and porosity of reservoir Ⅰ are high, it is mainly pure oil layer and oil-water layer, the property of reservoir Ⅰ is good. As a whole, it is the most favorable blocks for development.

Compared with reservoir Ⅰ, the effective thickness, average permeability and porosity of reservoir Ⅱ is poorer, it is mainly oil-water layer, as a whole, its development level is lower than block Ⅰ ,though it is the most widely distributed.

The porosity of reservoir Ⅲ is the poorest, the oil-water relationship is more complex, therefore, compared with reservoir Ⅰ and reservoir Ⅱ, the property and development effect of reservoir Ⅲ is the poorest[4].

V. CONCLUSION

According to the actual data of the producing well of development blocks of the eighth oil recovery factory in Daqing oil fields, by optimizing parameters, adopting the principal component analysis method assisted by the cumulative probability curve method to make the comprehensive reservoir evaluation of Putaohau blocks. It is accord with the actual development situation, at the same time, it has certain guiding significance for the formulation and adjustment of the development plan.

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