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Study on comprehensive quantitative classification and evaluation method of development index

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Abstract: The evaluation of development index is an important basis for the exploitation of oil, and the design and adjustment of oilfield development program. In view of the single factor evaluation results not only the characteristics of the development index, development index of comprehensive quantitative evaluation method is studied. This paper uses grey system theory, principal component analysis and analytic hierarchy process to determine the weight coefficient method. And the periphery of Daqing Putaohua reservoir developed blocks were evaluated comprehensively and quantitatively in the development index of classification, The results of the three evaluation methods of classification have good consistency, avoiding the single evaluation results is not only, in favour of the classification and evaluation of block.

Key words: *Development index; Comprehensive quantitative assessment; The grey system; Principal component analysis; Analytic hierarchy*

The evaluation of a condition of oil field exploitation, the planning of oil field development and the design and adjustment of oil field development plan are all based on the change characteristics of oilfield development index. Therefore, the evaluation of oilfield development indexes plays an important role in oilfield development work. Using different parameters to classify the blocks, the results are often different, only by the single factor of block classification can not fully reflect the nature of the block. At the same time, it is easy to appear by using single factor classification results are not the only, At the same time, using the single factor classification is prone to not the only classification results, the evaluation results are often not very accurate, when the parameter is large, and prone to conflicts. Therefore, in this paper, by means of grey correlation, principal component analysis and hierarchical analysis, three kinds of comprehensive quantitative classification methods to classify the development indexes.

I. DEVELOPMENT INDICATORS COMPREHENSIVE QUANTITATIVE ASSESSMENT METHOD

Development index is in the development of comprehensive quantitative evaluating parameters selection, the process of comprehensive evaluation of multiple factors, end up with a comprehensive evaluation index, and classifying block according to it.

$$\mathrm{B}EI = \sum_{i=1}^{n} a_i X_i \qquad (1\text{-}1)$$

Above formula: BEI-Block comprehensive evaluation index;

X_i - block evaluation paramete;

a_i - block evaluation parameters of weight coefficient;

n - The number of block evaluation parameters.

From formula (1, 1) can be seen that as the known parameters, only weight coefficient is unknown, only requires the weight coefficient, then the comprehensive evaluation index BEI can be calculated.

II. THE DETERMINATION OF WEIGHT COEFFICIENT

Because of the weight coefficient is the only one unknown, it is very important for the determination of value [1]. In this paper, the grey system theory method, analytic hierarchy process and principal component analysis to determine the block weight coefficient in the process of comprehensive quantitative evaluation research [2-4].

(1)The method of grey system theory

The grey system theory is the main method to seek the relationship between the various factors of the system by using gray correlation analysis, to find out the influence factors of the evaluation indexes, so as to grasp the main characteristics of things. In fact it is a develop trend of a system of quantitative description and comparison, it is selected, including the steps of parent sequence and sequence correlation coefficient, correlation degree and weight coefficient calculation.

①The selected parent and subsidiary sequence

To from the analysis on the internal structure of the data information judged and affecting factors of the relationship between things, have to use a certain quantitative index quantitative reflected by judging the nature of things. The number of indicators according to a certain sequence, called mother sequence correlation analysis, denoted as

$$\{X_t^{(0)}(0)\},\qquad (t=1,2,\dots,n) \tag{2-1}$$

The sub sequence is an ordered data, determining or influencing sub evaluation factors of the nature of things, considering there are m sub factors of main factors, so there is a sub sequence

$$\{X_t^{(0)}(i)\}\qquad (t=1,2,\dots,n;\qquad i=1,2,\dots,m) \tag{2-2}$$

②The original data transform

After the parent and subsidiary sequence be confirmed, there can be composed of the following original data matrix

$$X^{(0)} = \begin{bmatrix} X_1^{(0)}(0) & X_1^{(0)}(1) & \cdots & X_1^{(0)}(m) \\ X_2^{(0)}(0) & X_2^{(0)}(1) & \cdots & X_2^{(0)}(m) \\ \vdots & \vdots & \ddots & \vdots \\ X_n^{(0)}(0) & X_n^{(0)}(1) & \cdots & X_n^{(0)}(m) \end{bmatrix} \tag{2-3}$$

Because of the physical meaning of each factor in the system is different, dimension are also different in general. Therefore, the original data need to dimensionless. Generally use the initialization and homogenization of two methods.

③The correlation coefficient and correlation degree

If the mother sequence of the transformation is {Xt(1)(0)}, the sub sequence is {Xt(1)(i)}, at the same observation time, the absolute difference between the sub factors and the mother is

$$\Delta_t(i,0) = |X_t^{(1)}(i) - X_t^{(1)}(0)| \tag{2-4}$$

At the same observation time, the maximum value of the absolute difference between the sub factors and the mother factors is

$$\Delta_{\max} = \max_t \max_i |X_t^{(1)}(i) - X_t^{(1)}(0)| \tag{2-5}$$

At the same observation time, the minimum value of the absolute difference between the sub factors and the mother factors is

$$\Delta_{\max} = \max_t \max_i |X_t^{(1)}(i) - X_t^{(1)}(0)| \tag{2-6}$$

The correlation coefficient $L_t(i, 0)$ of the sequence of the mother and the child is

$$L_t(i,0) = \frac{\Delta_{\min} + \rho\Delta_{\max}}{\Delta_t(i,0) + \rho\Delta_{\max}} \tag{2-7}$$

The letter ρ in above formula is resolution coefficient, its role is to weaken the maximum absolute difference value is too large and distortion effects, improve each correlation coefficient significant difference, $\rho \in (0, 1)$.

The correlation degree between the sub factors to the parent $r_{i,0}$ is

$$r_{i,0} = \frac{1}{n}\sum_i^n L_t(i,0) \tag{2-8}$$

④The determination of weight coefficient

After calculating the degree of correlation, the a_i of weight coefficient can be obtained by normalizing treatment.

$$\alpha_i = \frac{r_i}{\sum_{i=1}^{n} r_i} \tag{2-9}$$

1）The analytic hierarchy proces

The application of mathematical tools with operational thought will decompose the complex problem into various factors, and by the domination relationship grouping form a hierarchy. To determine the relative importance of each factor, a decision-making method of thinking is determined by the interaction between the integrated factors and the role of the system. Using analytic hierarchy process to solve practical problems, the key is to decompose a complex system into several levels or subsystems according to the specific research problems, Establish the hierarchy structure, construct the judgment matrix, and then determine the relative importance of each factor in the system (weight coefficient).

①Hierarchical structure analysis

A complex system can always be expressed as a feedback hierarchy. Based on the structure of the system, the structure of a complex system can be decomposed into a hierarchical structure and a circular hierarchical structure [5].

②Build judgments matrix

According to the principle of hierarchy analysis, the establishment of a hierarchy of comprehensive quantitative index evaluation system. According to different parameter and the layer to build pairs of comparative judgment matrix, and construct the super matrix W.

$$W = \begin{vmatrix} w_{11} & w_{12} & \cdots & w_{1N} \\ w_{21} & w_{22} & \cdots & w_{2N} \\ \vdots & \vdots & \vdots & \vdots \\ w_{N1} & w_{N2} & \cdots & w_{NN} \end{vmatrix} \quad (2\text{-}10)$$

Type of w_{ij} for comparing two sort of relative weights （i , j =1, 2, …, N）

③The calculation of weight coefficient

The calculation of the weight coefficient, is actually solving the matrix W limit of scheduling problems. Because of the comprehensive quantitative evaluation index system is the development of a circular structure, the formula (2-10) can be changed into

$$W = \begin{vmatrix} w_{11} & 0 & 0 & \cdots & 0 & w_{1N} \\ w_{21} & w_{22} & 0 & \cdots & 0 & 0 \\ 0 & w_{32} & w_{33} & \cdots & 0 & 0 \\ \vdots & & & & & \vdots \\ 0 & 0 & 0 & \cdots & w_{NN-1} & w_{NN} \end{vmatrix} \quad (2\text{-}11)$$

When the level of internal independence, the formula (2-11) can be changed into

$$W = \begin{vmatrix} 0 & 0 & 0 & \cdots & 0 & w_{1N} \\ w_{21} & 0 & 0 & \cdots & 0 & 0 \\ 0 & w_{32} & 0 & \cdots & 0 & 0 \\ \vdots & & & & & \vdots \\ 0 & 0 & 0 & \cdots & w_{NN-1} & 0 \end{vmatrix} \quad (2\text{-}12)$$

The formula (2-12) take the limit can get the weight coefficient.

1）principal component analysis

A multivariate analysis method, these variables are often not independent, there is a complex relationship, and bring certain difficulty to the comprehensive analysis. To simplify the analysis of the objective, a large number of variables as linear combinations, merged into several major new variables, principal component, so as a small number of principal components to representing the main information of geological variables change. The data can be greatly reduced, and the correlation between the original data and the internal causes of the data are also reproduced. It includes the calculation of the mean and covariance, correlation coefficient matrix and the calculation of eigenvalues and corresponding eigenvectors, and the calculation steps of weight coefficient.

Equipped with N samples, each sample observed the P index, can be expressed as

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1p} \\ x_{21} & x_{22} & \cdots & x_{2p} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{np} \end{bmatrix} \quad (2\text{-}13)$$

The formula (2-13) can be regarded as a random variable of P dimensional normal distribution.

For the P dimensional normal distribution of random variables X= $(x_1, x_2, \ldots, x_p)^T$, he distribution of sample points in P dimensional space is a P dimensional ellipsoid, principal component analysis is through the orthogonal transformation, making the sample points in the direction of F_1 have maximum variance . The variance of the variance on the F_2 perpendicular to the F_1 was second; and the variance of the variance on the F_3 perpendicular to the F_1 and the F_2 was third. . . . . . Until the F_{p-1}, the last vertical and F1 , F2 , F3 , … Fp-1 , determination of F_p.

①Calculating the mean and covariance of each index, and then making it standardization.

$$\overline{x_i} = \frac{1}{N}\sum_{k=1}^{N} x_{ik} \qquad (i=1, 2, \ldots, P) \qquad (2\text{-}14)$$

$$S_{ij} = \frac{1}{N}\sum_{k=1}^{N} (x_{ik} - \overline{x_i})(x_{jk} - \overline{x_i}) \qquad (i, j = 1, 2, \ldots, P) \qquad (2\text{-}15)$$

$$x'_{ij} = \frac{x_{jk} - \overline{x_i}}{\sqrt{S_{ij}}} \qquad (2\text{-}16)$$

②Calculating the autocorrelation coefficient matrix R = $\mathbf{r_{ij}}$

Of which

$$r_{ij} = \frac{S_{ij}}{\sqrt{S_{ii} S_{jj}}} \qquad (i, j=1, 2, \ldots, P) \qquad (2\text{-}17)$$

③For the characteristics of self correlation coefficient matrix R value $\lambda_1 \geq \lambda_2 \geq \ldots \lambda_P$ and its corresponding characteristic vector U_1 , U_2 , …U_P

Of which

$$U_i = (u_{1i}\ u_{2i} \ldots u_{pi})^T \qquad (2\text{-}18)$$

④The calculation of the weighted coefficient

$$a_j = \frac{1}{P}\sum_{i=1}^{P} u_{ij}\sqrt{\lambda_j} \qquad (i=1, 2, \ldots P) \quad (j=1, 2, \ldots m) \qquad (2\text{-}19)$$

Where a_j is the weight coefficient of several principal components, rather than the weight coefficient of evaluation parameters. Therefore, by type (2-19) to calculate the comprehensive evaluation index BEI, turn it into

$$REI = \sum_{i=1}^{m} a_i f_i \qquad (m < P) \qquad (2\text{-}20)$$

among

$$f_i = \frac{U_i^T x}{\sqrt{\lambda_i}} \qquad (i=1, 2, \ldots, P) \qquad (2\text{-}21)$$

f_1, f_2, …, f_P , respectively, the first principal component of X, the second principal component, . . . *P* principal component.

III. APPLICATION OF COMPREHENSIVE QUANTITATIVE EVALUATION METHOD OF DEVELOPMENT INDEX.

Selecting the peripheral oil fields of Daqing putaohua reservoir developed blocks as the research object. Parameters affect the effectiveness of oil field development has a lot of, through different blocks the effect of development of parameters to classify, Analyzing block what plays a main role in the development of the parameters, so as to provide reference basis for oilfield development comprehensive evaluation. In this paper, the single well daily oil production, comprehensive water content, initial oil production intensity, initial oil production speed and oil recovery efficiency were used to evaluate the development of the block. Calculate the comprehensive evaluation index of each development block, set up the classification chart of evaluation index.

Establish a specific classification boundaries in the choice of parameters, if only to the samples, that is, the evaluation indexes were classified, not real reflect these sample points of the overall distribution. Therefore, the cumulative probability method to carry on the classification. The cumulative probability of different sample points not only can reflect the distribution of the data points in the sample, but also can classify the samples with different cumulative probability quantitatively.

Table 3-1 The parameter evaluation weight coefficient of block development in the development of the putaohua oil layer

Parameter	Grey correlation	Analytical hierarchy process
Daily single well oil production	0. 194	0. 2156
Comprehensive water content	0. 18	0. 13
The intensity of the early oil production	0. 2330	0. 2694
In the early oil production speed	0. 2010	0. 2007
Recovery prediction	0. 2	0. 19

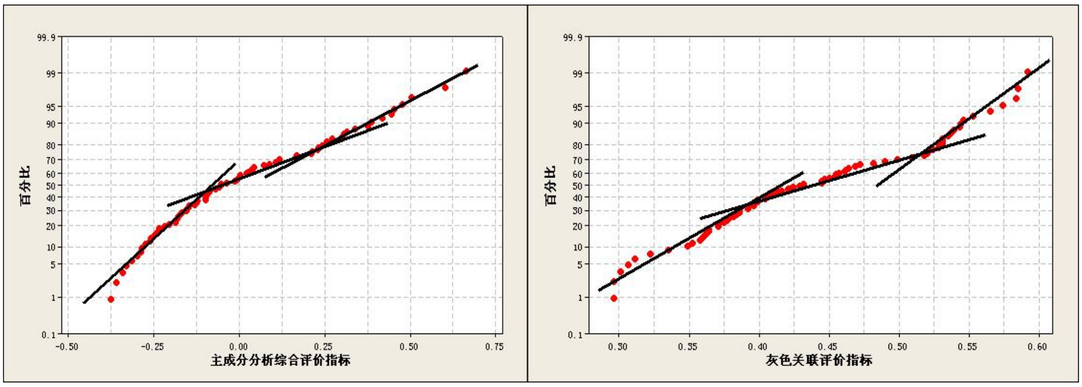

Figure 3-1 The grey correlation cumulative probability curves of development parameter

Figure 3-2 development parameter principal component analysis cumulative probability line

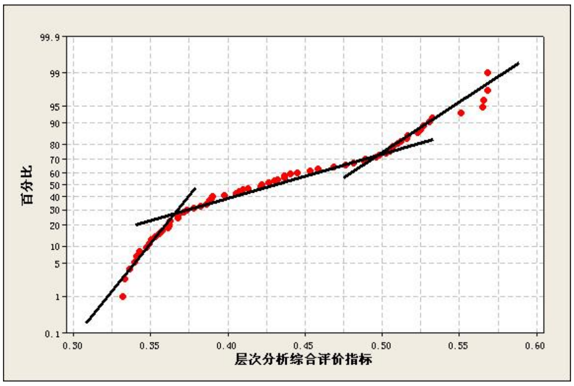

Figure 3-3 development parameter level analysis cumulative probability curve

Table 3-2 putaohua reservoir parameters have been development blocks developed multi-factor classification boundaries

Category	Ⅰ	Ⅱ	Ⅲ
Scope of grey correlation	＞0. 536	0. 359～0. 536	＜0. 359
Scope of principal component analysis	＞0. 208	-0. 182～0. 208	＜-0. 182
Scope of hierarchical analysis	＞0. 4887	0. 3491～0. 4887	＜0. 3491

Table 3-3 parameter synthesis classification of block development in the development of putaohua oil layer

Block	Grey correlation	Principal component analysis	Analytical hierarchy process	General classification
Fang 24	I	I	I	I
Xu 48－40	II	II	I	II
Xu 62－34	II	II	II	II
Xu 3	II	II	II	II
Xu 18	I	I	I	I
Xu 20-30	I	I	I	I
Xu 68-18	II	II	III	II
Xu 78-24	II	II	II	II
Xu 28	III	III	III	III
Xu 21	II	III	II	II
Xu 4	II	II	II	II
Xu 22	III	III	III	III
Zhao 405	II	II	I	II
Fang 139	II	II	II	II
Zhou 56	III	II	II	II
Zhou 53	II	II	II	II
Zhao 49-38	II	II	II	II
Zhao 5	III	III	III	III
Zhou 6	II	III	III	III
Zhou 57—F1	II	II	II	II
Fang 139(2008)	II	II	II	II
Zhou 191	I	I	I	II
Zhao 291（1998）	II	II	II	II
Zhao 291	I	I	I	I
Tai 5	I	I	I	I
Zhao 292	III	III	III	III
Zhao 39	III	III	III	II
Song Fangtun main body	I	I	I	I

By setting up the comprehensive evaluation index classification boundary, the different blocks of the grape flower oil layer were classified by three methods: gray correlation, hierarchical analysis and principal component analysis, and make a comprehensive classification. If the difference between the three classification results, then choose a relatively large proportion of that as a result of the comprehensive classification. Such as Xu 21 block of grey correlation, principal component analysis, analytic hierarchy classification results respectively were Ⅱ, Ⅲ, Ⅱ, as the result of the comprehensive classification Ⅱ.

IV. CONCLUSION

The key of the comprehensive quantitative classification and evaluation method is to determine the weight coefficient of each parameter. This paper uses three kinds of method to determine weights, the boundaries of the comprehensive evaluation index is clear to solve the often appears in the single factor evaluation process of reservoir evaluation results cross each other and not only, which conducive to correct classification and evaluation on the block. Although the evaluation indexes of the three methods are different, they have the same trend, which can prove the validity and reliability of the quantitative evaluation method, which can be used to guide the rational development of oil field. The method in this paper is also applicable to the classification and evaluation of other development indicators.

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