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Evaluation of unconventional hydrocarbon resources potential and mining benefit based on gray evaluation model

Yu Hu[1], Rui Lv[2], Zhikun Wei[3], Jie Zuo[3], Tingshan Zhang[1], Zhipeng Huan[1], Yiqiao Xu[4], Haoping Li[2]

Abstract. With the increasing exploration difficulty of oil and gas fields, good exploration benefits could not only save a lot of costs for enterprises, but also provide decision-making basis for oil and gas field managers. Therefore, the exploration benefits of oil and gas fields are particularly important. Therefore, the index system of oil and gas exploration benefit was constructed, the original data of exploration efficiency index of a certain oil and gas field for three consecutive years were adopted, and the indexes were normalized. The gray correlation degree was taken as the evaluation standard, conducting a comprehensive evaluation on the exploration efficiency for three consecutive years, and making an analysis of the results with features of comprehensive analysis, simple method and easy to calculate.

Key words. Oil and gas, Benefit evaluation, Gray evaluation, Relational degree.

1. Introduction

Over the years, many proved geological reserves obtained through exploration work have not been used by many oil and gas exploration and development work of China's oil industry enterprises after exploration, resulting in a large backlog of exploration reserves and a shortage of recoverable reserves contradictions. Although

[1]State Key Laboratory of Oil and Gas Reservoir Geology and Exploitation, Southwest Petroleum University, Chengdu 610500, Sichuan, China
[2]Petrochina Tarim Oil field Company, Korla 841000, Xinjiang, China
[3]Oil Production Plant No.1, Changqing Oilfield, Yanan 716000, Shanxi, China
[4]7. Petrochina Southwest Oil&Gasfield Company, Chengdu 610000, Sichuan, China

there are many technical reasons for such contradictions, the inefficient development of proved geologic reserves submitted by exploration is one of the very important reasons. For example, the unrepenthed reserves of PetroChina Company Limited (Petro China) has a large part of inefficient, inefficient and even ineffective reserves) in 2002, and recently the available oil and gas reserves have dropped more than the past. For this reason, it is necessary for oil industry enterprises to strengthen the economic judgment and value assessment of proven reserves in the oil and gas exploration stage according to the international oil and gas prices and business operation mechanism. However, due to the stage of exploration and evaluation, output, development investment and production cost, it is difficult to obtain comprehensive and real data for the parameters, which brings great difficulties to the exploration economic evaluation or the value assessment. The technical and economic evaluation of oil and gas reserves exploration over the years has been a very troublesome problem for the oil industry enterprises in our country.

At present, some large western oil companies are generally based on "effective method" accounting standards in the management of oil and gas reserves of commercial oil and gas (oil and gas) estimates, using relatively simple algorithms and criteria, that is, regardless of the previous investment, converting the initial output of oil and gas fields into sales revenue, after minus oil development and production costs, making comparison and judgment with sales price. In our country, due to some production units of oil companies are unmatchable with the financial data management and the limitation of the evaluation method itself, it has brought some confusion and inconvenience to the commercial oil and gas flow, the judgment of benefit reserves and the management of production. In 1992, The State Oil and Gas Reserves Commission has formulated some fixed criteria for the division of factors that have not taken into account changes in crude oil prices. Some experts and scholars, such as Chen Yuanqian, have studied preliminary empirical prediction formulas for economically recoverable reserves and yields. Luo Dongkun put forward commercial oil and gas by using the basic principles of cash flow. At the same time, the calculation model of economic evaluation of oil and gas resources is established on the basis of commercial oil and gas flow calculation method. However, the above research work can not be applied to the actual management of petroleum enterprises at present. Liu Shengmeng et al explored the calculation model of "single well economic output" and the relationship between drilling investment and depth in the early stage of petroleum development in Sinopec Henan Oilfield. The author of this paper also put forward the concept and algorithm of "benefit reserve" of PetroChina. At the same time, the criteria for determining the profitability of various types of oil and gas reserves are discussed in the standards for the management of oil and gas reserves. The so-called benefit reserves refer to the failure to accurately calculate the cash flow in the early stages of oilfield exploration and development, but it can initially determine the economic benefits and Usable oil and gas reserves.

Based on the analysis of the unused oil and gas reserves of PetroChina from 2001 to 2002, this paper established a preliminary evaluation method and index system of oil and gas reserves exploration feasibility, discussed the evaluation index of exploration feasibility and the parameters of reservoir reserves and depth Quantitative relationship between oilfields, and made a classification research on the economy and discriminant criteria of some unused reserves by taking CNPC Jilin Oilfield Branch as an example.

2. Oil and gas reserves management and exploration feasibility evaluation method

2.1. Basic Principle

The feasibility of an oil and gas exploration and production reserve exploration and the availability of reserve reserves generally require the calculation and study of indicators for technical and economic evaluation or value assessment. However, due to the inaccessibility of exploration stages, various production data and other parameters in the exploration phase, the technical and economic evaluation of exploration investment can not be carried out. In response to this problem, we apply the basic principles of input-output, make in-depth analysis and the establishment of relevant indicators and measurement methods by using the well-known commercial oil and gas flow method. According to the research, although the evaluation of oil and gas "benefit reserves" is determined by many subjective and objective factors, the more representative of these subjective and objective factors are mainly affected by the following four subjective and objective factors: oil and gas price, oil and gas reserves Scale, stable average oil and gas production, and reservoir depth. These factors will largely affect the investment in oilfield development, operating costs, production, sales revenue, thus affecting the economic value of reserves development. Based on the enlightenment of the above basic theories and research work ideas, this paper presents the concept of stable economic output limit, the minimum economic reserves of oil and gas zones, the minimum and minimum abundance limits of oil reserves, and puts forward the petroleum enterprise reserves management model and exploration feasible Sex concept.

2.2. Evaluation index and calculation method

According to the actual amount of investment in exploration and development as well as the related workload of the oil and gas field, the single-well apportionment of investment and production and operation costs per unit time can be analyzed and at the same time, according to the production of the same type of oil and gas, we can further measure the single-well unit sales revenue and various related costs, and further based on the basic principles of balance of payments to establish mathematical equations:

$$Q_e \times R_c \times P_{oil} = C_{pw} + C_o + O_c \,. \tag{1}$$

Where: Q_e is the economic output limit, R_c is the rate of commodity, P_{oil} is oil (gas) prices, C_{pw} is single-well apportionment of investment, C_o is operating costs,

O_c is for other costs. Thus:

$$Q_e = \frac{C_{pw} + C_o + O_c}{R_c \times P_{oil}} . \tag{2}$$

$$C_{pw} = \frac{E_C + D_C}{P_{pw} \times N_w} . \tag{3}$$

Where: E_C is for the exploration and investment, D_C is for the development and investment, P_{pw} is for the single-well production cycle, N_w is the number of wells that year, and we have:

$$C_{cpw} = \frac{C_o}{D_Y \times N_w} . \tag{4}$$

Where: C_{cpw} is for a single well operating costs, D_Y is for the current production days. In fact, the operating costs include direct operating costs and indirect operating costs. If the operating costs are divided into two parts, the mathematical model for calculating the ultimate output will become a quadratic equation, which will inevitably bring some difficulties to the calculation. To simplify the point of view, do not separate the operating costs. Other expenses include sales tax and surcharges, sales fees, management fees, resource taxes, royalties and other related expenses, can be determined by a detailed calculation method or the ratio method, these two measurement methods make our economic limit of yield and two Algorithm, namely: detailed calculation method (formula (5)) and ratio method (formula (6)):

$$O_c = \frac{A_{oil} \times O_{oil}}{Y_{oil} \times D_Y \times N_w} . \tag{5}$$

Where: A_{oil} is the oil (gas) zone capacity, O_{oil} is other costs for the oilfield, Y_{oil} is the total output of the oil field. The formula for calculating the ultimate yield at this time is formula (2).

$$O_c = R \times R_c \times P_{oil} . \tag{6}$$

Where: R is the ratio. We can get the following formula:

$$Q_e = \frac{C_{pw} + C_{cpw}}{R_c \times P_{oil} \times (1 - R_C)} . \tag{7}$$

Where: R_C is the rate. In general, the ratio method is often used in calculating the lower yield limit for exploration of oil and gas zones. By calculating the economic output limit of reserves, we can further get the economic scale of the lowest reserves of related oil and gas regions:

$$S_r = \frac{Q_e \times P_{pw} \times N_w}{R_a \times C_r} . \tag{8}$$

Where: S_r is the size of the economy reserves, R_a is recovery factor, C_r is the reserve factor. According to the level of technology reserves, C_r are given specifically, of which proven geological reserves of 1, controlled and predicted geological reserves between $0 \sim 1$.

$$S_{rd} = \frac{S_r}{S_{area}}\,. \tag{9}$$

Where: S_{rd} is the reserves of abundance; S_{area} is the oil area. If the relevant single-well data are complete, the calculation method we proposed above is not so complicated, because it is not necessarily related to the program of investment and development zone to determine the lower limit of production yield and the lower limit of reserve scale for determining the feasibility of oil and gas exploration exploration. If there is a test development block in the oil zone, it is not actually necessary to obtain the actual parameters such as single well investment and cost directly by calculating the relevant parameters of the whole oil zone. In this way, the calculation method we have established above will be simplified correspondingly.

3. Gray evaluation model

3.1. Standardization of the Original Data

The gray model evaluation index system established in this paper are both "very large" indexes. The data of the evaluation indexes can be treated with the extreme value method without dimension. The scale conversion of this method will not bring about the change of the proportional difference of the result. The formula for the very large index [6] is as follows:

$$X^i_{jt} = \frac{x^i_{jt} - \min x^i_{jt}}{\max x^i_{jt} - \min x^i_{jt}}, \quad (j = 1, 2, \cdots, n_i)\,. \tag{10}$$

Where, j is the original data of the evaluation of the city t corresponding to j indicator in the second indicator of A_i. x^i_{jt} is the data before standardization, x^i_{jt} is the data after the standardized, the processed data X^i_{jt} are both standard data of a very large dimension and a non-dimensional standard.

3.2. Single-level comprehensive evaluation

The first step: deal with the first level indicators in the evaluation system.

Use the matrix D_i to represent the first level indicator of i:

Reference optimal index means that selecting the maximum of the second-level indicators in the first-level indicators in t research object, making them as a matrix $D_i^{\max}$.

Calculate the correlation coefficient and construct the evaluation matrix.Grey relational analysis measures the degree of association according to the similarities or dissimilarities between the development trends of the factors.If the correlation between the two factors is high, the trend of the two factors is consistent; Reason, if the correlation coefficient is low, the two factors are less synchronous changes.Analysis of the correlation coefficient, you need to analyze the correlation between the individual indicators.If the optimal indicator set.

$$D_i^{\max} = [d_1^i, d_2^i, \cdots, d_{n_i}^i]^T . \tag{11}$$

As reference data,

$$D_i^t = \begin{bmatrix} d_{1t}^i & d_{2t}^i & \cdots & d_{n_i t}^i \end{bmatrix}^T, i = 1, 2, \cdots, n . \tag{12}$$

As the data to be compared, the correlation coefficient between the j index of the t study subject and the j index, the reference index set is:

$$\zeta_{jt}^i = \frac{\min\limits_k \left| d_k^i - d_{kt}^i \right| + \rho \max\limits_k \left| d_k^i - d_{kt}^i \right|}{\left| d_j^i - d_{jt}^i \right| + \rho \max\limits_k \left| d_k^i - d_{kt}^i \right|} . \tag{13}$$

Where, $i = 1, 2, \cdots, nk, j = 1, 2, \cdots, n_i.\rho$ is the resolution coefficient, general take $\rho = 0.5$, so we can draw the correlation coefficient ζ_{jt}^i between the indicators, and constitute the evaluation matrix B_i, so we put an indicator matrix D_i into the evaluation matrix B_i .

Calculate the weight of the second-level index, choose the entropy weight method [7] to deal with the weight of the index system, and determine the weight according to the size of the observed value information of each index. The calculation method is as follows: Entropy value e_j^i is used to represent the decision information of each index:

$$e_j^i = -\frac{\sum\limits_{k=1}^{t} X_{jk}^i \ln X_{jk}^i}{\ln t} . \tag{14}$$

Then by the weight formula:

$$W_j^i = \frac{1 - e_j^i}{\sum\limits_{j=1}^{t} (1 - e_j^i)} . \tag{15}$$

We can calculate the two-level index weight vector W_i

Calculate the evaluation results matrix of the first-level indicators

$$R_i = (W_i)^T B_i . \tag{16}$$

3.3. Establish a first-level index matrix C and its weight vector W

(1) Middle layer evaluation matrix .The middle layer evaluation matrix R consists of $R_i.$, i=1, 2, $\cdots$, n, $R = \begin{bmatrix} R_1 & R_2 & \cdots & R_n \end{bmatrix}^T$, select the maximum value of the matrix $R_{\max}$ to form the optimal set of indicators.

(2) Calculate the first-level index evaluation matrix C by the formula (2) .

(3) Calculate the first-order weight vector W by the formula (3) (4). Finally, we

can get the matrix F of evaluation results of the competitiveness of city cultural tourism in all prefecture-level cities in Shanxi Province:

$$F = W^T * C. \tag{17}$$

4. Experimental Analysis

4.1. Determine the decision matrix

In the evaluation of oil and gas exploration benefits, in this paper, in addition to the cost of space exploration rate and the empty exploration rate of seismic profile unit (smaller is better), others can be regarded as indicators of efficiency (the bigger the better). Therefore, we can get the optimal index set Shu (reference column) as shown in Table 1.

Table 1. Analyzes of the decision matrix

Indicator	Contestant year			
	Year of 2013	Year of 2014	Year of 2015	Reference Year
Air - shot rate of seismic section	18	2l	20	18
Seismic record pass rate	85	82	80	85
Earthquake records excellent product rate	60	55	50	60
Seismic section pass rate	88	85	90	90
Seismic Profile Quality Product Rate	63	60	60	63
Trap drilling success rate	75	72	80	80
Exploration drilling success rate	92	88	90	92
Average team year efficiency	1100	1300	1200	1300
Field production time rate	75	73	80	80
Field direct production time rate	68	65	60	68
Unit proven reserves exploration costs	1.8	1.4	1.5	1.4
Single Well Control Geological Reserves	7	6	6	7

4.2. Dimensionless Processing of Decision Matrix

Using equation (1), equation (2) of the 12 indicators of non-dimensional treatment, the results are shown in Table 2.

Table 2. The value of each dimensionless treatment results table

Indicator	Contestant year			
	Year of 2013	Year of 2014	Year of 2015	Reference Year
Seismic profile of empty gun rate	1	0	0.33	1
Seismic record pass rate	1	0.4	0	1
Earthquake records excellent product rate	1	0.5	0	1
Seismic section pass rate	0.6	0	1	1
Seismic Profile Quality Product Rate	1	O	0	1
Trap drilling success rate	0.38	0	1	1
Exploration drilling success rate	1	0	0.5	1
Average team efficiency	0	1	0.5	1
Field production time rate	0.29	0	1	1
Field direct production time rate	1	0.63	0	1
Unit proven reserves exploration costs	0	1	0.75	1
Single Well Control Geological Reserves	7	6	6	7

4.3. Calculate the correlation coefficient

From (3), we can calculate the correlation coefficient , , . .The calculation results are shown in Table 3.

Table 3. Association coefficient table

Indicator	Association coefficient $\rho = 0.5$		
	ξ_1	ξ_2	ξ_3
Seismic profile of empty gun rate	1	0.33	0.43
Seismic record pass rate	1	0.45	0.33
Earthquake records excellent product rate	1	0.5	0.33
Seismic section pass rate	0.56	0.33	1
Seismic Profile Quality Product Rate	1	0.33	0.33
Trap drilling success rate	0.44	0.33	1
Exploration drilling success rate	1	0.33	0.5
Average team efficiency	0.33	1	0.5
Field production time rate	0.41	0.33	1
Field direct production time rate	1	0.6	0.33
Unit proven reserves exploration costs	0.33	1	0.67
Single Well Control Geological Reserves	1	0.33	0.3

5. Conclusion

(1) As a result, we know from the results $r_1 > r_3 > r_2$ that the exploration benefit in 2013 is better than that in 2015 and the exploration benefit in 2015 is better than that in 2014.

(2) From the correlation coefficient Table 4, it can be seen that in 2014, except for the average fleet efficiency and proved reserves per unit proved to be better than those in 2013 and 2015, all the other indicators were not very satisfactory. This is the reason that oil and gas exploration The benefit is the worst reason. In addition to the seismic section qualification rate in 2015, the success rate of trapping drilling and the field production time rate are better than those in other years, other indicators have room for improvement. 2013 did not do well in terms of average fleet efficiency, unit proved reserves exploration and so on.

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References

[1] L. R. Stephygraph, N. Arunkumar: *Brain-actuated wireless mobile robot control through an adaptive human-machine interface*, Advances in Intelligent Systems and Computing, *397* (2016), 537–549.

[2] N. Arunkumar, V. Venkataraman, T. Lavanya: *A moving window approximate entropy based neural network for detecting the onset of epileptic seizures*, International Journal of Applied Engineering Research, *8* (2013) No. 15, 1841–1847.

[3] J. W. Chan, Y. Y. Zhang, and K. E. Uhrich: *Amphiphilic Macromolecule Self-Assembled Monolayers Suppress Smooth Muscle Cell Proliferation*, Bioconjugate Chemistry, *26* (2015), No. 7, 1359–1369.

[4] Y. J. Zhao, L. Wang, H. J. Wang, and C. J. Liu: *Minimum Rate Sampling and Spectrum Blind Reconstruction in Random Equivalent Sampling.* Circuits Systems and Signal Processing, *34* (2015), No. 8, 2667–2680.

[5] S. L. Fernandes, V. P. Gurupur, N. R. Sunder, N. Arunkumar N., S. Kadry: *A novel nonintrusive decision support approach for heart rate measurement* (2017) Pattern Recognition Letters. https://doi.org/10.1016/j.patrec.2017.07.002

[6] N. Arunkumar, K. Ramkumar, V. Venkatraman, E. Abdulhay, S. L. Fernandes, S. Kadr, & S. Segal: *Classification of focal and non focal EEG using entropies.* Pattern Recognition Letters, *94* (2017), 112–117

[7] W. S. Pan, S. Z. Chen, Z. Y. Feng.: *Investigating the Collaborative Intention and Semantic Structure among Co-occurring Tags using Graph Theory.* International Enterprise Distributed Object Computing Conference, IEEE, Beijing, (2012), 190–195.

[8] Y. Y. Zhang, Q. Li, W. J. Welsh, P. V. Moghe, and K. E. Uhrich: *Micellar and Structural Stability of Nanoscale Amphiphilic Polymers: Implications for Anti-atherosclerotic Bioactivity*, Biomaterials, *84* (2016), 230–240.

[9] L. R;Stephygraph, N. Arunkumar, V. Venkatraman: *Wireless mobile robot control through human machine interface using brain signals* 2015 International Conference on Smart Technologies and Management for Computing, Communication, Controls, Energy and Materials, ICSTM 2015 - Proceedings, (2015), art. No. 7225484, 596–603.

[10] N. Arunkumar, V. S. Balaji, S. Ramesh, Natarajan, V. R. Likhita, S. Sundari: *Automatic detection of epileptic seizures using independent component analysis algorithm* IEEE-International Conference on Advances in Engineering, Science and Management, ICAESM-2012, (2012), art. No. 6215903, 542–544.

[11] Y. Du, Y. Z. Chen, Y. Y. Zhuang, C. Zhu, F. J. Tang, J. Huang: *Probing Nanostrain via a Mechanically Designed Optical Fiber Interferometer.* IEEE Photonics Technology Letters, *29* (2017), 1348–1351.

[12] W. S. Pan, S. Z. Chen, Z. Y. Feng: *Automatic Clustering of Social Tag using Community Detection.* Applied Mathematics & Information Sciences, *7* (2013), No. 2, 675–681.

[13] Y. Y. Zhang, E. Mintzer, and K. E. Uhrich: *Synthesis and Characterization of PEGylated Bolaamphiphiles with Enhanced Retention in Liposomes*, Journal of Colloid and Interface Science, *482* (2016), 19–26.

[14] N. Arunkumar, K. M. Mohamed Sirajudeen: *Approximate Entropy based ayurvedic pulse diagnosis for diabetics - A case study* TISC 2011 - Proceedings of the 3rd International Conference on Trendz in Information Sciences and Computing, (2011), art. No. 6169099, 133–135.

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