Classifying Evaluation Method for Proved Reserves of Fuyu Oil Layer in a Certain Area

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Abstract. This paper puts forward classifying evaluation method for proved reserves of F oil layer in a certain area based on unit division by classifying and evaluating, optimizing and queuing. Firstly, the classification criteria of 11 individual evaluation indexes are established, and then the weight of synthetic evaluation classification are calculated via combining three methods: correlation coefficient method, principal component factor analysis method and analytic hierarchy process (AHP) method. The comprehensive score of each unit is calculated by using the method of comprehensive score weight analysis, and FI and FII with seven blocks in the whole area are divided into three categories according to the characteristics of reservoir development and oil-water distribution.

Introduction

S, P and G oil layers in the middle of a placanticline, as the main oil layers of one oilfield, have been put into development in the 1960s, however, the awareness and exploration of the lower F oil layers are still low. In recent years, through the evaluation and study of F layer in a certain area, the proved reserves of 1162.89 $*10^4$t were submitted in the west of development zone in 2012, 939 $*10^4$t in G area in 2013, and the proved reserves were divided into seven blocks on the plane. The reserves of each block differ greatly, and the oil test production varies greatly. At present, parameters describing and characterizing low permeability reservoirs include throat radius, percentage of movable fluid, starting pressure gradient, effective driving factor, abundance, effective thickness, displacement pressure and so on. There is no unified standard for low permeability reserves to do multi parameters comprehensive evaluation and reserves synthetic classification, and some parameters can only be obtained by core analysis in laboratory, and cannot be obtained by electric logging curve, which affects the popularization of evaluation methods. Most of the classification results are evaluated on the reservoir space without considering the oil-bearing property of the reservoir, which reduces the use value of the reservoir classifying evaluation. The synthetic classification of the proved reserves provides technical support for making a reasonable development plan in the area.

Geological Characteristics of F Oil Layer

The study area is G oilfield, T oilfield and X southern area in the area. The landform is saline-alkali plain. The land topography is higher in the North (139-149 m above sea level) and lower in the South (138-140 m above sea level). The terrain is less rugged and flatter. The average altitude of the oilfield is 140.6 M. The climate is dry and cold.

Structural Features. The structure in the study area is NNE trending and asymmetrical anticline structure. The dip angle of stratum in the west wing is generally about 14.7° with the steepest about 24°, while that in the east wing is generally about 3.2 to 4.5°. There are 3 local structures of X, T and G the F oil layer has the characteristics of "fault development, large number, small scale and NW-trending faults".

Sedimentary Features. F oil layer in the study area is mainly formed by shallow water delta deposits. Generally, it is a transgressive system from third to fourth segment of Quantou Formation.

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Under the depositional background of lacustrine transgression, the vertical sedimentary facies belt is continuous without sedimentary discontinuity.

Distribution Features of Oil and Water. The general trend of oil-water distribution in F oil layer is upper oil and lower water. With the increase of reservoir burial depth, the depth of oil bottom for different fault blocks increases. There is no uniform oil-water interface and the oil-water relationship is complex.

Reserves Calculation. According to the geological characteristics of F oil layer, seven (7) reserves calculation units are divided in plane, namely X76, X72, G8-59, X13-D2-125, G27-35, G12 and G111. Three layers of F I, F II, F III are divided in vertical with 17 sub-layers subdivided. Using the volumetric method, that is N=100Ah Sop o/Boi, the reserves of different types of sand bodies in the sedimentary unit of a single well can be calculated, and then the reserves of different types of sand bodies in sedimentary units of the whole area for all the wells can be obtained by their accumulation. The geological reserves of F I in F oil layer is 10,151,700 tons, and the geological reserves of F II is 6,622,200 tons.

Optimization of Reserves Classification Parameters

Principle for evaluation parameter selection:

(1) Parameters must reflect certain development geological characteristics and be typical among similar parameters.

(2)The parameters must reflect the most essential characteristics of the reservoir, the significant characteristics of the reservoir, and the block development effect.

(3) a parameter in the same layer must have obvious difference.

(4) The parameters must be easily obtained, quantified, scientific and reasonable.

Based on the above considerations, effective thickness, effective porosity, permeability, reserves abundance, oil production intensity, fluidity, number of main sand bodies drilled and oil production intensity ect are selected as evaluation parameters to classify and evaluate reserves [1, 2].

Classifying Evaluation Method for the Proved Reserves of F Oil Layer in X area

Single Factor Evaluation of Reserves Classifying Evaluation. The principle of single factor evaluation is to use the cumulative probability curve. The taxonomic significance of cumulative probability curve is that the closer the geological characteristics are, the closer the values of evaluation parameters are, correspondingly the larger the slope is, otherwise the smaller the slope is. Therefore, the parameters with different distribution characteristics will form linear sections with different slopes. Linear sections with different slopes reflect different layer properties, according to which reserves can be classified.

Based on the cumulative probability curve statistics of each index, the classification standard of each individual evaluation index is set up.

Multi Factors Evaluation of Reserves Classifying Evaluation. Both qualitative evaluation and quantitative evaluation can be used to evaluate the reserves. Since qualitative evaluation has the problems like: (1) the evaluation parameters are not unique; the classifying evaluation is difficult; and (2) the results of classifying evaluation are cross and contradictory, comprehensive quantitative evaluation method has been applied to F oil layer. Taking account of factors such as geology and reservoir, the evaluation methods are as follows:

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

Where: REI-layer comprehensive evaluation index; Xi-layer evaluation parameter; ai-weight coefficient of layer evaluation parameter; n-number of layer evaluation parameter.

Three methods including grey system theory method, principal component factor analysis method and analytic hierarchy process (AHP) were used to calculate the weight of the comprehensive evaluation classification indexes [3, 4].

Table 1 Item Classification of Evaluation Indexes

Classification Parameter	Category I	Category II	Category III
Thickness（m）	≥5.0	3.4~5.0	≤3.4
Porosity(%)	≥14.55	12.40~14.55	≤12.40
Permeability(10-3μm2)	≥2.70	0.55~2.70	≤0.55
Oil Saturation（%）	≥54	43.8~54	≤43.8
Oil Area（Km2)	≥10.60	3.14~10.60	≤3.14
Reserves Abundance(104t/km2)	≥29.66	19.33~29.66	≤19.33
Fluidity(10-3μm2/mPa.S)	≥0.12	0.02~0.12	≤0.02
Sedimentary Facies Quantification	≥2.87	2.39~2.87	≤2.39
Drilling Rate	≥0.44	0.33~0.44	≤0.33
Daily Oil Rate per Well(t/d)	≥3.7	3.55~3.7	≤3.55
Oil Production Intensity（t/d•m）	≥1.25	0.72~1.25	≤0.72

Grey Correlation. This method calculates the weight by considering the correlation between different evaluation factors, and introducing the correlation coefficient to determine the weight. The formula is as follows:

$$W_i = \frac{\sum_{j=1}^{m} r_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{m} r_{ij}} \quad (2)$$

Where W_i - weight; R_{ij} - correlation coefficient between evaluation factor I and J.

The weight can be calculated via the above formula automatically confirmed by the comprehensive evaluation system software for reserves.

Table 2 Weigh of Comprehensive Evaluation Indexes

weigh of evaluation indexes	effective thickness	oil saturation	effective porosity	fluidity	drilling rate	oil production intensity	oil area	reserves abundance	sedimentary facies quantification	daily oil rate per well
W_i	0.196	0.171	0.185	0.109	0.192	0.147	0.197	0.193	0.157	0.164

PC Factor Analysis Method. The procedures to calculate the weight by PC factor analysis

(1) Determine the evaluation factor and get the measured data matrix Xn * m;

(2) Standardize the measured data and calculate the correlation matrix Rn * m;

(3) Then obtain the contribution of the PC factor and the eigenvalue of the several first principal component factors whose accumulative contribution is more than 80% (or 85%) (or if initial eigenvalue is greater than 1, it will be automatically confirmed by SPSS software).

(4) The relative weight is calculated by the eigenvalue of each principal component factor (the sum of the relative weight from the absolute eigenvalue of each principal component factor).

(5) The actual weight is calculated by normalization of the relative weight.

The correlation matrix of comprehensive evaluation index is calculated by inputting each index into software SPSS (see Table 3). On this basis, the total variance and component score coefficient matrix can be obtained. The relative weight is calculated according to component score coefficient matrix, and the actual weight can be got after normalization [5, 6].

Table 3 Component Score Coefficient Matrix

Comprehensive Evaluation Index	Principle factor		Absolute Value of Principle Component		Relative Weight	Weight after Normalization（%）
	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 Porosity	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
Drilled Main Sand Bodies	0.394	-0.076	0.394	0.076	0.3371	0.17
Oil Production Intensity	0.302	-0.065	0.302	0.065	0.2633	0.13
Total			1.372	1.525	2	

Analytic Hierarchy Process (AHP). AHP mainly uses Yaahp software to calculate the weight of each index.

Main procedures:

1. Establish a hierarchical structure for problems.

A decision system can be broadly divided into three levels:

The highest level (target level): There is only one element in this level, which is generally the intended or ideal goal for problems analysis.

Intermediate level (criterion level): This level includes the intermediate links involved in achieving the goal. It can be composed of several levels, including criteria and sub-criteria to be considered.

The lowest level (scheme level): This level includes various measures and decision schemes that can be chosen to achieve the goal.

2. Determine the quantitative scale of thought judgment.

There are 1-9 kinds of scales in analytic hierarchy process, which can indicate the importance among different indexes.

3. Build pairwise judgment matrix and carry out consistency analysis (the ratio of maximum consistency is 0.1).

4. The relative weight of the comparative evaluation factor is calculated by the judgement matrix.

5. Calculate the combination weight of sub-factor of each level.

According to the above three methods, the weight of each classification index was calculated as Table 4.

Table 4 Statistics of Evaluation Index Weight

Calculation Method	Effective Thickness	Oil Saturation	Effective Porosity	Fluidity	Drilled Main Sand Bodies	Oil Production Intensity
Correlation Coefficient Method	0.20	0.17	0.19	0.11	0.19	0.15
Factor Analysis Method	0.19	0.13	0.14	0.25	0.17	0.13
AHP	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

Comprehensive Evaluation of Reserves Classification for F Oil Layer

The comprehensive score of each unit is calculated by using the method of comprehensive score weight analysis, and the seven (7) units in the whole area are divided into three (3) categories according to the characteristics of layer development and oil-water distribution.

Blocks of Categories I (2 units): the blocks with good geological conditions, large effective thickness, more layers of main sand body development, high reserves grade, higher oil test production than the economic limit production, and vertical wells development for economic use under the current development conditions;

Block of Categories II (1 unit): the block with poor geological conditions, lower reserves grade and productivity, small effective thickness, less layers of main sand body development, under the current development conditions, less economic benefits by the application of vertical well development, which can be developed and set up the capable production block through investment reduction, cost decrease etc.

Blocks of Categories III (4 units): the blocks with poor geological conditions, lower reserve grade and productivity, small effective thickness, less layers of main sand body development, under the current development conditions, no economic benefits by the application of vertical well development; which can be developed and set up the capable production block through investment reduction, cost decrease etc. on the premise of prior layer study, favorable layer search, horizontal well deployment.

Conclusion

Evaluation units can reflect the difference of reservoir types by classifying evaluation; further optimization of queuing can reflect the difference between different evaluation units in the same type of reservoir via comprehensive score weight analysis.

The comprehensive score of each unit is calculated by the application of comprehensive score weight analysis, and 47 units in the whole area are divided into three categories according to the characteristics of reservoir development and oil-water distribution.

References

[1]Yang Tongyou, Fan Shangjiong, Chen Yuanqian, et al. Calculating Methods of Oil and Gas Reserves (2nd edition) [M]. Beijing: Petroleum Industry Press, 1998.

[2]Li Zhengxi, Fuyang Oil Layer Logging Evaluation and Reserves Calculating Method Study in the Peripheral Area of Daqing Oilfield. Master's Thesis of Jilin University, 20070501.

[3]Zhao Wei. Research and Implementation on Grey Decision Evaluation Model for the Proved and Unused Reserves in Dagang Oilfield. Master's Thesis of Tianjin University, 20070501.16-18.

[4]Feng Dachen, Wang Wenming, et al. Evaluation and Research on Fuyang Oil Layer Available Reserves with Ultra-low Permeability [J]. Daqing Petroleum Geology and Development, Volume 23, Phase II 2004, 39-43.

[5]Huang Xuefeng, Li Jinggong, Wu Changhong, Genghong Xia, Gao Shujuan. Water injection wel l dynamic partition method of stratified cumulative water absorption [J]. Logging technology, 2004, 28 (5): 465-467.

[6]Cui Chengjun, et al. Three-dimensional reservoir modeling of BASUP53 reservoir. Special reser voir, 2004, 11(5): 18-21.