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Comparison of Oil Well Productivity Evaluation Methods Based on Different Data

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Abstract

Accurate prediction of well productivity is important to take proper engineering measures, and it has an important value on the increased cost of oil and gas exploration and development. Variety of different reservoir evaluation methods for well productivity based on different data, such as seismic data, mud logging data, well logging data, well testing data, formation test data etc. was compared in this paper, and the scale, scope and implications of the methods evaluation were also described. This provides a theoretical basis for comprehensive reservoir productivity assessment research, and can be a guidance for comprehensive evaluation of reservoir productivity based on variety of test data.

Key words: Productivity assessment; Seismic productivity; Logging productivity; Well test productivity; Cable test productivity

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INTRODUCTION

The productivity of oil and gas wells refers to the maximum production that a well can maintain. A correct evaluation of reservoir productivity can not only test the results of oil and gas exploration, but also provide the essentially basis for oil and gas field development. The production capacity prediction is an important basis for adopting correct engineering measures, and has important value for improving the economic benefits of oil and gas exploration and development (Mao & Li, 2001, pp.58-61). Oil testing and extraction etc. data are reliable reference for reservoir capacity evaluation, but the cost is high and not suitable to be popular (Zhang, Zhang, Zhang, Hao, & Shan, 2007, pp.24-27). At present, the productivity evaluation methods of oil and gas reservoir consist of seismic capacity evaluation methods, logging productivity evaluation methods, logging productivity evaluation methods, well testing capacity evaluation methods, and cable formation testing capacity evaluation methods, etc. (Xu & Li, 2005, pp.15-17).

1. PRODUCTIVITY EVALUATION METHOD BASED ON SEISMIC DATA

According to Biot's theory, underground reservoirs can be viewed as fluid-filled dual media. It is assumed that the instantaneous force generated by the source excitation generates a pressure gradient field and causes the reservoir volume to change. Besides, it makes the fluids in the pore to move relatively to each other, and motion law obeys the Darcy's law. The seismic records are the total reflection of the microscopic fluctuations of this medium on the surface (Chen & Guo, 1998, pp.86-90).

Based on the extracted seismic wave attribute, Wang and Zhang (2007, pp.87-89) used the neural network to establish a neural network training set on the basis of the known well productivity and the well-side seismic wave properties. Then, it was used to predict the oil and gas production capacity distribution of the LG block.

The seismic data reservoir productivity evaluation method is still in the theoretical research stage, and it is rarely used in the oilfield.

2. PRODUCTIVITY EVALUATION METHOD BASED ON MUD LOGGING DATA

One of the ultimate goals of the quantification development of logging data is to predict the production capacity of the reservoir. Although the capacity prediction formula is given in Darcy's law, it can only be applied to reservoirs under ideal conditions. Besides, the parameters in the formula is not only difficult to get but also complicated. Hence, it is difficult or even impossible to directly predict the productivity with the Darcy's law formula. If the oil source, reservoir sedimentary environment and burial depth are similar on the premise that blocks or horizons are classified, the oil properties, reservoir properties and formation pressure environment would be similar. So that, the main factors of reservoir productivity are oil thickness and oil abundance.

Lang and Guo (1995, pp.6-8) established a single logarithmic coordinate relationship between the pyrolysis content change of liquid hydrocarbon S1, heavy hydrocarbon S2 and total hydrocarbon S1+S2 and productivity of unit oil-bearing thickness, and obtained its linear regression equation. The results show that there is a good linear relationship between productivity of unit oil-bearing Q/H and pyrolysis content of total hydrocarbon on a single logarithmic coordinate system. Finally, reservoir productivity can be obtained by mathematical transformation.

This method, to a certain extent, compensates for the shortcomings of the Darcy productivity prediction formula. It should be noted that a large deviation may be produced, when this method is applied to predict productivity of abnormal pressure formation. Its advantage is that only a part of the preliminary wells need to be paralyzed and compared with the well test results for a new area, the capacity prediction equation can be initially established.

3. PRODUCTIVITY EVALUATION METHOD BASED ON WELL LOGGING DATA

The reservoir parameters obtained by geophysical logging methods mainly reflect the static characteristics of the reservoir and cannot directly reflect the dynamic characteristics. The main purpose of using logging data for reservoir capacity prediction research is to try to achieve this transition from "static" to "dynamic". Logging gets the physical properties of the formation and the static information of the reservoir fluid. The productivity reflects the dynamic information of reservoir energy and seepage capacity. Meanwhile, the logging information such as porosity, permeability and water saturation has a great correlation with the seepage capacity of the reservoir. Therefore, the production capacity of the reservoir can be predicted by analyzing the relation between static information and tested productivity.

The production capacity of oil and gas reservoirs is affected by many factors, and production capacity is a comprehensive reflection of various influencing factors. In summary, the factors affecting productivity can be broadly divided into two categories, one is the reservoir factor including the lithology, physical properties, hydrocarbon-bearing properties and fluid properties. The other type is the human factor, which includes the skin factor and the oil well radius. The skin factor is a comprehensive parameter. It is the comprehensive reflection of the oil layer pollution during drilling and downhole operations, the perfection of perforation, acidification, fracturing and transformation of oil layers, etc.

Studies have shown that there are 15 key parameters affecting yield. They are formation pressure, fluid viscosity, gas-oil ratio, effective thickness, effective permeability, skin factor, volume coefficient, compression coefficient, effective porosity, movable fluid porosity, Pressure coefficient, fluidity, oil saturation, irreducible water saturation and formation temperature (Liu et al., 2003, pp.325-329). These parameters can be obtained directly or indirectly from the dynamic and static logging data, except that the skin factor and pressure logging are not available.

Based on the basic theory of stable seepage and major factors of influencing productivity should be found. Then a productivity prediction model is established with appropriate mathematical methods to predict reservoir productivity. This technology is able to predict capacity in multi-layer mixed wells and single layers (Xu, Li, & Lu, 1999, pp.179-183; Hu, 2001).

The main work of productivity prediction based on well logging data is to establish the relationship between reservoir productivity and logging data based on the analysis of existing well logging, oil and gas testing and core analysis data in the study area. Then, reservoir capacity can be evaluated and predicted by logging data (Zhang, 2007, pp.23-25).

3.1 Theoretical Research

For low porosity and low permeability reservoir, the productivity prediction model is affected by sensitive factors greatly, the primary and secondary factors are not obvious in the low-yield case, and the prediction and evaluation of production capacity are relatively difficult. For these problems, Wang, Xu, & Gu (2009, pp.51-55) carried out preliminary experimental research on the production capacity prediction of low porosity and low permeability reservoirs, and compared and analyzed multiple production capacity prediction models and their applicable conditions.

Tan, Song, & Wu (2001, PP.101-106) begin with the Darcy's two - dimensional production equation, a theoretical equation of reservoir production capacity was derived. And the multivariate function between reservoir production capacity and reservoir effective porosity, permeability and resistivity was established on the basis of the functional relation between relative permeability and water saturation.

Ouyang (1994, pp.148-152) proposed that productivity index of gas layer was evaluated by rock permeability and water saturation.

Cheng and Yang (1999, pp.24-32) observed that flow capacity of fluid can be characterized by the original formation resistivity and the flushing strip resistivity, then productivity capacity is available.

3.2 Traditional Statistical Methods

Statistical regression method is a common approach for predicting productivity based on well logging. The statistical relation between porosity, permeability and rock specific surface etc. physical parameters and productivity indexes of testing wells in developed block is employed to predict reservoir productivity.

Mao and Li (2000, pp.58-61) employed a statistical regression method to establish a mathematical model of the productivity index of oil layer and oil phase permeability, and a mathematical model of the productivity index of condensate gas layer and gas phase permeability through the study of multiple oil and gas reservoirs in Tarim.

Zhu, Ren and Wei (1996, pp.36-40) established a multivariate nonlinear relationship between reservoir productivity index and porosity, irreducible water saturation, movable oil saturation, crude oil viscosity and nozzle diameter based on test oil data and reservoir parameters.

Rinaldi and Djauhari (1997, pp.183-190) built a statistical relationship between the capacity index and the corrected water and oil relative permeability by combining density, porosity and shale content with relative permeability data.

Gu and Ding (1993, pp.43-49) proposed the regression relationship between permeability and oil production index to predict productivity, based on the construction of a parameter of movable oil rock structure.

Lin et al. (2017, pp.226-230) presented a method for quantitatively calculating single well productivity by using envelope size index of lithological, physical and electrical curve.

Such methods do not take into account the effects of fluid viscosity and reservoir pollution, so the capacity prediction results are not satisfactory.

The traditional method of predicting reservoir productivity is to establish a unary functional relationship between "oil production index per meter" and "reservoir permeability". However, the mathematical model is too simplified to get a satisfactory prediction effect.

3.3 Modern Statistical Methods

Support Vector Machine (SVM) is a machine learning method first proposed by Cortes and Vapnik in 1995. It is a hotspot of machine learning research in recent years and has been successfully applied in many fields.

Tong, Shan, Liao and Wang (2008, pp.40-43) tried to use the well logging evaluation method to predict reservoir productivity based on the basic principles of seepage mechanics. They employed the current mature research and application of support vector machine technology to quantitatively evaluate the capacity. Their comparative analysis results showed the validity of the method.

Raleigh extended this work, and proposed BP-based algorithm to predict oil and gas reservoir productivity. But back propagation (BP) networks tend to converge slowly, easily fall into local minima, and their reasoning ability is poor.

The radial basis function (RBF) has been successfully applied in the fields of pattern recognition, function approximation, signal processing, system modeling and control, etc. (Whitehead & Choate, 1996, pp.869-880; Lu, Sundararajan, & Saratchandran, 1998, pp.308-318) However, the basic function width value of the ordinary RBF neural network is determined by empirical formulas or artificially selected without considering error distribution, so the effects are often not ideal in applications.

Li, Song and Xia (2006, pp.53-57) presented an improved algorithm for RBF neural network, which can adaptively "dynamically" determine the width value of the basis function. Compared with the ordinary RBF neural network, it not only has high fitting precision, but also has fast convergence speed.

Peng, Xu and Wang (1999, pp.20-22) set up a neural network expert system to predict single well production. Its input parameters consist of reservoir thickness, temperature, effective porosity, effective permeability, formation pressure, oil saturation, underground crude oil viscosity, underground crude oil density.

Tan, Song and Wu (2001, pp.20-23) used artificial neural network technology to predict reservoir oil production index by inputting reservoir permeability, porosity and electrical resistivity.

Xu, Li and Lu (1999, pp.179-183) employed fuzzy pattern recognition and artificial neural network technology to predict reservoir productivity by using effective porosity, permeability, hydrocarbon (or water) saturation and shale content as inputs.

Huang et al. (2006, pp.109-111) introduced the compensated fuzzy neural network into the logging capacity prediction by taking advantage of MATLAB's neural network toolbox. Further, they carried on training study with the known section of the oil well logging data to dope out the other sections productivity at the same area.

Du and Guo (2005, pp.54-56) proposed a specific probabilistic neural network method for the prediction of reservoir productivity.

Fuzzy neural network for well logging productivity prediction has the advantages of short learning period and high accuracy. It overcomes the problem that BP network is not easy to converge. The overall performance is better than the ordinary method and it is a powerful tool for pattern recognition.

Yang, Nie and Sun (2003, pp.48-50) introduced a new improved fuzzy neural network method, and compiled related algorithm programs in C language.

Since the ordinary neural network methods are based on the principle of empirical minimization, the steepest descent method is adopted in solving the learning problem. So that is easy to produce local convergence, and it is difficult to obtain the global optimal solution. In addition, the convergence speed is slow, which affects the calculation accuracy of result.

The accuracy of reservoir productivity, predicted by using conventional logging data and its processing results, is low (Xiao, Xiao, Li, Hu, & Chen, 1999, pp.279-282). When the conventional logging data is obtained, the fluid in the formation is stationary. Consequently, all of the measured parameters are static parameters in the logging information, and there is no seepage information of the formation fluid (Yang, Kang, Guo, & Yang, 2006, pp.84-86). However, the productivity of the reservoir depends not only on the static parameters, but also on the dynamic parameters that reflect the seepage state. This is the key to the low accuracy of reservoir productivity prediction using logging data.

Zhao, Hou, Jiang, Wu, and Yang (2009, pp.72-74) raised that the mud intrusion characteristics should be studied from the well logging data during the drilling process. According to the mud filtrate intruding into the reservoir and the original fluid in the reservoir being washed out, the percolation characteristics of the formation are determined, and the characteristic parameters reflecting the percolation characteristics of the reservoir are extracted. Then a statistical model can be established to forecast productivity by coming with oil test data.

Li, Zhang, Zhou, and Zhong (2001, pp.13-19) determined the influencing factors and variation laws of the saturation index and cementation index under dynamic development on the basis of experimental research on water flooding mechanism. Furthermore, a productivity prediction model for different development periods of oilfields is established, based on the well logging data and dynamic geological data.

The oil-water seepage in the mid-high porosity and permeability medium is basically subject to Darcy's law, so the production capacity prediction is relatively simple. The seepage mechanism of low-permeability reservoirs is very complicated, and does not follow Darcy's law. The factors affecting the production ability are many and prominent, so the production capacity prediction is very difficult (Zhu, Cheng, Yang, & Chen, 2008, pp.102-104; Gao, 2002).

The productivity prediction of low-porosity and low-permeability reservoir is relatively difficult. The main reasons are: (1) the prediction model is greatly affected by sensitive factors under low-yield conditions; (2) the primary and secondary factors are less differentiated in the low case of low productivity (He, 2002, pp.43-47).

4. CAPACITY EVALUATION METHOD BASED ON WELL TESTING DATA

Well testing can be divided into two types: stable well testing and unstable well testing. Stable well testing is also called system well testing or capacity well testing. First, flow rate and responding stable bottom-hole pressure and other related data are determined under different stable work systems. Then, according to these data, productivity can be gotten by drawing or analyzing. Finally, the reasonable production capacity, the reasonable working system and the reservoir parameters can be determined ('Well Testing Manual' writing group, 1992, pp.354-534).

(a) Single-phase Darcy flow

If the seepage law follows the single-phase Darcy flow, the productivity can be solve by a linear equation:

$$q_o = J\left(\overline{p} - p_{wf}\right) = J_o \Delta p \tag{1}$$

Where: $\overline{p}$ is formation pressure; p_{wf} is bottom-hole flow pressure.

(b) Single-phase non-Darcy flow

For non-Darcy flow, an exponential capacity equation or a binomial capacity equation is available.

Exponential capacity equation:

$$q_o = C\left(\overline{p} - p_{wf}\right)^n \tag{2}$$

Where n is the index of productivity equation($0.5 < n < 1$).

C is a constant related to reservoir and fluid characteristics; n is a flow regime index.

When n=1,c=J, the flow obeys a single phase Darcy flow;

$n > 1$, the flow is low velocity non-Darcy flow;

$n < 1$, the flow is high velocity non-Darcy flow

Binomial productivity equation:

$$\overline{p}_r - p_{wf} = \Delta p = Aq + Bq^2 \tag{3}$$

For non-Darcy flow of gas well, the pressure term of productivity equation is square pressure or square pseudo-pressure. The coefficients in the productivity equation can be obtained by plotting tested pressure and flow data. Thus, the productivity equations of the oil and gas well are obtained.

(c) Multiphase flow

For multiphase flow oil and gas wells, exponential capacity equation and the Vogel capacity equation are usually used to calculate productivity. The exponential capacity equation was proposed by Fetkovich (1973) in the form:

$$q_o = J_o\left(\overline{p}^2 - p_{wf}^2\right)^n \tag{4}$$

In the equation, in order to eliminate the nonlinear influence of the gas high pressure physical parameters on the seepage equation, the pressure term is replaced by square pressure.

Based on the numerical simulation results, Vogel established a dimensionless IPR curve equation for the well under dissolved gas flooding conditions:

$$q_o/q_{o\max} = 1.0 - 0.2\left(p_{wf}/\overline{p}\right) - 0.8\left(p_{wf}/\overline{p}\right)^2 \tag{5}$$

Where $q_{o\ max}$ equals maximum oil production when p_{wf}=0.

Unstable well testing consists of conventional well testing analysis method and modern well testing analysis method. Theory of conventional well testing is relatively complete and principle is simple. However, its analysis results can only reflect the average characteristics of the reservoir as a whole, and be influenced by human factors. Besides, this method requires oil and gas wells to have a long test time, and has poor ability to recognize the type of reservoir. Further, modern well testing analysis method establishes analysis method of the early data and recognition theory of the flow stage, which is improved on the basis of conventional well testing analysis method. It is able to quantitatively analyze the reservoir parameters of local or comprehensive reservoir, but its analysis results are multiple. So that, it should be repeatedly validated whether the model is consistent with the actual geological features, when the encountered reservoir has complex geological conditions (Xia, 2013, pp.100-103; Gao et al., 2016, pp.47-52).

5. CAPACITY EVALUATION METHOD BASED ON FORMATION TESTING DATA

The formation testing is a method that tests the oil and gas layer drilling or after completion to obtain various dynamic characteristic parameters of the formation and fluid, so as to timely and accurately evaluate the production layer. It is a temporary completion to determine whether the formation has industrial production capacity. The basic principle is to utilize the downhole test equipment or tools to isolate the test layer from other formations and the drilling fluid in the wellbore. Then, the fluid of test layer directly exposed to atmospheric can flows into the drill pipe under ΔP and be tested. It is characterized by fast speed, more information, and the most economical "temporary" completion method.

The main test methods include:

(a) Drill string test (DST)

DST consists of two types of available equipment. One is a multi-flow tester, which can only be used for vertical wells with casings or open-hole completion. It is noted that DST is generally not used for directional wells, offshore drilling. The other type is pressure control tester, which is suitable for offshore drilling, directional wells.

(b) Repetition formation test (RFT)

RFT is to determine pressure, permeability, and skin factor of the formation by measuring the relationship between flow and pressure and the fluid in the formation. It is suitable for open-hole or casing completion. RFT can take two fluid samples for one time, and has the advantages of doing little damage to formation and high testing efficiency. And its disadvantage is that the accuracy of quantitative interpretation is poor.

One of the main functions of RFT is to accurately evaluate reservoir capacity with cable formation test information, which can save costs compared to DST. However, in the actual field test, the calculation results of the RFT and DST often have large errors. Based on the assumption of reservoir homogeneity, uniform thickness and isotropic, RFT method is employed to calculate productivity through determining the average permeability of the test layer (Liu et al., 2000; Jean-François, Pablo, Pedro, & Riano, 2002; Andre, Canas, & Low, 2005). It is noted that the calculated capacity can only reflect the reservoir dynamics within the detection range (generally tens of centimeters to a few meters). And, the detection range of DST is much larger than that of RFT, because of long tested time (usually over 6-8 hours). Therefore, the small detection range is the main factor affecting the accuracy of RFT.

At present, the permeability interpretation methods of cable formation test include pseudo-steady-state pressure drop method, spherical flow method, cylindrical flow method, reservoir flow analysis method and plate fitting method.

Based on the analysis of generous cable formation test and DST test data, Zhao and Liao (2009, pp.283-288) offered a curve fitting method to compute the permeability and skin etc. parameters that are needed in production prediction.

Yang, Fan, Liao, & Zhao (2008, pp.105-107) recommended the spherical flow method or cylindrical flow interpretation method. First, the permeability of test point is calculated by the interpretation model screened by the straight line segment from the two maps drawn by these two methods. Second, the average longitudinal permeability in the whole reservoir thickness is gotten by calibrating the permeability of well logging with the permeability obtained by multipoint cable formation testing. At last, the productivity can be determined.

However, due to the current one switch test method used in the cable formation tester, it is impossible to correctly evaluate the production capacity. Based on the development of the FCT cable formation tester tool, Cheng, Li, An, & Liu (2005, pp.73-74) discussed the possibility of using a large displacement formation tester to replace the drill pipe formation test technology for capacity evaluation.

Guan, Li, Xu, Tang, & Yan (2008, pp.73-75) extended the detection radius of WFT through multi-well and multi-parameters reservoir lateral prediction technique based on geological statistics, and obtained the average thickness evaluation method considering reservoir unequal thickness and the average permeability calculation method taking into heterogeneity and anisotropy account.

Meng, Li, Du, & Sui (2010, pp.64-67) comprehensively analyzed the well logging data of reservoir permeability, porosity, water saturation and shale content, and finely classified the reservoir in the vertical direction according to the characteristics of sedimentary micro facies. Furthermore, the corrected permeability tested by cable formation tester is used to calibrate the well logging permeability and directly to calculate the output of each small layer. Finally, the total capacity of the reservoir is obtained by numerical integration.

The main functions of the conventional cable formation tester consist of sampling fluid, testing formation pressure, and identifying reservoir oil-water interface, testing reservoir flow coefficient, etc. But, the prediction chamber of conventional cable formation tester is small (10~20 m1), with the result that the test process is completed in only a few tens of seconds to a few minutes, and the pressure spread is usually in the range of a few centimeters to tens of centimeters. And, the permeability interpreted by pressure test data is the permeability of the invaded zone, and cannot reflect the true seepage characteristics of fluid (Zhang, Zhu, & Wang, 2002, pp.41-44; Lin, 1994, pp.25-60). Therefore, the research on reservoir productivity evaluation technology using conventional cable formation test data is relatively rare at home and abroad.

Because the time of cable formation test is shorter than the drill pipe formation test, the test data are mainly the pre-seepage data. Hence, the plate fitting method will have multiple solutions, the pseudo-steady state pressure drop method has a large interpretation error. Unfortunately, reservoir flow analysis method requires high accuracy of flow change measured in the process of testing. At present, this method has become an important method for oil and gas field exploration, especially for offshore oil and gas exploration.

6. COMPARATIVE ANALYSIS OF DIFFERENT EVALUATION METHODS

Different productivity evaluation methods depict different reservoir production stage and concept hierarchy.

Take LD oilfield NgⅢ oil formation as an example, in order to ensure the accuracy of productivity, DST was applied to forecast productivity. The well network of LD oilfield NgⅢ oil formation is shown in figure1, and its geology and reservoir parameters are listed in table 1.

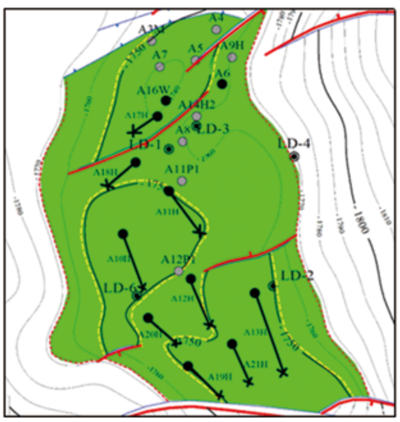

Figure 1
Well Pattern of LD Ng Ⅲ Oil Formation

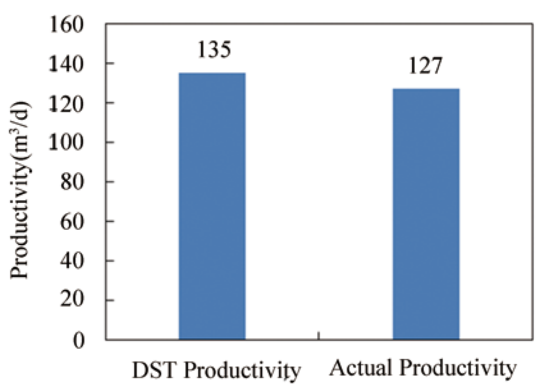

Figure 2
Comparison of DST Productivity and Actual Productivity

During the Overall Development Programming (ODP) stage, the productivity of LD oilfield was evaluated by DST method. First, according to the results of DST, an ideal productivity index was got. Then, based on the relationship between well log-interpreted permeability of whole block and that of tested formation, the ideal productivity index of a meter of the tested formation can be calculated. What's more, formation is usually effected by drilling fluid and completion method, a skin factor of 5 would be taken. Secondly, the recommended productivity index of a meter was the product of flow efficiency of 5 skin factor and ideal productivity index of a meter. Then, drawdown pressure was taken 2.5 MPa, according to the development experience of similar oilfield of Bohai Bay. Finally, productivity can be determined, and the recommended productivity was 105~150 m^3/d, as shown in table 1.

According to the comparison result of the productivity forecasted by DST and actual early productivity, the productivity forecasted by DST is close to the actual value, as shown in figure 2. The margin of error is only 6.3%. Moreover, DST is a method that can be used to calculate productivity directly and precisely.

Table 1
Productivity Index of LD Oilfield Ng III Oil Formation Calculated by DST

Parameters	Value
well name of tested well	LD-2
net pay thickness(m)/layer amount	14.0/2
average permeability of block (mD)	1255
permeability of testing layer (mD)	1265
oil viscosity (mPa·s)	5.8
daily oil production (m^3/d)	114.9~268.7
drawdown pressure (Mpa)	1.614~2.503
productivity index of a meter (m^3/(MPa·d·m))	5.09~7.67
average productivity index (m^3/(MPa·d·m))	6.41
skin	-0.30
ideal productivity index of single layerm^3/(MPa·d·m)	6.06
average productivity index of single layer for block (S=5) (m^3/(MPa·d·m))	3.53
Drawdown Pressure (MPa)	2.0~2.5
net pay thickness in well spacing area (m)	12.0
comprehensive coefficient	0.5
recommended productivity of directional well (m^3/d)	42~53
productivity multiple	2.5~3.0
recommended productivity of horizontal well (m^3/d)	105~150

Table 2
Early Productivity of LD Ng III

Well name	Operation time	Net pay thickness	Horizontal segment length	Productivity	Drawdown pressure	Productivity index of a meter
		m	m	m^3/d	MPa	m^3/(MPa.d.m)
A10H	2009/10/15	13.0	416	149	-	-
A11H	2009/10/16	12.0	391	78	-	-
A12H	2009/10/16	12.0	375.5	107	0.5	17.8
A13H	2009/10/16	9.0	640	230	-	-
A17H	2009/10/16	7.0	200	70	0.6	16.7
Average	-	-	-	127	-	—

In summary, based on literature research and oilfield practices, the following four meaningful conclusions are obtained:

(a) Seismic data can be used to analyze the reservoir structure, reservoir thickness variation and predict spatial distribution of reservoir heterogeneity. Therefore, reservoir productivity obtained by seismic data will reflect the difference of in three-dimensional space. Unfortunately, the seismic data reservoir productivity evaluation method is still in the theoretical research stage, and cannot be applied in the field.

(b) Well logging productivity evaluation method is to establish a relationship between productivity and well logging parameters tested well with statistical regression method on the basis of the productivity evaluation of single well formation test. For the new drilled wells, the production can be estimated by using well logging data, without drill stem testing. As a result, test costs and time can be saved a lot. For the reservoirs with weak heterogeneity, prediction of reservoir productivity by logging method can meet the needs of reservoir engineering. But, for the reservoirs with strong heterogeneity and wells in new exploration areas, well logging method is unable to evaluate reservoir productivity effectively.

(c) Well testing capacity evaluation method has been widely used in reservoir engineering. The reservoir productivity tested by well testing method is the average productivity within the supply radius (usually within a few hundred meters around the tested well). For a multilayer reservoir with thin interlayers, it is impossible to accurately seal each pay with packers. So that, the production capacity of a single reservoir cannot be obtained. What's more, the drill string formation test takes a long time, has large emissions and high test cost. Consequently, the drill stem testing is greatly restricted, especially in offshore oilfields.

(d) Capacity evaluation method based on Cable formation test is a new type of oil and gas reservoir productivity evaluation method. Its instrument function is equivalent to a small drill pipe formation tester. The test range is from tens of centimeters to several meters around the wellbore. Cable formation tests has its own GR test sub, which can accurately determine the position of the instrument docked in the reservoir, take optimal test points, perform multiple points testing and sampling, and determine the change of reservoir heterogeneity in the longitudinal direction. Finally, the average production capacity of the reservoir can be calculated through calibrating reservoir heterogeneity with heterogeneity measured by well logging test. Cable formation test takes a short time (each test point only takes several minutes to several tens of minutes), and low cost.

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