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Productivity Prediction Approach of Complex Tight Gas Reservoir in Yingtai Area

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Abstract

Productivity is the core of evaluation of undeveloped reserves. Productivity prediction is the significant content of oilfield plan deploying, development plan, dynamical analysis, oil and gas wells allocation and development plan regulation. As an example of tight gas reservoir in Yingtai area of Jilin Oilfield, according to internal factors in productivity prediction and the lithologic character of this region which consists of volcanic rock and clastic rock, this paper proposes two combination parameters to predict productivity. The different prediction results of these two methods are compared and analyzed. Based on the verification of two wells, "quasi-formation coefficient" has higher precision, the average relative error being 4%. It has reference meaning in the productivity prediction to other gas reservoirs with the same type and similar geologic conditions.

Key words: Tight gas reservoir; Quasi-formation coefficient; Gas well; New well productivity; Prediction

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INTRODUCTION

Gas well productivity is an important parameter of gas reservoir engineering and main basis for the guidance of gas well allocation and design of development plan. Gas well productivity is completed by gas test.The longer the gas test cycle is, the higher the cost will be. The main influences on the gas well productivity are reservoir physical property and pressure. Therefore, we usually predict gas well productivity by static data. On one hand, the cost can save much. On the other hand, it has shorten the production building period.

The main methods of gas well productivity prediction have formation coefficient, gas productivity index, unit formation pressure, specific productivity, and so forth. The method of formation coefficient is using the fitted formulas by *A* and *B* coefficients of tested gas wells and ground physical property parameters of new wells in the block to calculate the coefficient of productivity equation of new wells, determine the productivity equation and predict the productivity[1]. The method of gas productivity index calculates gas productivity index by productivity equation, carries on the curve fit for the gas productivity index of the whole block to some extent, finds out the relationship between gas productivity index of the block and ground physical property parameters and gets to know the level of productivity in the block[2]. The method of unit formation pressure adds up open flow capacity effective formation coefficient, finds out relationship between them, takes advantage of well logging and testing information as well as determines effective formation coefficient, open flow capacity of gas wells and productivity[3]. The method of specific productivity establishes the relations between open flow capacity and formation physical property of unit formation pressure and formation thickness, finds out the corresponding relationship by productivity equation, predicts and evaluates productivity of different location in the well field[4].

The above four methods all need permeability information to predict productivity. However, the permeability information of Yingtai is too less to predict in those methods. Based on the geologic characteristic of complex tight gas reservoir in Yingtai area of Jilin Oilfield, this paper selects appropriate parameters to predict productivity.

1. GENERAL GEOLOGY OF THE STUDY AREA

The study area is located in Longshen 2 and 3 well fields of Yingtai area in Zhenlai County, Baicheng city of Jilin Province. The main gas producing formation exists in lower series of mesozoic cretaceous in the Second Member of Yingchang Formation. This well area has 23 drilled wells, of which 12 gas test wells and 12 industry gas flow wells have been finished. All the gas wells produce industry gas flow after being fractured, which reveals preferable development potential.

This area belongs to Yingtai fault depression in the north of west fault depression of the south Songliao Basin. The complex fault depression has the feature of the dustpan-like south part and the duplex fault north part. Influenced by deep controlled fracture and multistage tectonization, deep local structures mostly develop block related to fault, fault nose structure (mostly pearlitic distribute along the faulted zone) and anticline[5].

The reservoir is the lithology gas reservoir. Without being controlled by structure, the lithology and lithofacies change fast. The gas layer distribution is controlled by sedimentary facies belts. The bigger the bed thickness is, the bigger the accumulated gas thickness is. Controlled by lake basin evolution and volcanic eruption, the study area is volcanic sedimentary phase between volcanic phase and sedimentary facies of terrigenous clastic, characterized by volcanic sedimentary sequence.With analysing on physical property of 144 sedimentary pyroclastic rock samples of the Second Member of Yingchang Formation in Longshen 2 and 3 well areas, the porosity is general 5%-9%, the average porosity is 7% and the maximum porosity is 16%. The average permeability is 0.05×10^{-3} μm^2 and the maximum permeability is 1×10^{-3} μm^2. It belongs to complex tight gas reservoir with a large range of physical property and strong heterogeneity.

2. METHOD OF QUASI-FORMATION COEFFICIENT FOR PRODUCTIVITY PREDICTION

2.1 Parameter Optimization

The main factors affecting the productivity of the fracturing gas well are reservoir physical property parameters such as effective thickness, porosity, permeability and gas saturation, which belong to intrinsic factors. As gas reservoir thickness becomes larger, the vertical gas well productivity increases[6]. When the reservoir physical property is good on the whole, the reservoirs have crude pore throats, large porosity, high gas bearing formation permeability and the sorting from good to excellent. In this condition, it is easy to reach the ideal effect after carrying out fracturing work. In the case of the high gas saturation, water production rate turns out to be low[7] and the gas well productivity is high.

The external factor affecting the productivity of the gas well is the change of formation pressure. Differences of tectonic position and formation producing energy loss during operation can cause the change of formation pressure. Based on the basic seepage theory, Liu Qiguo[8] holds that during early production stage layered production contribution is approximately equal to formation coefficient before the pressure wave travels to the border ,when the effect of wellbore storage and skin factors aren't considered. When reaching the border, over a productive transitional period, the pressure wave is gradually distributed in the proportion of formation reserve the pressure won't affect sublayer production distribution at the time of commingling productive. Because the gas wells in Yingtai area is in the early development stage, this research doesn't take formation pressure as a parameter for productivity prediction.

Effective porosity is an important index to reflect the oil and gas storage and connectivity. Effective thickness is an important basis for understanding the formation energy and measure the productivity status. It is limited to rely on any factor as a parameter of quantitative statistics to establish productivity relations. The conventional method of the formation coefficient for productivity prediction takes the multiplication form of permeability and effective thickness. According to the form and considering the study area permeability data is difficult to obtain, the author proposes "quasi-formation coefficient"for productivity prediction.

$$\text{Quasi-formation coefficient} = \Phi\cdot h, \quad (1)$$

Φ: Effective porosity, decimal;

h: Effective thickness, m.

Besides, the factors affecting the productivity of the gas well are porosity, permeability and gas saturation. Gas saturation is the foundation of oil and gas storing and output. It is difficult to establish correlated quantitative statistics relation by simple gas saturation data. For one thing, the core data and log data is difficult to accurately compute the original gas saturation of gas reservoir. For another, gas testing may not be accurate quantification only on the basis of the gas saturation for selecting the gas layers. Therefore, take the same form of multiplication that combines gas saturation and effective porosity, namely $\Phi\cdot S_g$, which is another parameter standard of productivity prediction.

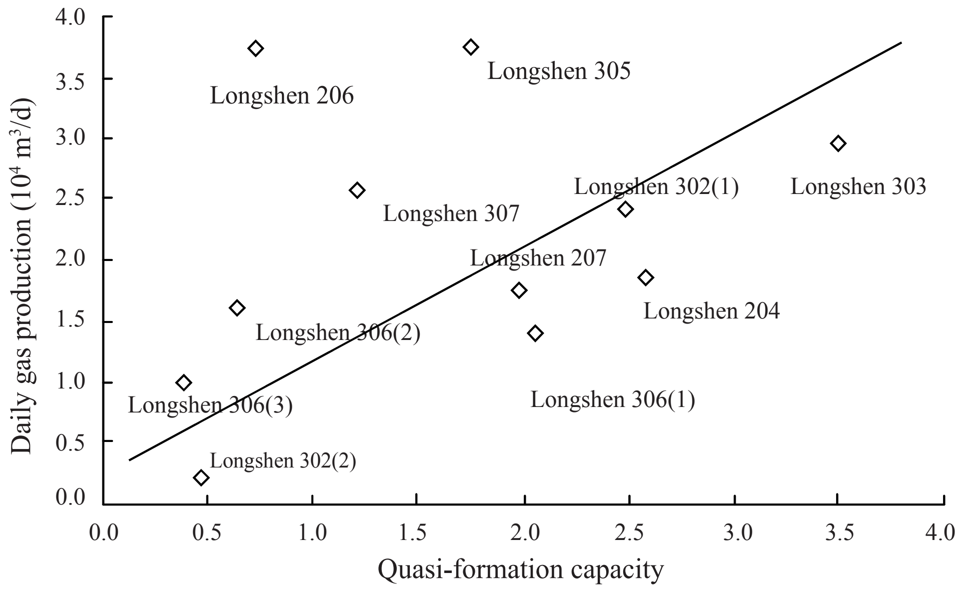

Figure 1
Relation Between Quasi-Formation Capacity and Daily Gas Production of the Gas Testing Wells

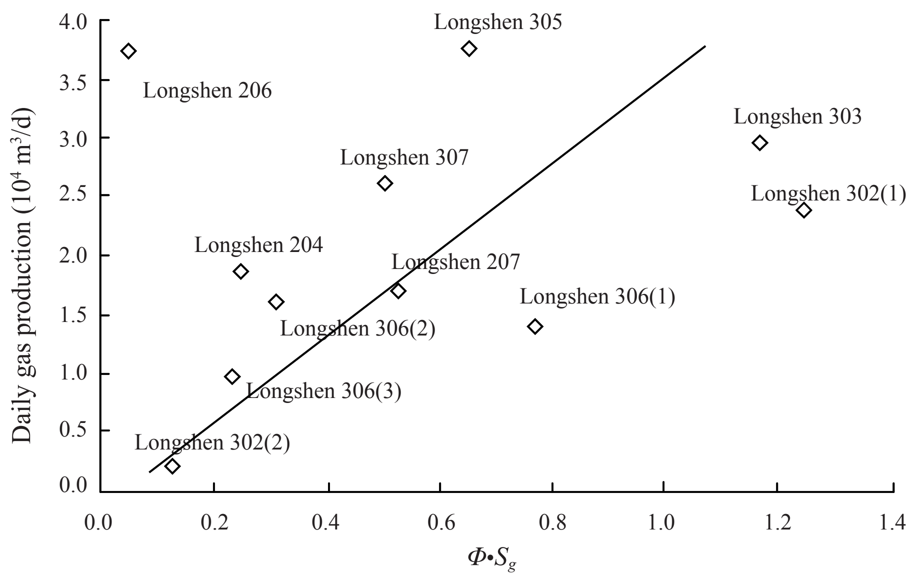

Figure 2
Relation Between $\Phi \cdot S_g$ and Daily Gas Production of the Gas Testing Wells

Draw relation fitting figures with daily gas production of the gas testing wells, corresponding quasi-formation capacity and $\Phi \cdot S_g$ (Figures 1 and 2). From the figures, the scatter distributes from the upper right to the lower left of the area. Quasi-formation capacity and $\Phi \cdot S_g$ are positively correlated with daily gas production. As the quasi-formation capacity and $\Phi \cdot S_g$ increase, daily gas production increases. But these scattered points distributed poorly, with a bad relevance. In view of the complex lithologic character of Yingtai area, the lithology of each gas testing well section is divided into two series including volcanic rock and clastic rock. Then draw relation fitting figures with quasi-formation capacity, $\Phi \cdot S_g$ and daily gas production of the gas testing wells (Figures 3 and 4).

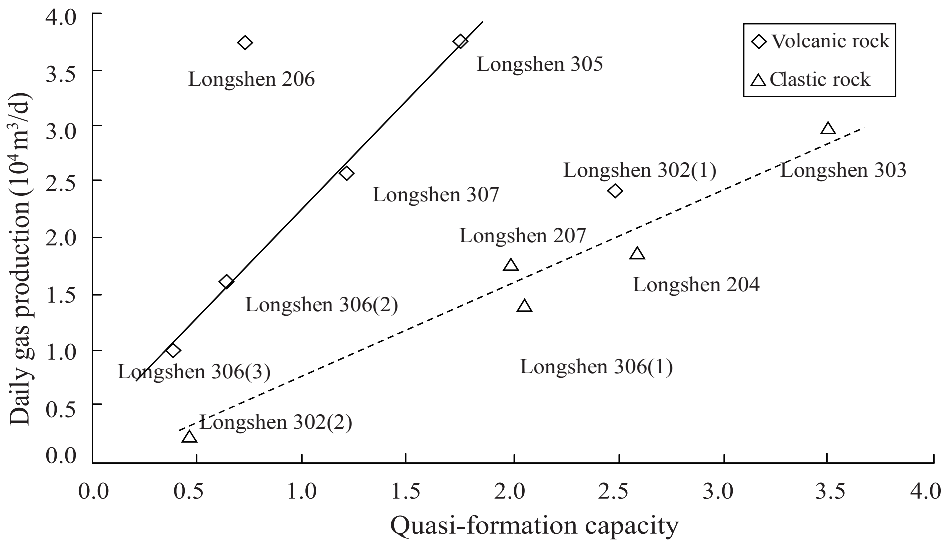

Figure 3
Relation Between Quasi-Formation Capacity and Daily Gas Production of the Gas Testing Wells

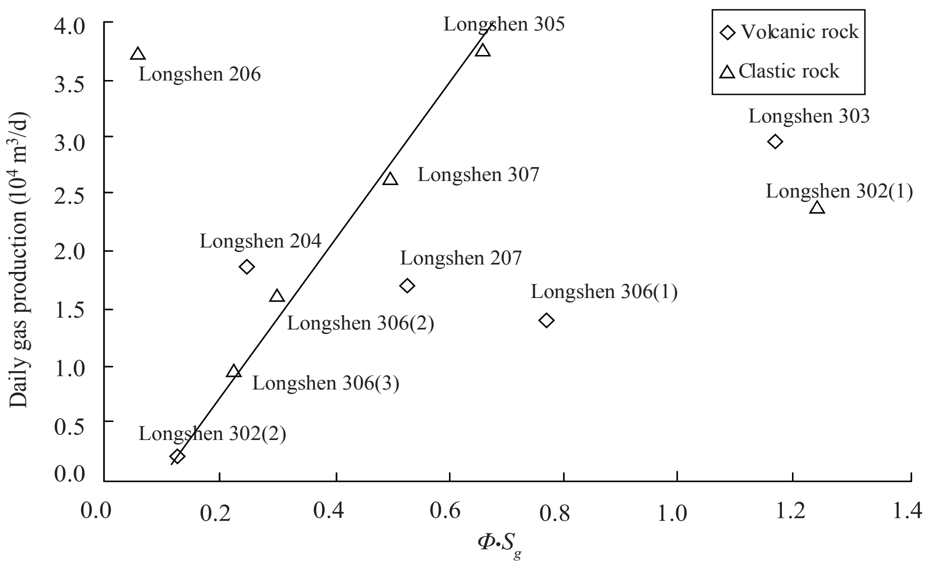

Figure 4
Relation Between $\Phi \cdot S_g$ and Daily Gas Production of the Gas Testing Wells

From Figures 3 and 4, $\Phi \cdot S_g$ and daily gas production have bad correlation. However, quasi-formation capacity can more clearly reflect the law of daily gas production under different lithology. After dividing lithology, there is better correlation between quasi-formation capacity and the daily gas production. So we can use quasi-formation capacity which has two kinds of lithology as the productivity prediction parameters of this area.

2.2 Outliers Analysis

The quasi-formation capacity and daily gas production of clastic rocks have good correlation. However, in the relation curve of volcanic rock quasi-formation capacity and daily gas production, there are two outliers, namely Longshen 302(1) and Longshen 206. The cause of abnormity can be analyzed from fracturing technology, reservoir physical property and lithology (Figure 5).

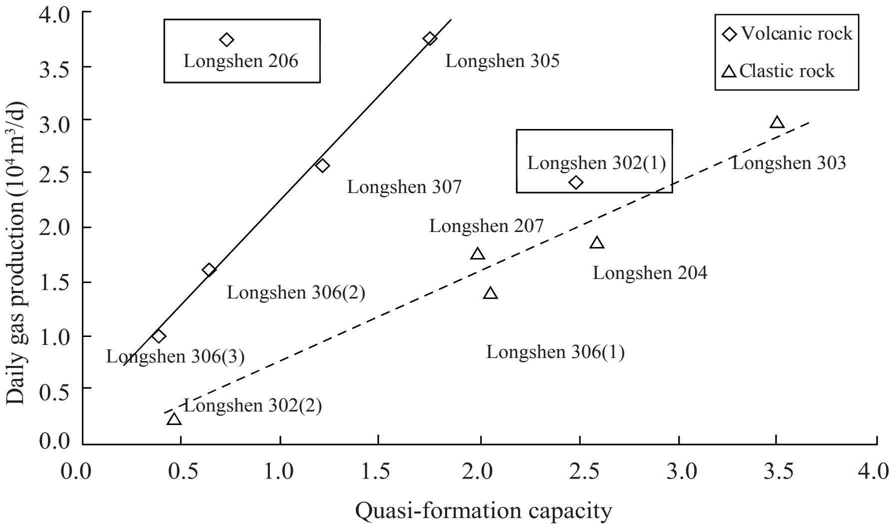

Figure 5
Outlier Analysis

Table 1
Data of Outlier Analysis

Wellname	Interpretation layer	Section (m)	Effective thickness (m)	Porosity (%)	Quasi-formation coefficient	Fracturing size		Llithology		Interpretation result	Daily gas production (km³/d)
						Adding sand per meter (m³/m)	Cumulative adding sand (m³)	Volcano rock thickness (m)	Clastic rock thickness (m)		
Longshen 206	270-272	4,454.0-4,439.0	7.4	0.093	0.72	7.30	54	15	0	Gas reservoir	37.59
Longshen 302 (1)	243-298	4,005.0-3,685.0	28.9	0.085	2.50	1.38	40	8	0	Gas reservoir	23.80

Reservoir physical property and lithology are the internal causes of affecting reservoir gas production. The external causes are rational allocation of fracturing parameters. The greater the strength of adding sand is, generally speaking, the greater the strength of fractured productivity is. Abnormal high values of Longshen 206 are caused by adding a large amount of sand. In the first section gas testing section of Longshen 302, effective thickness is large. Therefore, quasi-formation capacity is big while few amount of sand per meter is added and the volcano rock is thin, which leads to abnormal low value.

2.3 Formulas for Productivity Prediction

After removing outliers, the following formulas can be regressed respectively on the volcanic rock reservoir and clastic rock reservoir, according to the relation curve of the quasi-formation capacity and initial single well production of gas testing wells.

Fitting relation of the volcanic rock,

$$q_g = 19.952\Phi h + 2.2929, \quad R^2 = 0.9963. \qquad (2)$$

Fitting relation of the clastic rock,

$$q_g = 8.8658\Phi h - 2.7078, \quad R^2 = 0.9904. \qquad (3)$$

2.4 Verification of Productivity Prediction

Vertify the above empirical formula of single well productivity by the average daily gas production of 2 gas testing wells in this area in November, 2013. The maximum prediction relative error is 5.3% and the average relative error is only 4%, indicating that this method has higher accuracy on productivity prediction.

Table 2
The Average Daily Gas Production of 2 Gas Testing Wells

Wellname	Φh	Predicted production (km³/d)	Actual output (km³/d)	Relative error (%)	The average relative error (%)
Longshen 309	1.47	31.62	33.31	5.3	4.0
Longshen 207	2.32	17.86	17.38	2.7	

CONCLUSION

(a) The internal factors affecting the productivity of the gas well are reservoir physical property parameters such as effective thickness, porosity, permeability and gas saturation. The external factors affecting the productivity of the gas well are the change of formation pressure.

(b) The quasi-formation coefficient established by different lithology and daily gas production has good correlation. Quasi-formation coefficient can be used to predict productivity. The prediction gas production conforms well to the actual gas production. Therefore this method can be used to predict the daily gas production effectively.

REFERENCES

[1] Zhao, J. C., Zhang, S. H., & Qi, C. X. (2010). Research on method of splitting production calculation and analysis of practical results. *Inner Mongolia Petrochemical Industry*, *3*, 29-30.

[2] Huang, Q. H., Cao, W. J., & Yang, L. K. (2000). A new method of determining gas wells productivity. *Natural Gas Chemical Industry*, *20*(4), 59-60.

[3] Xie, X. L., Zhu, Y. X., & Ji, G. (2004). The evaluation method of gas reservoir productivity and its application. *Natural Gas Geoscience*, *15*(3), 276-278.

[4] Li, Y. H., Wang, J. J., & Wang, X. (2011). Study on the method of rapid productivity predicting of gas wells in ancient times in Jingbian gasfield. *Petrochemical Application*, *30*(10), 15-16.

[5] Wang, Y., Zhu, G. S., & Wang, F. (2005). Application of fine structure interpretation and reservoir prediction technique in the exploration of Yaoyingtai area. *Progress in Exploration Geophysics*, *28*(4), 285-289.

[6] Fan, X. J., Huang, Y., & Deng, J. H. (2011). Relationship between reservoir physical property and productivity. *Natural Gas Technology and Economy*, *5*(4), 29-32.

[7] Yang, D. X., Yang, J. S., & Zhang, Z. T. (2010). Study on the factors affecting the productivity of fractured gas wells. *Drilling & Production Technology*, *77*, 32-33.

[8] Liu, Q. G., Wang, H., & Wang, R. C. (2010). The calculation and influencing factors of multilayer gas reservoir wells layered production contribution. *Journal of Southwest Petroleum University* (*Natural Sciences*), *32*(1), 80-84.

