Study on the main controlling factors of horizontal well production capacity in tight gas reservoirs in Ordos Basin

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Abstract. Affected by various geological factors and engineering factors such as reservoir characteristics, horizontal section length, fracturing scale, etc., there are large differences in the production capacity of the single well of the volumetric fracturing horizontal well in the 8th section of the Sulige block box, but the main control factors are not clear. To this end, taking more than 180 horizontal wells in Sulige Area A as a sample, the Pearson correlation method was used to analyze the influence of geological and fracturing construction parameters on production capacity, and the main control factors of single well production capacity were clarified. The results show that the total sand volume, total liquid volume, effective reservoir drilling rate, horizontal section length, effective number of cracks, construction displacement and average sand ratio are the main control factors affecting the production capacity of the horizontal well in the block, based on the above understanding, optimizing the fracturing construction parameters has good guiding significance for the efficient development of tight gas.

Keywords: tight gas reservoirs, horizontal wells, capacity master factors, Pearson correlation analysis.

1. Introduction

Sulige gas field is located in the Ordos Basin, structurally subordinate to the Yishan slope, the main production layer is the Permian stone box formation, the lithology is dominated by clastic sandstone, the pressure coefficient is less than 0.9, the average porosity is less than 10%, the effective permeability is less than 0.1×10^{-3}um^2, which is a typical low-porosity, low-pressure, low-permeability and low-abundance "four low" lithological gas reservoirs. Affected by multiple factors of geological engineering such as reservoir characteristics and fracturing transformation, the production shows the characteristics of large differences in the production capacity of horizontal wells and low production and low efficiency of some wells, so it is of great guiding significance to clarify the main control factors of production capacity and optimize the development of technical countermeasures for the subsequent efficient development of tight gas. [1-2]

At present, scholars at home and abroad have studied more on the influencing factors of the production capacity of horizontal wells for shale gas fracturing in North America, mainly using spatial statistics method, neural network method, gray correlation method and other methods, but compared with North American shale gas, the inland compact gas high-quality reservoir thickness is small, the heterogeneity is strong, and the tight gas pressure coefficient of Ordos Basin is low, and the research results are not fully adapted to the tight gas of Sulige gas field. In order to solve the problem of large difference in the production capacity of horizontal wells in the Sulige gas field in Ordos Basin, this paper starts from the perspective of geological engineering integration, based on the geological data, construction data and production data of Block A, takes more than 200 horizontal wells as samples, analyzes the influence of various geological engineering factors on production capacity by Using the Pearson Correlation Method, screens out the main control factors of production capacity, and provides support for improving the development effect of tight gas based on the main control factor fracturing construction parameters.[3-4]

2. Overview of the study area

The main gas producing horizons in Su a block are the strata of He8 member of Lower Shihezi Formation and Shan 1 member of Shanxi formation of Permian system, in which He8 member is subdivided into 6 sub layers and Shan 1 member is divided into 3 sub layers, and the average burial depth of gas reservoir is 3150 ~ 3500m; The sand body of Shan 1 member belongs to meandering river facies, with the sedimentary characteristics of multi-channel low curvature meandering river (or intertwined River). The lithology is mainly continental sedimentary rock shoulder sandstone. The reservoir pore types in this area include rock debris solution pore, intergranular pore, intergranular pore, heterobasic solution pore and shrinkage pore, among which rock debris solution pore is the main one. Among them, compared with He8 member, the rock debris solution pore in Shan 1 member is significantly reduced and the intergranular pore is significantly increased, which should be caused by different sedimentary environment and diagenesis. The overall heterogeneity of pore throat structure of reservoir in the block is strong, with small main contribution throat, small pore throat, high displacement pressure, poor sorting, low continuous phase saturation and low permeability. The development of sandstone in the block is relatively rich, and the sand body is widely distributed. It is distributed in a wide strip extending from north to south in the work area.[3]

The production capacity of a single well varies greatly, and this paper analyzes more than 200 horizontal wells that are put into production under the same development technology policy and have a cumulative production time of more than half a year as the research object.

3. Analysis of main control factors of single well production capacity

The target block is a typical low-porosity, low-pressure, low-permeability, low-abundance "four low" lithological gas reservoirs, so only through large-scale transformation can industrial output be obtained, and its gas production is affected by two major factors: geology and engineering.[5]

3.1. Geological Factors

3.1.1. permeability

Because the filtration of fracturing fluid and the conductivity of proppant increase with the increase of effective permeability, the permeability is an important factor that must be considered in the optimization of fracturing materials. The permeability of the target block is mainly concentrated at 0.2-1.5md, the permeability of layer 1 of Shan formation is concentrated at 0.25-0.75md, and the overall permeability distribution of box 8 is similar to that of the target block. From the statistical logging data, there is no obvious correlation between the overall permeability distribution of the target block and the average monthly cumulative production in the initial 90 days. Under the natural production system, the permeability and production show a certain positive correlation.

3.1.2. mud content

The shale content in the target block is mainly concentrated in 10%-20%. Similarly, the number of wells in He8 formation and intermittent production system account for most of the data. On the whole. There is no obvious correlation between the mud content of the target block and the average monthly cumulative production in the initial 90 days. There is a certain negative correlation between the mud content and production of natural production wells, measure continuous production wells and changguan well. The higher the mud content, the higher the fracture pressure, the difficulty of fracture making, and the production after fracturing also decreases.

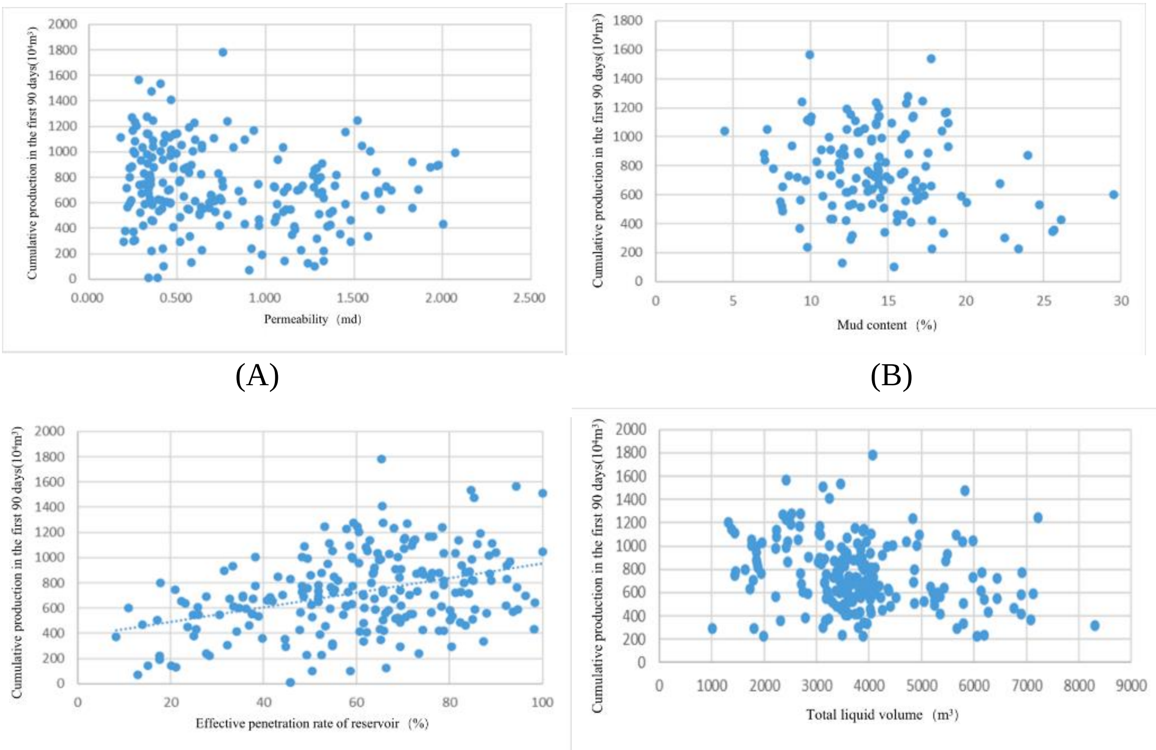
3.2. Engineering Factors

3.2.1. effective penetration rate

The effective drilling rate of the reservoir in the target block is 10%-90%, which is widely distributed. There is an obvious positive correlation between the effective reservoir penetration rate under different horizons and different production systems and the average monthly cumulative production in the initial 90 days. It is suggested to optimize the well trajectory and improve the effective reservoir penetration rate; To increase production.

3.2.2. total liquid volume

The total liquid volume of single wells in the target block is concentrated in 2000-6000m^3, the total liquid volume of single wells in Shan 1 formation is 3000-5000m^3, and the liquid volume of single wells for continuous wells and long-term shut in wells is about 4000m^3. It can be seen from the statistical data that when the total liquid volume of a single well is 1000m3, the production is very low. When the liquid volume is greater than 4000m^3, the production decreases with the increase of the liquid volume. This is because with the expansion of the fracture, the filtration of the fracturing fluid becomes more and more serious. Too much liquid volume can not create a long fracture, resulting in low efficiency of the fracturing fluid. If the amount of fracturing fluid is too small, it can not cause the expected fracture length.



(A) (B)

(C) (D)

Figure 1. Analysis of factors affecting production capacity

3.3. Analysis of Main Control Factors

Combined with the correlation between the above influencing parameters and production, taking reservoir geological parameters, drilling data, logging interpretation data, fracturing data and production data as data sets, Pearson correlation coefficient method is used to determine the correlation degree between various factors and production, and random forest algorithm is used to obtain the influencing factors of multiple factors on production capacity, so as to quantitatively evaluate and determine the main controlling factors of production capacity.[6]

The influence laws of different parameters on the reference sequence are different, and there is no single positive correlation or negative correlation. On the one hand, the effective thickness, oil saturation, permeability, porosity and other physical parameters of the reservoir have a significant impact on the physical properties of the reservoir, and then have a great impact on the reference series (i.e. post fracturing output), and they are positively correlated with the reference series in a certain range, which is suitable for the treatment of production benefit type; On the other hand, although there are uncertainties in the impact of most factors on the reference series, some scholars choose the benefit type for treatment in relevant research, which shows that the selection of benefit type treatment is reasonable from the whole. Therefore, the benefit type in the extreme value method is finally used to deal with the basic data dimensionless.

$$Y_i(k) = \frac{x_i(k) - \min x_i(k)}{\max x_i(k) - \min x_i(k)}, \quad i \in (1,2,\cdots,m), k \in (1,2,\cdots,n) \tag{1}$$

In the field of statistics, Pearson correlation coefficient is often used to measure the linear correlation between two variables. The value of Pearson correlation coefficient is between - 1 and + 1;- 1 indicates the complete negative correlation between the two variables, + 1 indicates the complete positive correlation between the two variables, and 0 indicates that the two variables are completely independent; The closer it is to 1 or - 1, the stronger the linear correlation between the two variables. The calculation formula is as follows:[7]

$$\rho_{x,y} = \frac{\operatorname{cov}(x,y)}{\sigma_x \sigma_y} \tag{2}$$

Table 1. Results of Multi Parameter Correlation Analysis.

Parameter	Correlation coefficient	Parameter	Correlation coefficient
Total sand	0.53	Total liquid volume	0.42
Effective reservoir penetration rate	0.37	Long horizontal section	0.23
Number of effective cracks	0.21	Construction displacement	0.19
Average sand ratio	0.15		

Through the correlation coefficient between production and the two variables of the seven main influencing factors selected, it is found that the correlation degree between different factors and production is as follows: total sand volume > total liquid volume > effective reservoir penetration rate > horizontal section length > number of effective fractures > construction displacement > average sand ratio.

4. Conclusions

(1) The productivity difference of tight gas horizontal wells is the result of the comprehensive action of many factors. High quality reservoir and effective horizontal section length are the basis to ensure the production of single wells. On this basis, the organic matching with large-scale effective fracturing transformation is the main controlling factor for the high yield of tight gas horizontal wells.
(2) Using Pearson correlation coefficient method algorithm, seven main control factors of tight gas productivity are determined, including geological parameters and engineering parameters. According to the weight, they are total sand volume, total liquid volume, effective reservoir penetration rate, horizontal section length, effective fracture number, construction displacement and average sand ratio.

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References

[1] Fu Jinhua, Niu Xiaobing, Tan Weidong, et al. Geological characteristics and exploration and development progress of tight gas in Zhonghe 8 section of Ordos Basin[J]. PetroChina Exploration, 2019, 24(5)1-10.

[2] Li Jinbu, Bai Jianwen, Zhu Lian, et al. Volume fracturing and its practices Sulige tight sandstone gas reservoirs, Ordos Basin[J]. Natural Gas Industry, 2013, 33: 65-69.

[3] Sun Bing, Liu Lifeng, Ding Jianghui Study on main geological factors controlling productivity of tight oil horizontal wells [J] Special oil and gas reservoir, 2017, 24 (2): 5

[4] Liu Wei, Li Chaoxia, LV Yanping, et al Analysis of influencing factors of EUR in Bakken tight reservoir in the United States [J] Petroleum Geology and engineering, 2016, 30 (2): 3

[5] Zhan Lufeng, Guo Bincheng, Wei Yuanjiang, et al Analysis of main controlling factors of tight oil production based on deep learning method [C] / / CPS / SEG Beijing 2018 International Geophysical conference and exhibition

[6] Sun Jing, Liu Dehua, Zhang Liang, et al Grey correlation analysis of influencing factors of decline in low permeability reservoir [J] Special oil and gas reservoir, 2012, 19 (002): 90-93

[7] Ji Lei, Li Juhua, Xiao Jialin Application of random forest algorithm in multi-stage fracturing reconstruction of shale gas field [J] Daqing Petroleum Geology, 2020, 39 (6): 7