Sweet Spots Selection Of Low-Abundance Coalbed Methane Reservoir

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Abstract

Low abundance coalbed methane reservoirs are characterized by low abundance, unclear factors affecting gas well productivity, and strong heterogeneity. These characteristics make the development of gas reservoirs difficult. The study is based on well logging interpretation and the guidance of the gas well production capacity against these difficulties. Using methods of the gas reservoir production characteristics analysis and numerical simulation, the relationships among the low abundance of CBM reservoir production well productivity, reserves abundance, main coal desorption pressure, interlayer interference, and continuous water drainage, were studied. Studies have shown that the main controlling factors of low abundance of CBM are block construction factors, resource abundance and gas saturation. The study also confirmed that 2# coal seam is not suitable for mining with the main coal seam, and 6# coal seam in some areas is suitable for mining with the main coal seam. This method is highly targeted, has a strong production basis and high reliability based on the current production situation of the block.

Geological Characteristics of AA block

The AA coalbed methane block is located in Shanxi Province. The Permian and Triassic systems are widely distributed in gullies and mountain tops. The main structural framework is the north-northeast parallel fault. The north-south fold runs through the central and western part of the Xishan coalfield, forming a syncline coal basin with a gentle slope in the east and a steep slope in the west. The coal-bearing rocks in this area include the Middle Carboniferous Benxi Formation, the Upper Carboniferous Taiyuan Formation, the Lower Permian Shanxi Formation and the Lower Shihezi Formation. The development layers are mainly 2#, 6#, 8# and 9# coal seams. The main coal seam is 8# and 9# coal seam. The physical properties of the main coal production layers in the area are basically the same, showing black or dark brown color, the streak color is dark black or brown, glass-strong glass luster. The hardness is generally 3-4, with certain toughness, mostly block structure, and primary fissures are well developed. It is so brittle to be broken into powder, with staggered or shell-shaped fracture, bulk density 1.39-1.43 tons/cubic meter. The main characteristics of the whole area is that the thickness of the main coal seam is thin, the gas content is low, the distribution is uneven, and the development is difficult.

Analysis of Main Control Factors of Production

Block Construction Factors. Affected by the late tectonic movement, a nasal structure was formed in the

DOI: 10.14800/IOGR.1156
Received March 2, 2019; revised May 14, 2020; accepted May 20, 2020.
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middle of the block. It leads to stress concentration in the strata near the structure, and the effect of reconstruction measures is poor. It is difficult to add sand during fracturing, which is difficult for engineering reconstruction. The gas content is low and the coal structure is broken, forming a low production area. High and stable production wells are mainly distributed in non-structural areas. The structural area is characterized by low output and difficulty in stabilizing production. At present, the average gas production of a single well in a non-structural area is 5 times that of a structural area.

Resource Abundance. Resource abundance is an important factor for evaluating coalbed methane reservoirs, and it is also a key factor affecting the productivity of coalbed methane (Yan et al. 2008; Chen et al. 2010; Wu et al. 2018; Tian et al. 2018). AA block is affected by reservoir-forming factors, among which the resource abundance is low, and the distribution is uneven. There are currently few indicators to evaluate resource abundance, especially for coalbed methane. The application of well logging data can solve the problem of characterizing resource abundance of heterogeneous coalbed methane. In areas with relatively mature development, using logging data to study reserves abundance has achieved good results. The result was well verified in the later development.

Gas Saturation. There are less experimental data on desorption and adsorption during the development of coalbed methane reservoir, so is measurement data of gas saturation, which cannot be evaluated in the whole region (Liu et al. 2013; Li et al. 2020). According to the desorption characteristics of coalbed methane, the desorption characteristics of the whole area can be evaluated by the critical desorption pressure of upper main layer.

According to the statistics of observed gas pressure and gas production volume of no.8 coal in the whole region, the observed gas pressure is exponentially related to the average gas production volume of a single well, and the gas production effect is better when the observed gas pressure reaches 1.8MPa (**Figure 1**).

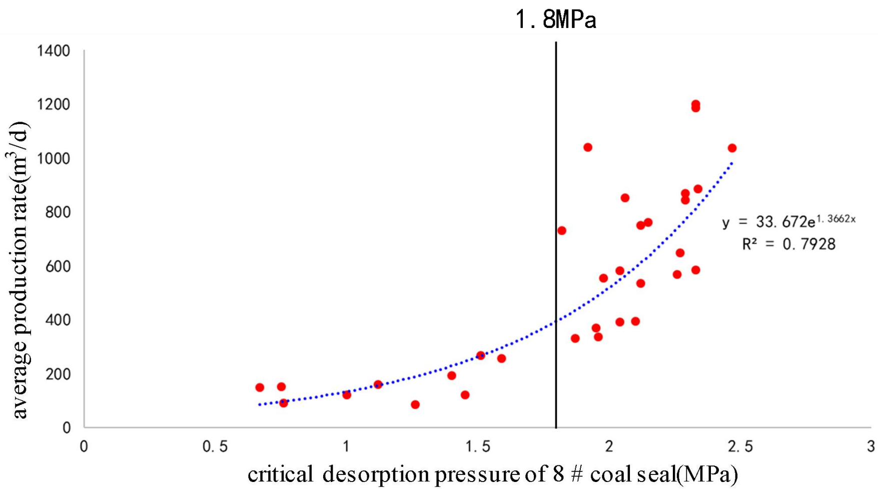

Figure1—The relationship between the gas critical desorption and average gas production rate.

Research on Different Layered and Combined Production

Productivity Performance Law of Co-Production Wells in the Whole Area. According to the perforation situation of existing wells, the production situation of wells with different perforation conditions is analyzed (Qin et al. 2018; Qin et al. 2010; Zhang and Tong 2007). The analysis results are shown in **Figure 2**. Regardless of the co-production of 8# and 9# coal, or the co-production of 6#, 8# and 9# coal, after adding 2# coal, the production is significantly reduced. Regardless of the co-production of 8# and 9# coal, or the co-production of 2#, 8# and 9# coal, after adding 6# coal, the production is significantly reduced.

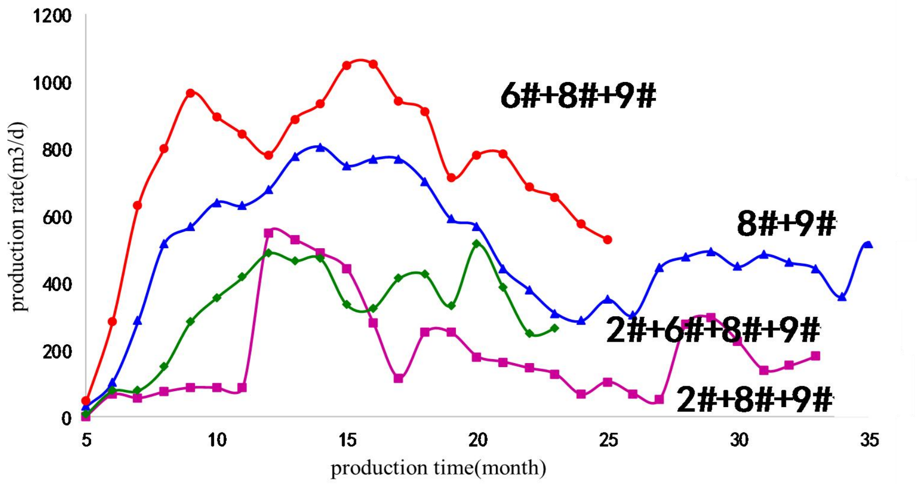

Figure 2—Different production rate with different layer combination.

Comparison of Combined Production Capacity in the Same Well Group. This study compared 28 wells in 10 different well groups. Different production wells in the same well group have similar geological characteristics, consistent development processes and production schedule, but different co-production layers. The optimal combination of layers can be determined by comparing the production effect of different single wells in the same well group.

Through this comparison (**Table 1** and **2**), 2# coal is not good for co-production with main coal seam, and well groups with good co-production effect are basically located in the area with high abundance of 6# coal reserves.

Table 1—The comparison of well production contains 2# coal and not contains 2# coal.

Well group name	Well number contains 2# coal	Well number not contains 2# coal	Average well production contains 2# coal(m^3/d)	Average well production not contains 2# coal(m^3/d)
No.1	2	3	556	839
No.2	2	4	632	909
No.3	3	4	509	798

Table 2—The comparison of well production contains 6# coal and not contains 6# coal.

Well group name	Well number contains 6# coal	Well number not contains 6# coal	Average well production contains 6# coal(m^3/d)	Average well production not contains 6# coal(m^3/d)
No.1	2	3	446	732
No.2	2	4	773	721
No.3	3	4	711	732
No.4	4	2	899	733
No.5	2	3	936	802
No.6	4	1	831	701
No.7	3	3	956	785

Therefore, 2# coal seam is not suitable for co-production with 8# coal seam and 9# coal seam, which is mainly due to the long distance between 2# coal seam and 8# coal seam and 9# coal seam. Those coalbed seams are not under the same pressure system, and interlayer interference is great. The distance between 6# coal seam and 8# coal seam is shorter. Those layers are under the same pressure system and interlayer interference was smaller. When the reserves abundance of 6# coal seam reaches a certain value, it can be co-produced with 8# coal seam and 9# coal seam.

Research on the Combined Production Limit of Non-Main Coal Seam and Main Coal Seam. A numerical simulation model of three-layer co-production in AA block is established to study the contribution of 6# coal gas production when 6#, 8#, 9# coal is combined. the basic parameters of the model displayed in Tab. 3. The model has 1280 grids, including three formations, representing coal seam no. 6, no. 8 and no. 9 successively from top to bottom. The production well type is directional well, of which the development method is constant pressure production. The numerical model is displayed in **Figure 3**. **Table 3** shows the basic parameters that were used to build the model. When the abundance of 6# coal reserves reaches 0.25 bcm/km^2, the gas production of a single well increases by 610,000 cm (**Figure 4**), the increase of production rate reaches 24%, and the contribution amount reaches 18%, which is suitable for co-production.

Table 3—The basic parameters of the model.

Parameters	Values
Average depth, m	650
6# coal thickness, m	1.5
8# coal thickness, m	4.5
9# coal thickness, m	3
Permeability, mD	0.05
Porosity, %	4.5
Original pressure, MPa	2.26
Original gas content, m^3/t	9.9
Gas saturation, %	48
Langmuir volume, m^3/t	20.49
Langmuir pressure, MPa	2.58

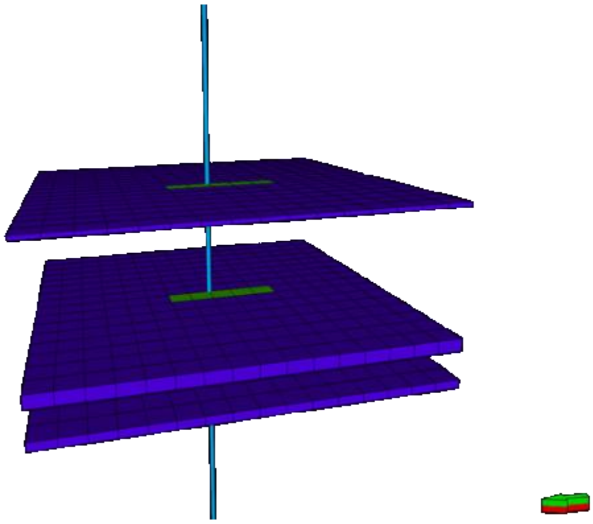

Figure3—Numerical simulation model of reservoir.

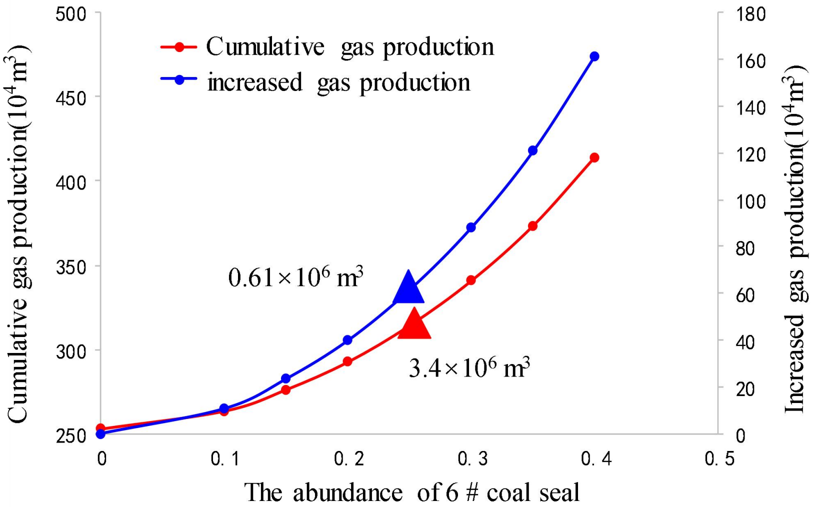

Figure4—Contribution of 6# coal under different reserve abundance.

Well Pattern Optimization

When the permeability of AA block is between 0.01mD-0.1mD, the diffusion of pressure drop funnel was difficult. Especially, when the coal seam in the block is thin, selecting directional well development will result in low recovery factor and poor economic benefits for the entire block. According to the drilling condition in block AA in the early stage, the effective drilling catching rate of horizontal well is relatively low in some areas, and the economic benefits of using horizontal wells are poor. Moreover, for the areas where geological parameters are not implemented, the horizontal well development has great risks. To sum up, the mixed pattern of directional well and horizontal well is selected for development this time, with horizontal well as the main one and directional well as the secondary one to improve the development efficiency.

Under the influence of the direction of hydraulic fracture extension, there is a large gap between the gas productivity in the fracture extension direction and perpendicular to fracture extension direction (**Figure 5**). In view of this feature of strong heterogeneity, the diamond well network is used as the basic well pattern to deploy wells in the block. The long side of the diamond well pattern is consistent with the direction of fracture extension, while the short side is perpendicular to the direction of fracture extension.

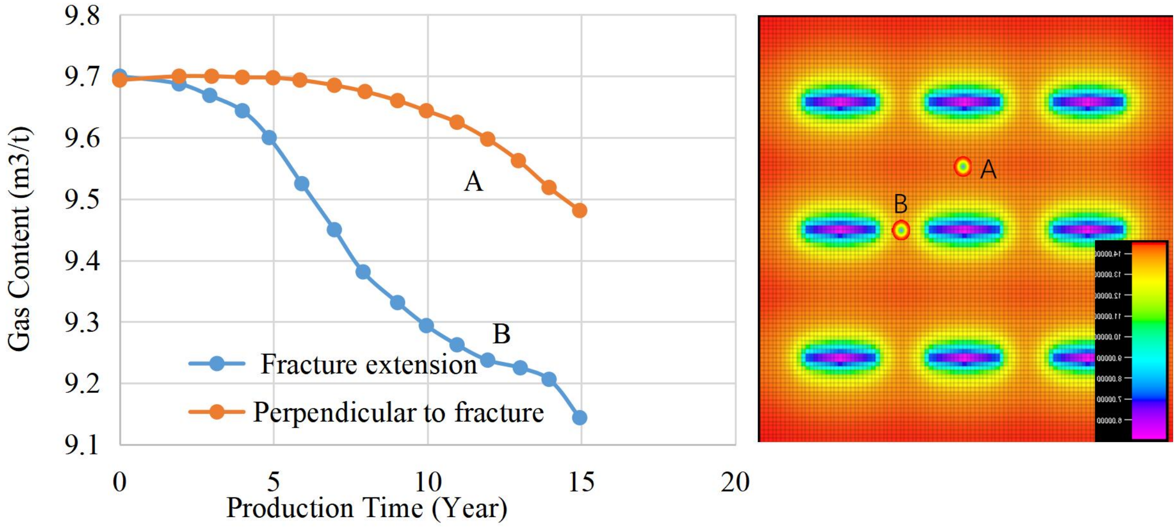

Figure 5—Gas content change along fracture extension direction and perpendicular to fracture in 8# coal.

Conclusions

In this study, we conducted geological research, production analysis, numerical simulation, and summarize the conclusions as follows,

1. The AA block is affected by the late tectonic movement, and a nosal structure formed in the middle. Nosal structure is the main reason for the formation of low-yield areas. Other main factors affecting the productivity of a single well are the resource abundance and gas saturation of the block.
2. Since they are not under the same pressure system, the 2# coal seam in the whole area is not suitable for co-production with 8# coal seam and 9# coal seam. 6# coal can be produced together with 8# coal seam and 9# coal seam when the reserves abundance reaches 0.25 bcm/km^2.
3. The AA block is currently suitable for the development by a mixed directional wells and horizontal wells, with horizontal wells as the main and directional wells as the secondary. The directional wells are better deployed with diamond pattern with the long side of the diamond pattern consistent with the fracture extension direction, while the short side perpendicular to the fracture extension direction.

Acknowledgement

We appreciated the fund "National Science and Technology Major Project-CBM development from high-rank coals in the Qinshui Basin" (2017ZX05064) for financial support.

Conflicts of Interest

The author(s) declare that they have no conflicting interests.

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