

Influence of complex geological structure on horizontal well productivity of coalbed methane

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Abstract. Complex geological conditions have a great influence on the mining of coalbed methane (CBM), which affects the extraction efficiency of CBM. This investigation analyzed the complicated geological conditions in the Liujia CBM block of Fuxin. A geological model of heterogeneities CBM reservoirs was established to study the influence of strike direction of igneous rocks and fault structures on horizontal well layout. Subsequently, the dual-porosity and dual-permeability mathematical model was established, which considers the dynamic changes of porosity and permeability caused by gas adsorption, desorption, pressure change. The results show that the production curve is in good agreement with the actual by considering gas seepage in matrix pores in the model. Complicated geological structures affect the pressure expansion of horizontal wells, especially, the closer to the fault structure, the more significant the effect, the slower the pressure drop, and the smaller the desorption area. When the wellbore extends to the fault, the pressure expansion is blocked by the fault and the productivity is reduced. In the study area, the optimal distance to the fault is 70 m. When the horizontal wellbore is perpendicular to the direction of coal seam igneous rock, the productivity is higher than that of parallel igneous rock, and the horizontal well bore should be perpendicular to the cleat direction. However, the well length is limited due to the dense distribution of igneous rocks in the Liujia CBM block. Therefore, the horizontal well pumping in the study area should be arranged along the direction of igneous rock and parallel plane cleats. It is found that the larger the area surrounded by igneous rock, the more favorable the productivity. In summary, the reasonable layout of horizontal wells should make full use of the advantages of igneous rock, faults and other complex geological conditions to achieve the goal of high and stable production.

Keywords: CBM; horizontal well drainage; intrusive igneous rock; pressure distribution; sealing fault

1. Introduction

Coalbed methane (CBM) is a combustible organic gas produced in the process of coalification. It is a high-quality and clean unconventional energy (Walter and Ayers 2002, Sarhosis *et al.* 2016, Jiang *et al.* 2018, Pan *et al.* 2013). Many scholars pointed out that the productivity of the CBM is mainly affected by geological and engineering conditions (Jackson and Reddy 2007, Clark 2011, Wu *et al.* 2019a, b, 2020a, b, Hu *et al.* 2021, Zhao *et al.* 2021, 2022, Chu *et al.* 2022). For the geological condition, the main factors including gas permeability, content, fault, igneous rock dyke and other complex geological structures, and the engineering condition include changes in CBM reservoirs during drilling, completion and stimulation (Salmachi and Karacan 2017). The vertical wells and horizontal wells are two main types of CBM drilling (Whittles *et al.* 2007,

Hungerford *et al.* 2013, Schatzel *et al.* 2012). Horizontal CBM wells are more suitable for the development of low-permeability CBM (Clarkson and Qanbari 2016, Yan, *et al.* 2019, Wu *et al.* 2021a, b, 2022a, b). The completion interval is longer, which can maximize the communication between fracture channels. The pressure relief area is larger, and the output of the single well is higher. It can enhance the connectivity of fault block gas reservoir and has the reasonable length control and directional control that the vertical fractures do not have.

On the basis of making full use of the geological conditions of coalbed methane development, understand the drainage and production law of coalbed methane and obtain high and stable production gas wells. MacDonald (2006) studied the influencing factors on well productivity by statistical analysis, simulation and geological coupling analysis. The permeability of CBM reservoir is significantly influenced by the fracture distribution in the coal, and the distribution of fractures also affects the migration of the CBM (Pan *et al.* 2014). The geological accumulation, sedimentary environments and coal accumulation periods have large differences in many basins, so the CBM productivity and reservoir production increase have different characteristics. Maricic *et al.* (2008) used geological parametric analysis to optimize the number of

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wells, the total length and spacing of the wells to optimize the drilling position of the multilateral wells and horizontal wells. Li *et al.* (2018) analyzed the influence of deep CBM geological conditions on CBM development in the eastern edge of Ordos Basin, and studied the impact of deep CBM geological conditions with high reservoir pressure, high temperature and high stress on CBM development. However, the geological conditions of coal reservoirs in China are complex, and the pressure expansion of coalbed methane reservoir under complex geological conditions is affected by geological structure (Yan *et al.* 2021, Dong *et al.* 2021, Bustin and Clarkson 1998, Liang *et al.* 2014). There are still many technical problems to be solved and improved in horizontal well mining. Coal bearing basins have undergone complex tectonic transformation movement, resulting in extremely complex coalbed methane geological conditions. For specific coal reservoir conditions, corresponding development technical conditions should be adopted.

Dual-porosity and dual-permeability are currently the most widely used gas migration model with the highest recognition by scholars. Li *et al.* (2018) established a dual porosity and dual permeability (DPDP) model, which combines gas adsorption and gas permeability correction to describe the fluids flow of multi-stage hydraulically fractured horizontal wells in shale-gas reservoirs and transient pressure behavior. Prob *et al.* (2012) regards the coal seam as a dual-porosity and dual-permeability system, considered the influence of water in the coal matrix, and established a numerical model. The development of the proposed numerical model incorporates the effects of water presence in the coal matrix and the phenomena of coal shrinkage and swelling. Xu *et al.* (2021) studied the influencing factors of coalbed methane production through numerical simulation based on dual porosity and dual permeability models. At present, the mathematical model of CBM drainage mostly ignores the existence of free gas in matrix pores, and only assumes that the desorption gas on the inner surface of coal matrix directly diffuses into the fracture system, which is not very accurate. Adding the seepage equation of free gas in matrix pores in the model makes the study of CBM out-flow and extraction law more in line with the reality and the accuracy of productivity prediction is higher.

This thesis uses a dual seepage model to study pressure-sensitive reservoirs. This model not only considers the dual permeability characteristics of the coal reservoir, but also considers the change of permeability and porosity pressure-sensitive formation. The mathematical model of matrix pore system and fracture dual pore system considering the dynamic changes of porosity and permeability of coal reservoir caused by gas adsorption, desorption and pressure change are established. A mathematical model of dual permeability flow is established. Taking Liujia coalbed methane block in Fuxin as the engineering background, the geological model considered the complex geology of faults, igneous dikes and irregular folds in the actual reservoir. The geological model of heterogeneous coalbed methane reservoirs has been established. Combining the igneous rock and the special geological structure of fault to study

the horizontal well layout, it makes full use of complex geology advantages of the coal reservoirs around the igneous rock, such as the high permeability and porosity, and the gas reservoir area formed by fault hindering coalbed methane migration. And it also makes better use of the advantages of horizontal wells to obtain more fractures and increase production, which will have great research value.

2. Establishment of mathematical model of double hole and double permeation

2.1 Fundamental equation

(1) The diffusion of gas from the matrix system to the fracture system is governed by Fick's first law

$$\frac{\partial V_m}{\partial t} = -\frac{1}{t} [V_m - V_E(p_{mg})] \quad (1)$$

$$q_{vm} = -F_G \frac{dV_m}{dt} \quad (2)$$

where, q_{vm} represents desorption diffusion rate, $m^3/(m^3 \cdot d)$; V_m represents average gas concentration in micropores of coal matrix, m^3 ; F_G represents geometric factor; V_E represents adsorbed gas content in the micropores of coal matrix in equilibrium with the free gas in the pores of matrix; t represents adsorption time, d .

(2) Water quality exchange between the matrix system and the fracture system obeying the channeling equation

$$q = \alpha \frac{\rho_w}{\mu_w} (p_{fw} - p_{mw}) \quad (3)$$

where, q represents water channeling flow, kg/m^3 ; α represents channeling coefficient; P_{fw} represents pressure of water in fracture, MPa; P_{mw} represents pressure of water in matrix, MPa; ρ_w represents water density, kg/m^3 ; μ_w represents viscosity, $mPa \cdot s$.

(3) Pressure-sensitive model of porosity and permeability

With the drainage of gas and water in coal reservoirs, the change of reservoir pressure leads to the dynamic change of porosity and permeability of coal reservoirs, which is described by Palmer-Mansoori model (Palmer and Mansoori 1998).

$$\frac{\phi}{\phi_0} = 1 + \frac{C_m}{\phi_0} (P - P_0) + \frac{\varepsilon_1}{\phi_0} \left(\frac{K}{M} - 1 \right) \left(\frac{\beta P}{1 + \beta P} - \frac{\beta P_0}{1 + \beta P_0} \right)$$

$$C_m = \frac{1}{M} - \left[\frac{K}{M} + f - 1 \right] \beta \quad (4)$$

$$\frac{K}{K_0} = \left(\frac{\phi}{\phi_0} \right)^i$$

where, β represents matrix compression coefficient, MPa^{-1} ; C_m represents average gas concentration in matrix; ε_1 represents langmuir volumetric strain constant, m^3/t ; K

represents bulk modulus of elasticity, MPa; M denotes elastic modulus of restraint, MPa; ϕ represents porosity; f represents parameters between 0 and 1.

2.2 Mathematical model of gas and water two phase seepage in double hole and double permeation

(1) Crack system:

Water phase

$$\nabla \cdot \left[\frac{\rho_w k k_{rw}}{\mu_w} (\nabla p_w - \rho_w g \nabla H) \right]_f + \alpha \frac{\rho_w}{\mu_w} (p_{fw} - p_{mw}) - q_{fw} = \left[\frac{\partial(\phi_w s_w)}{\partial t} \right]_f \quad (5)$$

Gas phase

$$\nabla \cdot \left[\frac{\rho_g k k_{rg}}{\mu_g} (\nabla p_g - \rho_g g \nabla H) + D_f \nabla \left(\frac{S_g}{B_g} \right) \right]_f + \frac{V_m}{\tau} \left(C_m - \frac{V_L P_g}{P_L + P_g} \right) - q_{fg} = \left[\frac{\partial(\phi_g s_g)}{\partial t} \right]_f \quad (6)$$

(2) Matrix system:

Water phase

$$\nabla \cdot \left[\frac{\rho_w k k_{rw}}{\mu_w} (\nabla p_w - \rho_w g \nabla H) \right]_m - \alpha \frac{\rho_w}{\mu_w} (p_{fw} - p_{mw}) - q_{mw} = \left[\frac{\partial(\phi_w s_w)}{\partial t} \right]_m \quad (7)$$

Gas phase

$$\nabla \cdot \left[\frac{\rho_g k k_{rg}}{\mu_g} (\nabla p_g - \rho_g g \nabla H) + D_f \nabla \left(\frac{S_g}{B_g} \right) \right]_m - \frac{V_m}{\tau} \left(C_m - \frac{V_L P_g}{P_L + P_g} \right) - q_{mg} = \left[\frac{\partial(\phi_g s_g)}{\partial t} \right]_m \quad (8)$$

where, ϕ represents porosity; B represents volume coefficient; s represents fluid saturation; q represents production of coal reservoir under unit volume, $\text{kg}/(\text{m}^3 \cdot \text{d})$; D represents gas diffusion coefficient, m^2/d ; k represents permeability, μm^2 ; p represents fluid pressure, MPa; μ represents viscosity, $\text{mPa} \cdot \text{s}$; kr represents relative permeability; V_L represents langmuir volumetric strain constant, m^3/t ; P_L represents langmuir pressure, MPa; f, m represents fissures and matrix; subscripts w and g represent water and gas, respectively.

2.3 Auxiliary equation

Fissures system: $s_{fg} + s_{fw} = 1, p_{fgw} = p_{fg} - p_{fw}$

Matrices system: $s_{mg} + s_{mw} = 1, p_{mcgw} = p_{mg} - p_{mw}$

2.4 Definite condition

(1) initial condition

$$P_i(x, y, z, t)|_{t=0} = P_i(x, y, z, 0) \quad S_i(x, y, z, t)|_{t=0} = S_i(x, y, z, 0)$$

(2) boundary condition

When under the boundary condition: $\frac{\partial P}{\partial n}|_{\Gamma_2} = 0$;

Internal boundary conditions for coal seam gas wells with fixed output: $r \frac{\partial P(r, t)}{\partial r}|_{r_w} = \text{constant}$.

3. Geological conditions of Liujia CBM block

Liujia CBM block of Fuxin is the first effective low rank coal development block in China. But as the magmatic intrusion is serious, resulting in most dikes distribution in the middle of the block, and impact on the occurrence of coal-bed methane greatly (Prabu and Mallick 2015). The range, distribution and occurrence of magma intrusion in the block will be reflected in the tectonic map of Fig. 1. The irregular strips indicate the intrusion path and fault distribution of igneous rocks respectively. One of the main reasons in the block of abundant coal-bed gas resources is the angry effect of the intrusion of magmatic rocks. When igneous intrusions on the coal seam baking coal metamorphic degree increased, the near igneous dikes and sills will be at large porosity and good permeability. Block divided into separate small regions by the trap and sealing action of the magmatic rocks, and then the local enrichment of the resources in the block formed.

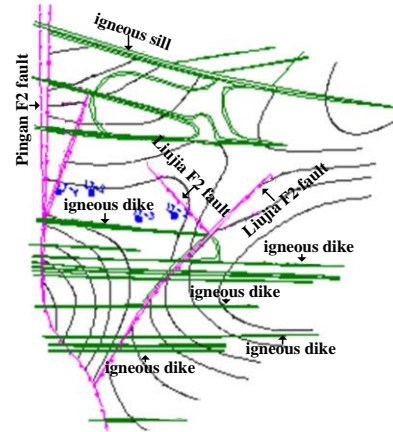


Fig. 1 Structural map of Fuxin Liujia CBM block

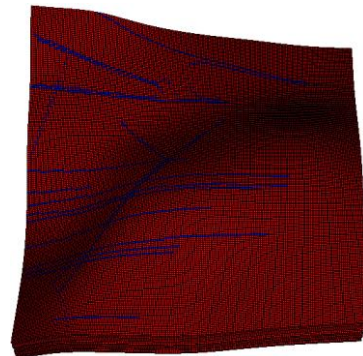


Fig. 2 Three-dimensional geological model

Table 1 The main parameter of numerical simulation

Reservoir	Surface cleat permeability/mD		End cut permeability/mD		Porosity/%		Initial pressure /MPa	Langmuir pressure /MPa	Diffusion coefficient 10 ⁻³ /m ² /d
	Common reservoir	Near the igneous rock	Common reservoir	Near the igneous rock	Common reservoir	Near the igneous rock			
Sunben	0.5	0.8	0.17	0.26	4.7	7.4	6.740	9.98	2.16

The reservoir geological model is established on the basis of the actual geological conditions of the coal-bed gas block in the Liujia block, as shown in Fig. 2. The upper boundary is igneous bedrock having a closed effect on the migration of coal bed gas, treated as a closed boundary. The lower boundary is an isobaric boundary. As the fault in the Liujia block is a compression and torsion fault, the left boundary is separated by the F2 fault, treated as a closed boundary. The right boundary is not affected by mining, treated with closed boundary as well. The basic parameters used in the simulation are shown in Table 1.

4. Numerical simulation of horizontal well drainage in Liujia block CBM

Based on the black oil model, it is improved to make it suitable for CBM production and drainage. Adding water phase permeability and channeling flow, the gas-water two-phase dual porosity and dual permeability model is established, and then solved by finite difference method.

4.1 Model reliability verification

Through the comparison of the production curve and simulation results from Liujia vertical shaft LJ-1, the reliability of the proposed model is verified. From Figures 3 and 4, it can be seen that the daily gas production and water production of a simulated single well are in good agreement with the actual daily production. indicating the reliability of the mathematical models and geological models.

The trend of the production simulated curves of dual-porosity and dual-permeability model and dual-porosity and single-permeability model is consistent. Due to well shut in and well opening, the actual production curve suddenly rises and falls, with a large fluctuation range. however, the simulation result of double porosity is in the middle of the fluctuation curve, which fits better with the actual curve.

4.2 Influence of the relative position of the fault and igneous rock with the horizontal well on the productivity

The gas production capacity and economic net present value (NPV) of horizontal wells are predicted based on the established gas-water two-phase flow model of dual-porosity and dual-permeability CBM. Study and analyze the influence of special geological structure strike of fault and igneous rock on productivity and economic NPV. The economy NPV reflects the net contribution of the project to the national economy, and the greater net present value, the better economic benefits, the formula is as follows

$$NPV = \sum_{i=0}^n \frac{B_{Ti} - C_{Ti}}{(1+r)^i} \tag{9}$$

where C_{Ti} and B_{Ti} represent total cost and total benefit for i years; n denotes period of calculation; r represents benchmark capital yield. Vertical drilling cost of Coal-bed gas in Liujia District calculated as 253.45 million yuan per well; Horizontal drilling cost calculated as 0.35million yuan/m, CBM industry benchmark yield is 12%.

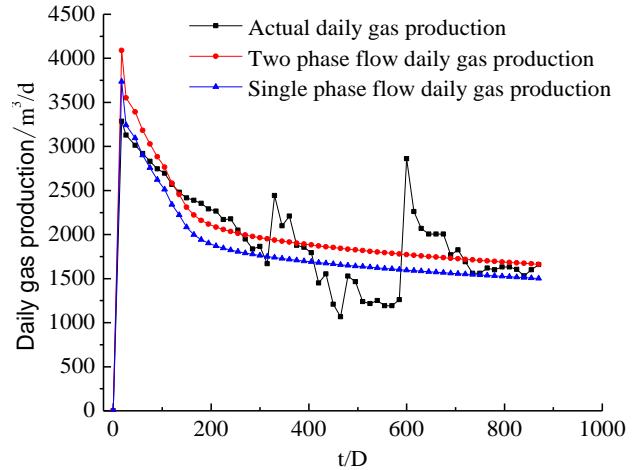


Fig. 3 Contrast of forecast daily gas production and actual data of LJ-1 under the condition of dual-permeability and single-permeability

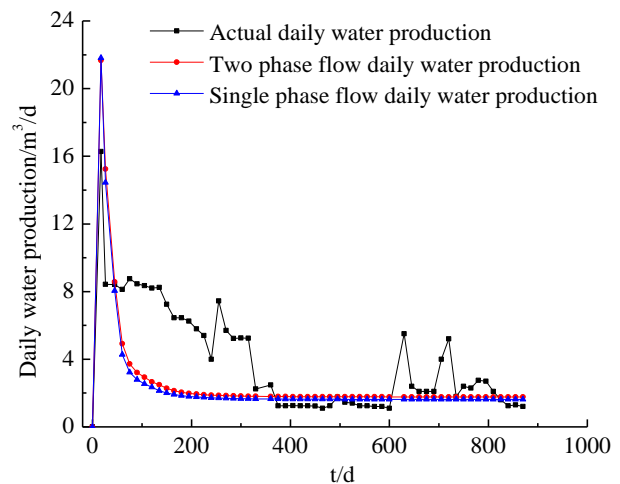


Fig. 4 Contrast of forecast daily water production and actual data of LJ-1 under the condition of dual-permeability and single-permeability

4.2.1 Influence of the relative position of the wellbore and the fault on the productivity

In view of the influence of complex geological conditions on the gas reservoirs in the Liujia area. The sealing effect of the fault will prevent the migration of CBM to the outside and the characteristics of permeability and porosity in the vicinity of igneous rocks have been fully considered as well. Therefore, horizontal wells are built near igneous rocks and faults. In the middle of two igneous rocks, located at the 7 m of the fault, setting horizontal wells with different wellbore directions. The horizontal wells of deviates from faults in Fig. 5 and horizontal wells of towards from fault in Fig. 6, which will be used to study the influence of fault tectonic strike on productivity of horizontal well.

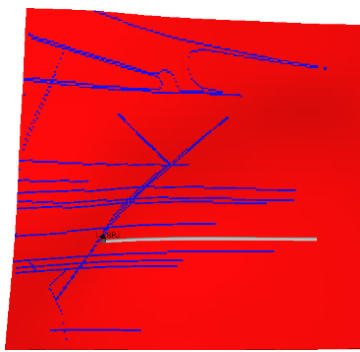


Fig. 5 Horizontal well position of well bore deviates from fault

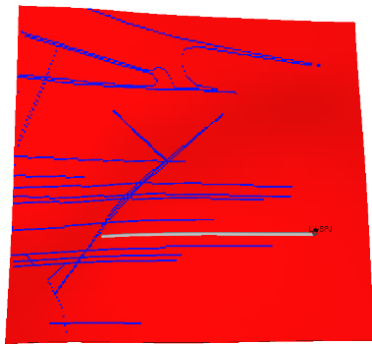


Fig. 6 Horizontal well position of well bore looks toward fault

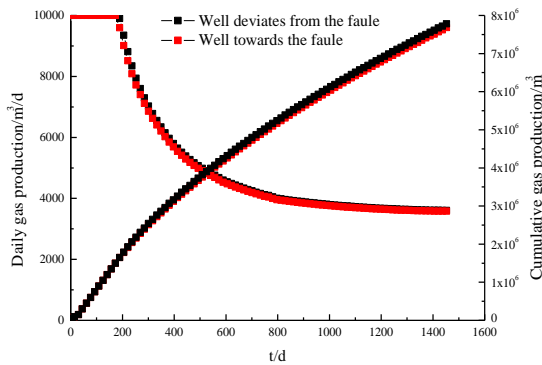
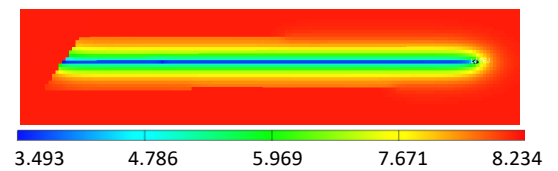
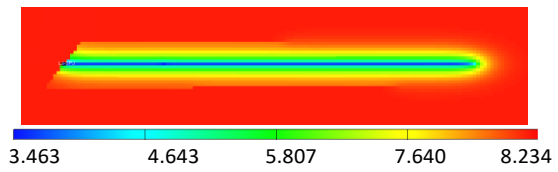


Fig. 7 Contrast of horizontal well gas production of well bore deviates from and looks toward fault

As shown in Fig. 7, when the horizontal wells are set in two ways, the trend of yield change is similar. While the output of deviating from the fault is higher than that towards from the fault. When using horizontal well drainage, the yield depends mainly on the horizontal section. Because the horizontal section communicates more fractures in the reservoir after fracturing, and the pressure expansion of the horizontal section of the well towards the fault is blocked by the fault, the production of the well deviated from the fault is higher than that towards the fault. However, the output is only a little higher, this is because the expansion of reservoir pressure around the vertical section of horizontal wells deviating from faults is also affected by faults. As the distance between the fault and the well increases, the interference will gradually weaken (Bachu *et al.* 2013).

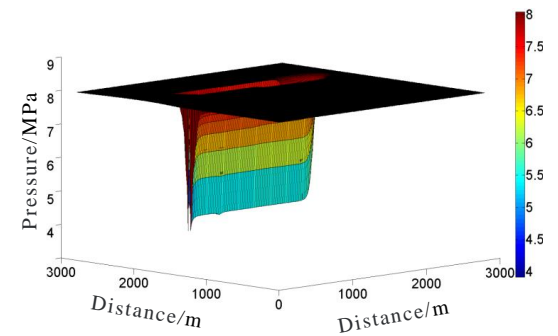


(a) Well bore toward fault

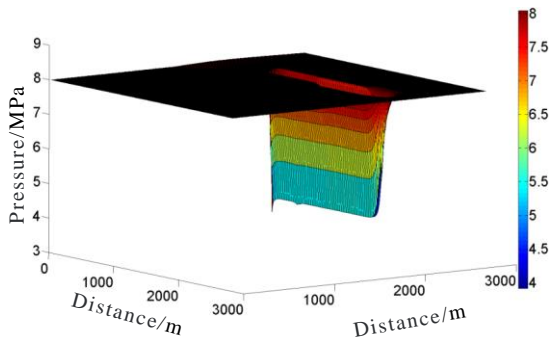


(b) Well bore deviated fault

Fig. 8 Reservoir pressure changes of horizontal shafts



(a) One side of the fault



(b) Deviation from one side of a fault

Fig. 9 3D contour map to reservoir pressure in a fault well

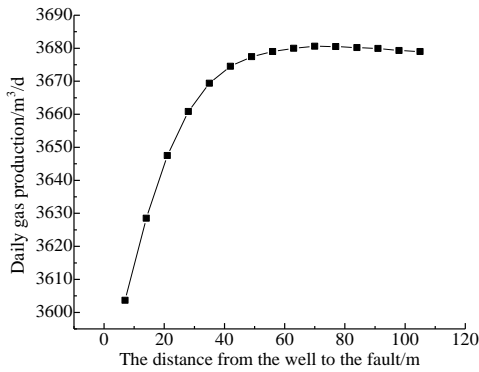


Fig. 10 Gas production comparison under different distances from fault

By well towards the faults pressure change in Fig. 8, with the continuous drainage, pressure ring will spread outward along the wellbore around. The pressure drop range much larger than the vertical wells, the pressure ring appearing in parallel to the wellbore. Wellbore pressure around the wellbore from periphery to the wellbore gradually decreasing. When the pressure transferred to the fault is obstructed, it will propagate along the fault, and the density and gradient of the pressure ring are large. While, when the pressure is transmitted to the north and south side of the igneous rock wall, the pressure circle parallel to the igneous rock will continue to expand to the far distance. From the flat pressure drop funnel in Fig. 9, the pressure gradually decreased from the upper to the lower, and the bottom pressure of the funnel is least, which is closest to the wellbore position. From Fig. 9(a), it is known that the pressure drop at the side of the fault is slow, the pressure drop range is smaller, and the fault barrier is obstructed significantly. While from Fig. 9(b), the pressure drop on one side of the deviate from fault is full, and the decrease speed is faster.

4.2.2 Optimum distance between well body and fault

In order to analyze the effect of faults on the productivity of horizontal wells, the production of horizontal wells distributed at different distances from the fault is compared. When the distance between the horizontal well and the fault is from the near to far, horizontal well production is gradually increasing in Fig. 10. But the increase is small. When the distance between the fault and the horizontal well is more than 70 m, the production changes stable. After this position, the effect of fault barrier on pressure expansion is weakened. The pressure expanding uniformly. Therefore, the horizontal well bore should not only be deviated from the fault setting but also should be ensured that the distance between the fault and well bore is moderate, so as to avoid the effect of the fault on the pressure expansion.

4.2.3 Influence of the level permeability of igneous rock and reservoir on the productivity

Considering that igneous rock has the function of gas generation, storage and trap for coal-bed methane reservoir, and it has good breathability around igneous rock, it is

necessary for us to study the influence of relative position of igneous rock and horizontal well on its productivity. Therefore, two open spaces between igneous rocks are chosen, as shown in Figs. 11 and 12. Horizontal wells parallel and perpendicular to the igneous rock strike are designed at the middle position, and considering the short distance between two igneous rocks, the length of the well bore is set as 84 m finally.

In Fig. 13, the initial and peak output of the vertical igneous rock is higher than that of the parallel igneous rock. But with the extension of production time, the daily output of horizontal wells in vertical igneous strike is decreasing gradually. The production decline faster and the stable production period is shorter, which is not conducive to long-term production. Relatively, the parallel igneous strike

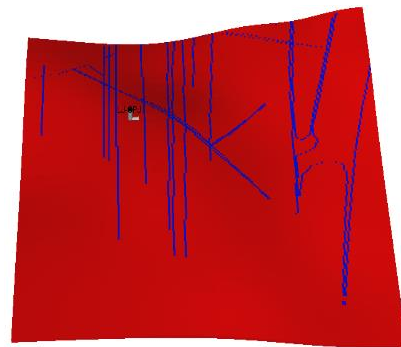


Fig. 11 Well bore vertical to igneous rock

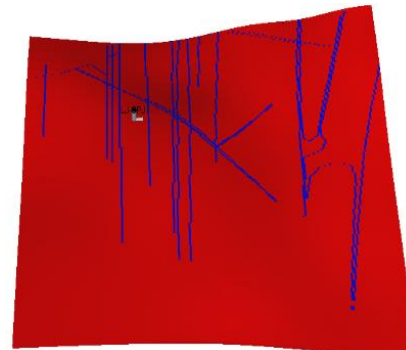


Fig. 12 Well bore parallel to igneous rock

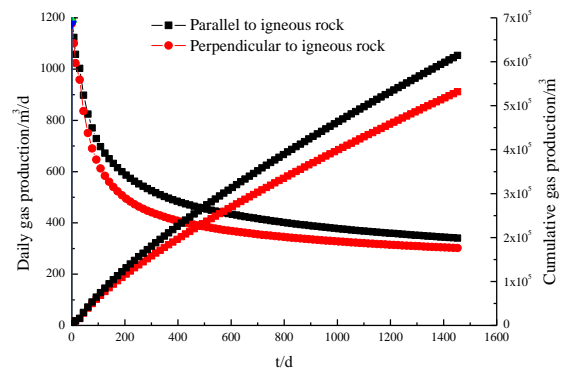


Fig. 13 Comparison of gas yield between parallel and vertical igneous rocks

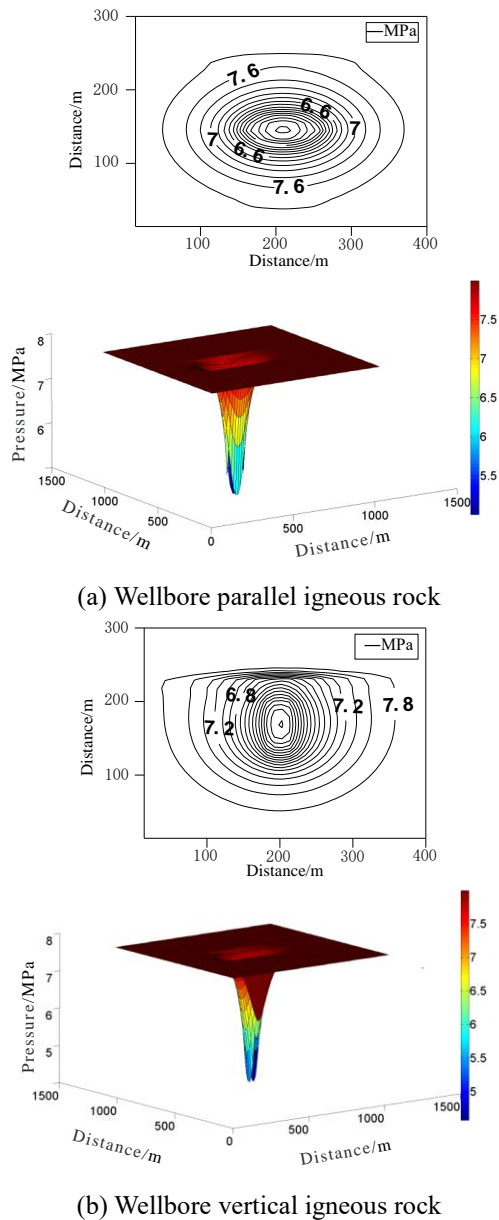


Fig. 14 Reservoir pressure 2D and 3D contour map

will get a longer period of stability, and the decline in production decline is slower.

From the pressure drop circle in Figure 14, due to the short length of the well body, the pressure contour is ellipse which is similar to the vertical well pressure drop, expanding outward along the horizontal well with the elliptical shape. The fracture direction of a horizontal well is perpendicular to the direction of the wellbore, and in the block, the igneous rock is parallel to the direction of the surface cleat. Comparing the horizontal well pressure changes in the direction of vertical and parallel reservoir cleats, when vertical wellbore, the well end pressure expansion will be affected by the igneous rock block, which is because the permeability of igneous rocks near the metamorphic zone is good. During drainage, pressure descending along the igneous rock expands outward rapidly. Due to the high permeability in the face cleat direction, the

Table 2 Comparison of economic net present value of parallel and vertical igneous rocks

Unit: Million yuan	parallel	vertical
Production cost	282.85	282.85
Net present value	-162.73	-152.83

pressure expansion in the fracturing direction is accelerated, enlarging the area of pressure drop. When parallel wellbore, Due to the high permeability in the face cleavage direction, the pressure drop circle extends far along the east-west direction. but the pressure drop range is smaller than that of the parallel butt cleat. From the three-dimensional elliptical funnel in Fig. 14, the pressure drop of vertical igneous rock is more quicker than that of parallel ones, indicating that the lager permeability in the cleats direction accelerates the pressure reduction of horizontal wells in the vertical igneous rock strike, thus causing the increase of the output.

But because Liujia block of igneous rocks are densely distributed along the horizontal well, when the horizontal well is vertical to face cleat, the length of wells will be affected by igneous rock barrier, which cannot give full play to the horizontal well and the coal seam contact area. Therefore, in order to increase the desorption of coal-bed methane desorption area effectively, the horizontal well in Liujia area should be parallel to face cleat set.

The above study shows that the horizontal well has better productivity when the shaft is perpendicular to the cutting direction. But considering the economic factors, the horizontal well section is too short as shown in Table 2, the economic net present value of two horizontal wells will be negative, and the project will not be accepted. This is due to the particularity of the dense distribution of igneous rocks in the Liujia block. Horizontal well in the direction of vertical bedding, as the length of the wellbore is restricted by the geological conditions, the economic benefit will be poor. However, when along with the direction of surface cleats (that is, along with the fire diagenetic direction), the length of the wellbore can be increased in a reasonable range, which can effectively increase the net present value of the economy. Therefore, considering the productivity and economic benefits, the horizontal well set in the direction perpendicular to the face cleat is not reasonable. What's more, the distributions of wells in the Liujia area are all near the igneous rocks where the gas is more and the igneous rocks are all the direction of east-west, therefore, the setting of horizontal wells in Liujia block should be set in the east-west direction.

4.2.3 Influence of igneous rock on the optimum range of well body

In order to study the influence rule of igneous rock on horizontal well productivity, horizontal well between North and South two igneous rocks are set as illustrated in Fig. 15, designing 6 wells surrounded by igneous rocks with different areas. In the 4.2.2 section, it can be found that the well bore is more than 70m away from the fault, and the interference from the fault is significantly reduced, and the first well is set up at the best distance from the fault, the

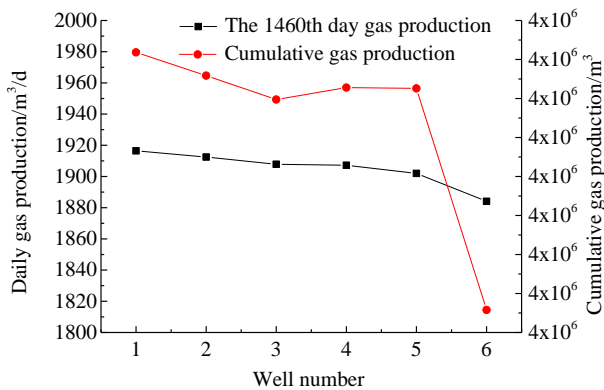
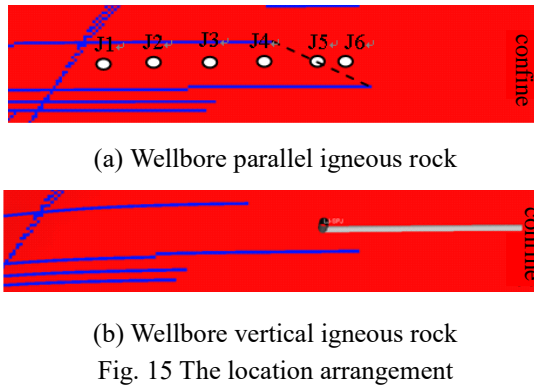


Fig. 16 The output of 1460th day

fifth well at t the midpoint of the connecting line between the east end points of the two groups of igneous rocks. Considering the limited distance from the area to the east side of the reservoir, the length of the horizontal section is selected as 840 m. And the results of the calculation are shown in Fig. 16. By comparison, with the range of horizontal wells surrounded by north-south igneous rocks gradually decreases, the output will also decrease, which is also the cause of the decline in production as the wellbore moves eastward shown in Fig. 10 of 4.2.2 section.

4.3 Influence of complex geology on productivity of horizontal well

Comparing the horizontal well after position optimization with the well without complex geological conditions, and verifying the productivity advantages of complex geological conditions to horizontal wells, the optimal location of the area surrounded by the fault and the volcanic rock is selected. That is, it meets the requirement that the area surrounded by the north and South igneous rocks is the largest and 70 m away from the fault, as shown in Fig. 17. The daily output of complex geology is 39% higher than that without complex geological production, the total yield of complex geology is 22% higher than that without complex geological. The pressure expansion is faster, the desorption area larger. It is obvious that complex geology is beneficial to the production of horizontal well and should make full use of the advantages of geological conditions.

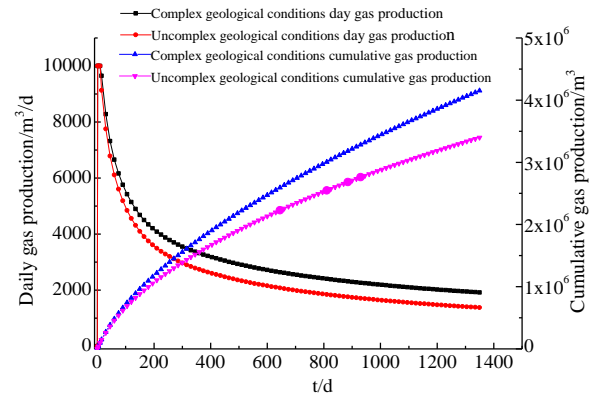


Fig. 17 Productivity comparison of horizontal wells

5. Conclusions

This thesis studies the influence of complex geological conditions on the productivity of the CBM in the Liujia block. The main conclusions are listed as follows.

(1) A dual permeability model of gas-water two-phase flow matrix system and fracture system is established based on the characteristics of low-permeability coal seams and the migration of the CBM. The model considers the processes of desorption, diffusion and channeling. And the dynamic changes in permeability and porosity of pressure-sensitive reservoirs. Numerical simulation results show that the model can better describe the actual production curve.

(2) The established heterogeneous geological model can consider the actual complex geological conditions, such as reservoir folds, igneous rocks and fault structures. The sealing effect of faults and igneous rocks can not only form gas enrichment, but also improve the physical conditions of the reservoir.

(3) The pressure expansion and production of coalbed methane reservoirs are affected by the complex geological structure. The horizontal wellbore should deviate from the fault direction and the distance between the wellbore and the fault should be set to 70 m, which is the optimal distance that the interference to the horizontal well is the minimum.

(4) The production of the CBM in the cleat direction perpendicular to the cleat of the reservoir is higher than that of the parallel plane cleat. This is due to the fact that the larger permeability in the vertical direction accelerates the pressure drop speed in the fracturing direction and the larger pressure drop area. However, the dense distribution of igneous rocks along the cleat direction in the block limits the length of horizontal wells. Horizontal wellbore parallel cleat is the most suitable choice for local conditions. The larger the area of the well body surrounded by igneous rocks, the more favorable the impact of coal metamorphic characteristics around the igneous rocks on the productivity of horizontal wells and the more ideal the productivity.

(5) Igneous rocks have a more significant impact on the productivity of horizontal wells than faults, which is due to the improvement of physical properties of surrounding reservoir caused by the invasion of igneous rock. The rational use of complex geological structures for the layout

of horizontal wells is very important to increase the production of low-permeability coalbed methane wells.

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