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Research Article

A Method to Evaluated Gas Content with Coalbed Methane Reservoir Based on Adsorption Theory and Production Analysis

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In the process of coalbed methane development, the gas content not only determines the reserves of methane in coal reservoir but also is the most important geological parameter affecting the production of coalbed methane. The gas content directly determines whether coalbed methane can be developed efficiently. However, in the current development evaluation process, it is very difficult to accurately predict the gas content in coal seams. An efficient and accurate method to predict gas content has not been found yet. This is mainly restricted by the development mode and technology of coalbed methane. In the current low-cost development model, gas content test data are relatively scarce. Under such circumstances, it is difficult to accurately evaluate the distribution of CBM gas content in the whole area. At the same time, the gas content of coalbed is the key parameter for efficient development of coalbed methane. Under normal circumstances, gas content heterogeneity will result in a large gap between development effects in different regions. At present, there is no evaluation method for gas content parameters of coal reservoir. Under this background, the key parameters of coalbed methane development in southern Qinshui Basin were evaluated. On the basis of systematically summarizing and understanding the development law of coalbed methane in different types of coal reservoirs, a gas content evaluation method based on adsorption theory and production dynamic analysis is proposed. Combined with the coalbed methane production model and isothermal adsorption model, the critical desorption pressure can be calculated accurately by using the bottom hole pressure when casing pressure occurs in production wells. The critical desorption pressure correction model of coalbed methane was innovatively established. Langmuir equation was used to accurately characterize the adsorption characteristics of coalbed methane. Forming a new method for gas content prediction in the case of fewer coring wells. The gas content evaluation technology coupled with isothermal adsorption theory and production dynamic analysis saves the development cost of coalbed methane and improves the prediction accuracy of coal seam gas content in noncoring wells. At the same time, there is a good relationship between the predicted results and the measured gas content at well points. The coincidence rate reached 97.37%. This technology can effectively improve the prediction accuracy of coal seam gas content. This technique is suitable for the productivity evaluation of coalbed methane reservoir. It can also provide scientific basis for the development and reserve evaluation of coalbed methane reservoirs at home and abroad.

1. Introduction

Coalbed methane is the methane gas in coal seam. There are two main ways of coalbed methane occurrence in coal seam: free and adsorption. The methane in coal seam is mainly in adsorption state, and there is little free gas. The gas content and structure are the main factors affecting CBM production [1]. Whether in the exploration stage or in the development stage, how to evaluate the gas content of coalbed methane becomes particularly important. Coal is an organic reservoir, and CBM reserves are calculated by gas content rather than saturation of free gas in pores. At present, coalbed methane is a kind of gas field with poor economic benefit and needs to be developed with low cost. In the process of development, gas content testing is less. It is necessary to find an effective method to evaluate the distribution of gas content in the CBM reservoir.

Different scholars have carried out a lot of research work on the adsorption characteristics of methane molecules by coal. Anderson et al. first measured the desorption/adsorption isotherms curve of methane, nitrogen, carbon dioxide, and other gases in coal seams by volume method and found hysteresis [2]. Joubert et al. perfected the volume method and established the relationship between adsorption capacity and coal moisture content [3]. Kim further established the adsorption correlation formula including moisture, gray level, coal rank, pressure, and temperature, which is mainly used to evaluate the adsorption of shallow and low pressure coalbed methane [4]. Langmuir isothermal adsorption equation is widely used at present. So far, for coal samples filled with pure gas of different coal rank and geological age, all adsorption data measured in experiments can actually be described by Langmuir equation [5]. Gregory and Karen also found the limitations of Langmuir model through experiments. The adsorption characteristics of water-bearing coal seam under high pressure were studied by volume method to simulate formation temperature, and the adsorption experimental data were correlated with Langmuir model. The results show that the experimental gas content is higher than the actual gas content. The desorption isotherm measured in the experiment has obvious hysteresis phenomenon. The experimental results show that Langmuir model is not suitable for fitting isothermal adsorption experimental data under high pressure [6]. An adsorption model with different concepts is needed to study the effect of temperature on gas content of coalbed methane. Langmuir adsorption theory assumes that adsorbed gas covers the surface of coal matrix. Dubinin's theory is basically contrary to Langmuir's theory. It assumes that adsorbed gas fills the pores of coalbed. Considering the influence of temperature on adsorbed gas volume, two equations, namely, Dubinin-Astakhov equation and Dubinin-Radushkevich equation, are derived according to Dubinin theory. Both equations show that the adsorbed gas volume decreases exponentially with temperature. Dubinin-Astakhov equation and Dubinin-Radushkevich equation can correct isothermal adsorption curve and CBM content to another appropriate temperature condition by Dubinin equation and Kirchhoff equation. Two constants in Dubinin-Radushkevich equation and three constants in Dubinin-Astakhov can be calculated using the adsorption data measured in the experiment. The CBM content at the required temperature and pressure is then calculated [7]. Freundlich equation can be used for monolayer adsorption, especially in medium pressure range. Its form is relatively simple, and calculation is also more convenient, so it is widely used. However, the constants in the equation have no clear physical significance and cannot explain the mechanism of adsorption. The above equations are used to characterize the adsorption behavior of coal to methane molecules. Through analysis and comparison of the assumptions, operating conditions, and characterization equations of different models, it is believed that Langmuir equation can accurately characterize the adsorption characteristics of coalbed methane. Methane is adsorbed on the surface of coal matrix by single molecular layer, and the correlation coefficient of isothermal adsorption curve fitted by measured adsorption amount under different pressures is greater than 0.99, accurately characterizing the adsorption behavior of coalbed methane. Based on the isothermal adsorption curve of coal seam measured by exploration well, the corresponding critical desorption pressure is calculated according to the gas content of coal seam. Based on the relationship between measured gas content and critical desorption pressure, gas content can be calculated by critical desorption pressure.

There are currently three methods for predicting gas content to supplement evaluation. One is to evaluate the gas content of reservoir by inversion method of elastic parameters of seismic data. Xiaolong et al. selected coal samples with different coal rank and coal quality, combined with laboratory testing and actual drilling data analysis, and determined that the modulus attribute was sensitive to the detection of ton coal gas content. At the same time, density is more sensitive to gas content than compressional wave velocity. Based on this, the inversion method of coalbed methane three-parameter elastic modulus (relative change of Lamet constant, shear modulus, and density) based on seismic data was established [8]. Xinping and Fuyi analyzed that seismic data and coalbed AVO technology can be used to predict the reserve enrichment and high permeability positions of reservoirs, which can provide a basis for deployment of exploration and development wells. Using logging data to conduct preevaluation and reevaluation before and after fracturing in coalbed methane wells can avoid capital waste, achieve the goal of improving the success rate of drilling and single well production, and achieve commercial production [9]. Jinshan and Weiyao analyzed the existing CBM drilling data and 3D seismic data. Through correlation fitting, the prediction model of floor elevation and gas content of No. 8 coal seam in Karoo Basin of Africa and the predicted gas content of No. 8 coal seam are obtained, and then compared with the measured gas content of the coal seam drilling data, the prediction accuracy is more than 85% [10]. Zijing et al. proposed an improved BP neural network prediction method characterized by artificial bee colony algorithm. The prediction results are basically consistent with the variation trend of gas content in each well, and the prediction accuracy is high [11]. Lutong et al. found a seismic sedimentology method to reveal the sedimentary microfacies of high frequency sequences in the coal-bearing Shanxi Formation of the Zhongyu area in the central-western of the Qinshui Basin [12]. The other is to evaluate gas content by logging characteristics. The literature of Jie et al. is based on the geological, logging, and coal test data of No. 3 and No. 15 coal seams in the southern Qinshui Basin. The gas content is calculated by regression analysis, Langmuir coal rank equation, KIM method, and BP neural network method, and the results are compared. Generally, the logging interpretation method would have a good application effect to evaluate the coalbed methane content in the south block of Qinshui Basin [13]. Zhang et al. proposed a zonal gas content prediction method based on the impact of geological factors on gas content. Combined with a large number of laboratory test data, the influence of sedimentary, structural, and hydrodynamic conditions on the gas content of coal seam is analyzed, and the main controlling factors are obtained. Through fuzzy hierarchy analysis, the difference of geological factors is quantified and the geological partition is realized. Principal component analysis is introduced in each partition. A large number of conventional logging curves in the field were fully utilized to conduct multiple regression and establish a prediction model for coal seam gas content

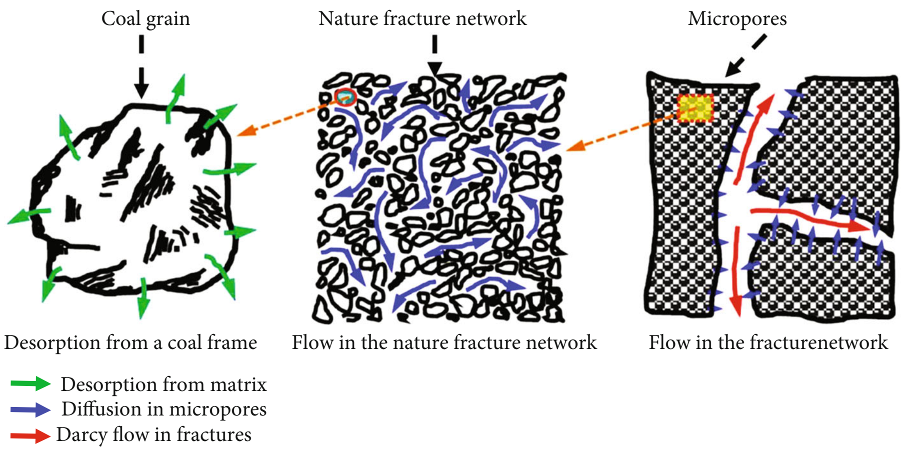

FIGURE 1: Desorption and diffusion in the matrix and Darcy flow in the fracture.

[14]. Li et al. proposed to use the cross entropy algorithm to determine the global optimal parameters of support vector machine and build the best prediction model to predict the porosity, permeability, and gas content of an unexplored block in the southern Qinshui Basin driven by well-seismic joint data [15]. In order to solve the problem of quantitative interpretation of coal seam gas content, Chi et al. used coal logging data and coal core desorption data as input and output parameters to build a depth confidence network and then predict coal seam gas content. The results show that depth confidence network has the best prediction effect, followed by probabilistic statistical method, and SVM is the worst [16]. Based on the logging response characteristics of coal seam gas content, Tao et al. analyzed the correlation between logging parameters and gas content, proposed the logging parameter optimization strategy combining mean impact value technology and least squares support vector machine technology, optimized the logging parameters, and constructed a set of logging model suitable for coal seam gas content prediction [17]. Banerjee and Chatterjee developed a methodology to identify prospective coal seam by establishing multiple regression models between geophysical well log parameters and organic and inorganic contents from laboratory-tested core samples for one seam [18]. The third is to establish the regression relationship between thickness, depth, thickness, and gas content. Min et al., taking Jincheng mining area as an example, analyzed the influencing factors of CBM content based on the basic theory of CBM geology and the improved slope degree of grey incidence. Furthermore, the coalbed methane content is predicted by grey multivariable static model GM(0,N) and compared with the results of multiple regression analysis. The results show that the main influencing factors of CBM content determined by grey correlation analysis with improved slope correlation degree are reliable. The prediction of coal seam gas content by GM(0,N) model requires less sample data, simple principle, convenient calculation, and high prediction accuracy [19]. Xiangrong and Haijiang analyzed the control effect of coal seam gas content based on the geological data of coal field exploration and borehole test data of coalbed methane wells, combined with the characteristics of regional geological background. Through correlation analysis and multivariate statistics, the main controlling factors of coal seam gas content are obtained. The mathematical model of coalbed methane gas content prediction is established, which has important guiding value for coalbed methane development [20]. According to Xiaominget al., taking the geological strength index as the link, the thickness, gas content, permeability, and brittleness index of different coal structures in a coal seam section were quantitatively characterized. Based on an analytical hierarchy process, a system for the evaluation of coal reservoir CBM production potential was constructed considering different coal structure in coal seam sections [21]. Hui et al. introduce a parameter fault scale to quantify the scale of faults, which is described by fault length, fault throw, and the investigated area and propose a horizontal grid method to determine the faulting influence on current gas content [22].

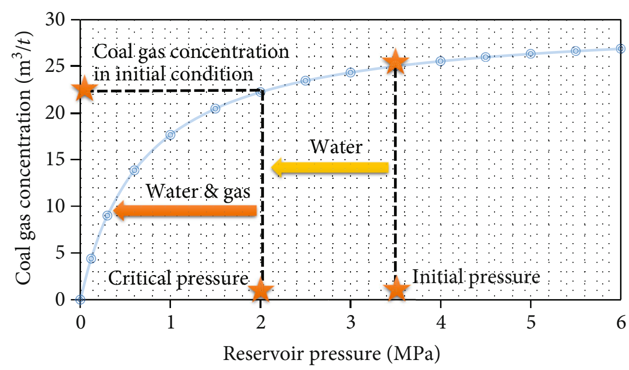

FIGURE 2: Gas content change during coalbed methane development.

2. Coalbed Methane Adsorption Model and Applicability

2.1. Assumptions

(1) The adsorption model of gas is isothermal adsorption; it follows the isothermal adsorption equation [23]

(2) The adsorption of gas in coalbed methane is unsaturated

(3) The gas present in coal seams is only methane

(4) The temperature in the coal seam is constant

(5) The boundary of reservoir is closed boundary with no external gas source supply and no gas escape

2.2. Adsorption Model. Adsorbed gas is adsorbed in coal matrix in a dynamic equilibrium way. In the development process, with the decrease of reservoir pressure, adsorbed gas is gradually resolved from adsorbed state into free gas. Free gas flows into the natural fracture system through diffusion, and eventually methane gas flows into the hydraulic fracture through the natural fracture and eventually into the wellbore (Figure 1) [24].

For unsaturated coalbed methane reservoirs, in the original state, the reservoir pressure is greater than the critical desorption pressure. During production, the pressure in the formation is gradually reduced through an earlier drainage process. When the formation pressure decreases to the critical desorption pressure, the gas begins to desorption and enters into the natural fracture system to participate in the flow and is finally mined (Figure 2). Therefore, the production system of drainage and production is the characteristic of coalbed methane development.

The adsorption curve of high-rank coal in southern Qinshui basin belongs to type I. Langmuir isothermal adsorption equation can be used to describe the adsorption and desorption of coalbed methane. According to the T2 spectrum characteristics of coal samples, the pores in the coal seam are mainly dominated by adsorption pores, followed by seepage pores and small fracture pores (Figure 3). According to the isothermal adsorption test data, the fitting relationship between the isothermal adsorption test data of coalbed methane in Qinshui Basin and Langmuir isothermal adsorption curve is very good (Figure 4 and Table 1).

The decision coefficient is defined as

$$\mathrm{DC} = b_i^2 + 2\sum_{j\neq i} b_i r_{ij} b_j. \tag{1}$$

Based on isothermal adsorption theory, Langmuir equation was used to establish the calculation method of gas content. Langmuir equation can be expressed as

$$V = \frac{PV_L}{P + P_L}. \tag{2}$$

The coal gas content corresponding to the original reservoir pressure is the maximum adsorption capacity of coal seam, that is, the saturated gas content. In unsaturated coalbed methane reservoirs, the measured gas content is less than saturated gas content. When the coal reservoir pressure decreases to the corresponding pressure of the gas content, the coalbed methane begins to change into free state after coal desorption. Therefore, the measured gas content of coal seam corresponds to the critical desorption pressure. Gas content calculation formula (2) shows that when the pressure is the critical desorption pressure, the corresponding gas content is the original gas content of coal seam. The gas content of coal seam can be calculated according to the critical desorption pressure.

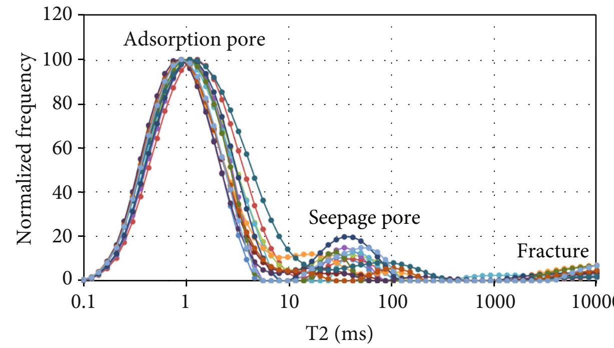

FIGURE 3: T2 spectrum characteristics of No. 3 coal in SZ block.

$$V_i = \frac{P_c V_L}{P_c + P_L}. \tag{3}$$

2.3. Method Application Conditions. The method presented in this paper can accurately predict the gas content of the block, but it also needs to be combined with relevant geological parameters and production data. Therefore, in the process of use, the target area needs to have certain conditions:

(1) There are parameter wells evenly distributed throughout the target area, and the isothermal adsorption test is carried out for parameter wells. The density of parameter wells determines whether the isothermal adsorption equation is accurate

(2) The reservoir depth and drilling technology are basically the same in the whole area, which is conducive to reducing the error of converting bottom hole flow pressure to critical desorption pressure

3. Gas Content Calculation

According to Equation (3), the most important parameter in the calculation of gas content is the formation pressure near the wellbore when gas is seen. According to the percolation mechanism of the reservoir, the pressure is funneled in the formation, with the lowest pressure near the bottom and the highest pressure at the boundary. Therefore, the formation pressure at the bottom of the well is the critical desorption pressure of the coal seam. However, there is an error between the critical desorption pressure and the formation pressure at the bottom of the hole when gas is detected, because the flow cannot be accurately monitored instantaneously. How to correct this error is the key to calculate the critical desorption pressure accurately.

At present, there are two main errors in measuring bottom hole flow pressure when gas is detected. One is affected by the well storage effect. When coalbed methane around the

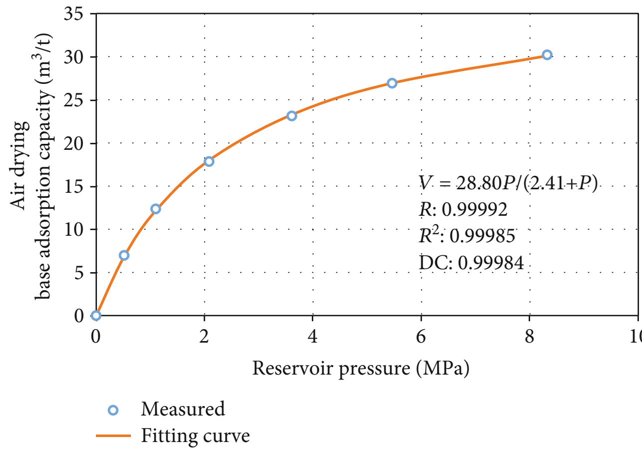

FIGURE 4: Fitting diagram of gas content in SZ block.

TABLE 1: Data from 7 samples from 2 wells.

The sample	The correlation coefficient	Correlation coefficient squared	Decision coefficient
Sample 1	0.9999	0.9999	0.9998
Sample 2	0.9999	0.9999	0.9998
Sample 3	0.9999	0.9997	0.9997
Sample 4	0.9995	0.9991	0.9991
Sample 5	0.9997	0.9995	0.9995
Sample 6	0.9947	0.9894	0.9889
Sample 7	0.9996	0.9992	0.9992

well begins to desorption into the wellbore, it needs to rise to the oil casing annulus through the wellbore liquid column and then be detected by the wellhead pressure gauge. This process can result in delayed detection. When we detect casing pressure at the wellhead, it is already past the well storage stage, which can cause errors. The second is the accuracy of the wellhead pressure gauge. When the pressure range in the wellbore is small, the pressure gauge cannot detect the pressure. When the pressure is detected by the pressure gauge, the bottom hole pressure is already below the critical desorption pressure. Therefore, the data need to be corrected when calculating the critical desorption pressure.

Through the analysis of the causes of the errors, it can be found that the main factors affecting the test errors include pressure gauge specifications, well structure, and coal seam depth. Under the same conditions, linear regression can be used for correction (Figure 5). The same regression equation can be used to correct critical desorption pressure in the same block, where pressure gauge specifications, well structure, and depth are essentially the same.

According to Langmuir isothermal equation and linear regression equation, gas content and can be expressed as

$$V_c = \frac{aPV_L + bV_L}{aP + P_L + b}. \quad (4)$$

4. Field Application

4.1. Gas Content Calculation in SZ Block. SZ block is located in the south of Qinshui Basin. The main coal seam for development is No. 3 coal of Shanxi Formation. The block is a monoclinal structure, low in the east and high in the west, gentle in the east, fault-fold area in the middle, and relatively developed faults in the north. The sedimentary environment is delta plain facies, located in interdistributary bay, which is favorable for coal forming environment.

4.2. Calculation of Relationship between Gas Content and Bottom Hole Pressure in Gas Well. The block covers an area of 388.3 km^2, but there are only 20 isothermal adsorption test wells. The test data include gas content and critical desorption pressure (Table 2).

The critical desorption pressure and gas content were regressed by the test data in Table 2. The critical desorption pressure has a good correlation with gas content, and it accords with Langmuir isothermal adsorption curve equation (Figure 6). This indicates that the adsorption properties of coal reservoirs in the block are similar with little difference. The gas content can be calculated using the critical desorption pressure by regression Langmuir equation. Langmuir equation of SZ block is

$$V = \frac{26.32P}{1.65 + P}. \quad (5)$$

Currently, 9 of the wells listed in Table 2 are in production. All 9 wells have produced gas (Table 3). The bottom hole pressure of the whole area can be corrected by the bottom hole pressure and the measured critical desorption pressure of 9 wells (Figure 7). Through regression, the relationship between critical desorption pressure and bottom hole flow pressure when gas is seen is

$$P_c = 1.3050P_g - 0.0435. \quad (6)$$

According to formulas (5) and (6), the relationship between gas content in SZ block of Qinshui basin and

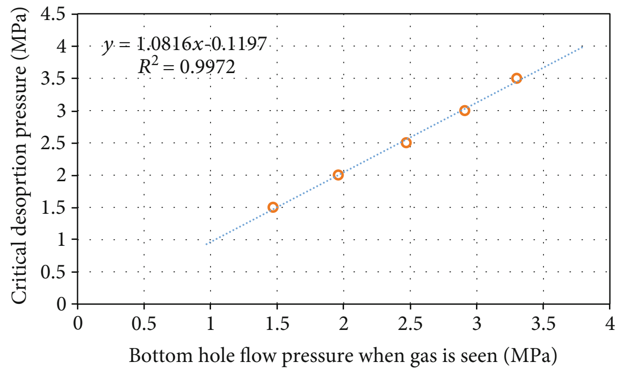

FIGURE 5: Linear regression corrects critical desorption pressure.

TABLE 2: Critical desorption pressure and gas content of SZ block.

Well name	Critical pressure (MPa)	Gas content (m^3/t)
SZN02	0.63	8.33
SZN05	0.61	6.82
SZN09	0.99	7.18
SZN16	1.63	14.27
SZS01	0.93	9.27
SZS02	0.80	8.48
SZS03	1.63	14.13
SZS04	0.69	8.79
SZS05	0.70	7.50
SZS06	1.21	7.59
SZS07	3.32	19.16
SZS09	0.79	11.01
SZS11	2.30	14.91
SZS11-1	2.42	13.71
SZS12	0.59	7.50
SZS13	0.91	9.83
SZS15	0.20	2.34
SZS17	1.90	13.06
SZS19	1.80	15.50
SZS20	0.31	4.90

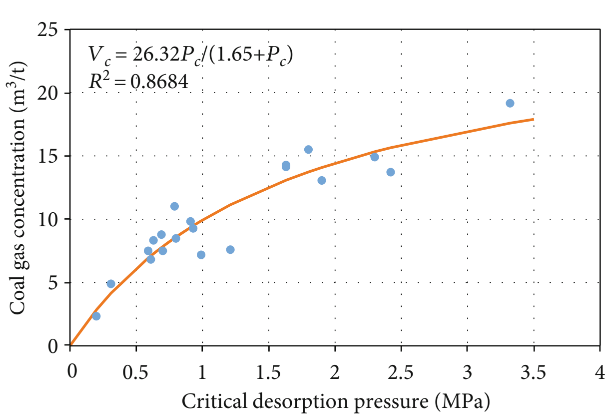

FIGURE 6: Relationship between critical desorption pressure and gas content.

TABLE 3: Critical desorption pressure and bottom hole pressure at begin of gas flow.

Well name	Critical pressure (MPa)	BHP when gas is seen (MPa)
SZN16	1.63	1.25
SZS01	0.93	0.71
SZS03	1.63	1.08
SZS04	0.69	0.61
SZS06	1.21	0.98
SZS11	2.30	1.66
SZS13	0.91	0.52
SZS17	1.90	1.50
SZS20	0.31	0.21

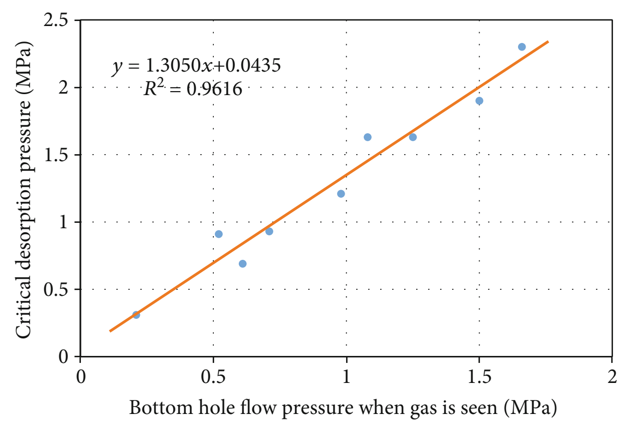

FIGURE 7: Relationship between critical desorption pressure and bottom hole pressure at begin of gas flow.

bottom flow pressure of gas well can be obtained as follows:

$$V_c = \frac{34.3476P_g - 1.1449}{1.3050P_g + 1.6065}. \tag{7}$$

4.3. The Calculation Results. Take the calculation results of No. 3 coal in block W of SZ block as an example. Block W covers an area of 21.2 km^2, with two gas content test wells and 171 drainage and production wells, 160 of which have gas. The calculated and tested gas content results of the two production wells are shown in Table 4. A total of 136 gas-producing wells with smooth production curve were selected. According to the bottom hole pressure and formula (7) of 136 wells, the initial gas content data of each well point were obtained, and the gas content of the plane of block W was evaluated (Figure 8).

4.4. Gas Content Calculation in pH Block. pH block is located in the southeast slope belt of Qinshui Basin, and the main coal seam is No. 3 coal of Shanxi Formation. pH block is located in delta front, favorable coal forming environment, and thick coal belt development area. The block area is 17 km^2. The structure of the demonstration area is simple, with north-

Table 4: Comparison of calculated and tested gas content in block W.

Well name	Tested gas content (m^3/t)	Calculated gas content (m^3/t)	Error (%)
SZS01	9.27	9.38	1.2
SZS03	14.13	14.09	0.3

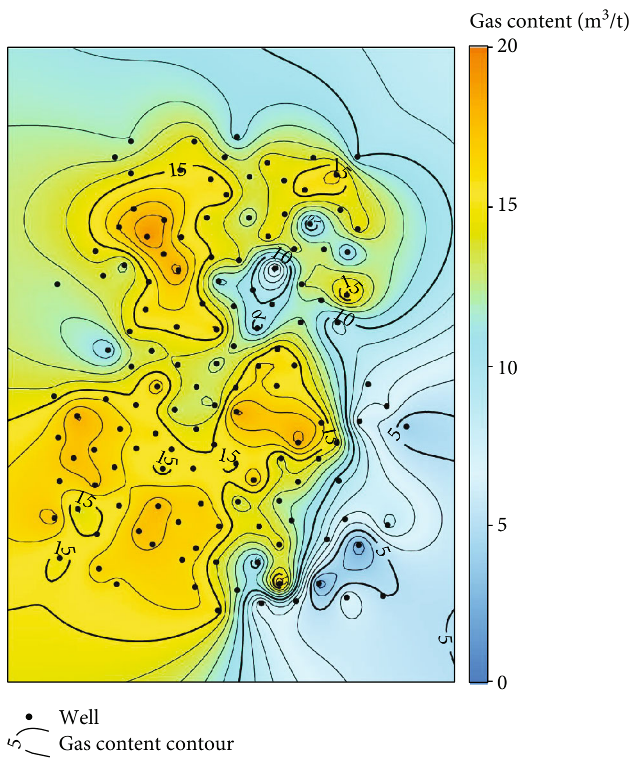

Figure 8: Gas content contour of W block for 3# coal seam of SZ block.

south folds and pH syncline in the middle. The top surface of the area is low in the middle and high in the two wings.

4.5. Calculation of Relationship between Gas Content and Bottom Hole Pressure in Gas Well. The correlation between the critical desorption pressure and the bottom flow pressure of No. 3 coal in pH block is analyzed through the test data of parameter well. The linear regression diagram of critical desorption pressure and bottom flow pressure in gas well was established (Figure 9). Through correlation analysis, the relationship between critical desorption pressure and bottom flow pressure of No. 3 coal in pH block can be obtained as follows:

$$P_c = 1.3263P_g + 0.7131. \quad (8)$$

There are a lot of gas content test data in pH block. Through the laboratory gas content test data, isothermal adsorption curves of different areas can be obtained. Due to the small area of the whole pH block, the coal seam is evenly distributed and the heterogeneity is weak, and there

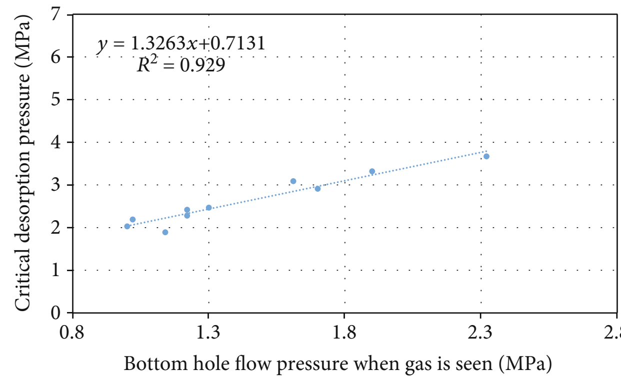

Figure 9: Relationship between critical desorption pressure and bottom hole pressure at begin of gas flow.

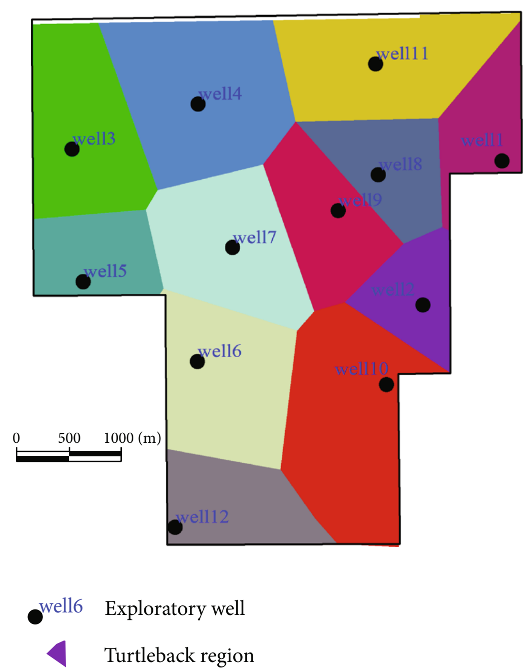

Figure 10: Isothermal adsorption curves of different regions with pH block.

is no fault in the whole area. Geologically, the pH block can be considered as a whole. Therefore, the zoning is mainly based on the location of the test well. The well control range of the test well is used as the basis for zoning. Different isothermal adsorption curves were used for each small area to calculate data more accurately (Figure 10).

4.6. The Calculation Results. Combined with the isothermal adsorption curves of each block and formula (8), the gas content of the current production wells in pH block can be calculated, and then, the gas content of the whole area can be evaluated (Figure 11).

The calculated results are compared with the measured results. The error can be controlled within 8% by using this method. Compared with the six wells, the average error of gas content calculation by this method is 2.63%. The method provided in this paper has high accuracy in calculation

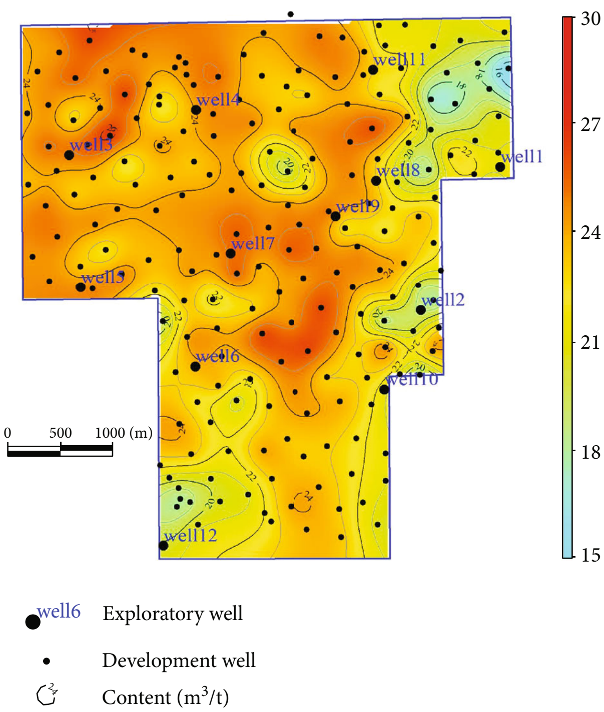

Figure 11: Calculation results of gas content in pH block.

Table 5: Comparison of measured gas content with calculated gas content.

Well name	Measured gas content (m^3/t)	Calculated gas content (m^3/t)	Error
Well 1	30.9	29.6	4.2%
Well 2	27.6	28.1	1.8%
Well 3	27.8	27.6	0.7%
Well 4	15.91	15.75	1.0%
Well 5	10.73	10.63	0.9%
Well 6	9.45	10.13	7.2%

(Table 5). The error in Table 5 are defined as

$$\text{Error} = \frac{|\text{Measured gas content} - \text{Calculated gas content}|}{\text{Measured gas content}} \times 100\%. \tag{9}$$

5. Article Innovation

In the development of coalbed methane reservoirs, gas content has always been an important parameter for evaluating coal reservoirs. However, due to the limitations of the low-cost development model, the measured data of gas content are less. Most of the development wells use indirect forecasting. There are currently three evaluation methods, but they are all pure geological evaluations, ignoring the production data of coalbed methane wells. In this paper, an innovative method is proposed to combine experimental testing with production dynamics to calculate the gas content of coal seams. There are two main innovation points:

(1) Through the analysis of T2 spectroscopic characteristics of coal samples, the pore distribution characteristics of coal reservoirs are clarified. Combined with the isothermal adsorption test data, the applicability of the Langmuir isothermal adsorption equation is verified. This is a prerequisite for the use of methods

(2) By inverting the adsorption-desorption process in the coal seam, the gas content of the coal seam under the original conditions was obtained. By means of the critical desorption pressure of the coal seam and the bottom hole pressure of the gas appears under the same completion method of the proposed contract block, the bottom hole pressure of the gas appears can be corrected and the prediction accuracy of the method can be improved

6. Conclusion

On the basis of systematically summarizing and understanding the development law of different types of coal reservoirs, this paper puts forward an evaluation method of coal seam gas content based on adsorption theory. The critical desorption pressure is calculated by bottom hole pressure when casing pressure occurs in production well. Langmuir equation was used to accurately characterize the adsorption characteristics of coalbed methane. A new method for accurately calculating coal seam gas content based on production data is developed. Through the above analysis, the following conclusions can be summarized.

(1) Langmuir isothermal adsorption equation can be used to describe the adsorption and desorption of coalbed methane in high-rank coal in southern Qinshui Basin. The pores in coal seam are mainly dominated by adsorption pores, followed by seepage pores and small fissure pores. The measured data show that the fitting relationship between isothermal adsorption test data and Langmuir isothermal adsorption curve is very good

(2) The critical desorption pressure is different from the bottom hole flow pressure at gas exposure. This difference is mainly affected by three factors: pressure gauge specification, well structure, and coal seam depth. Within the same block, the three factors are basically the same. The bottom hole pressure at gas exposure can be corrected to the critical desorption pressure by linear regression

(3) The gas content error of reservoir calculated by the corrected bottom hole pressure at gas exposure of gas well is small. In the case of abundant isothermal adsorption curves in the whole region, the calculated results are compared with the measured results. Compared with the six wells, the average error of gas content calculation by this method is 2.63%. The method provided in this paper has high accuracy in calculation

Symbols

V: Volume gas content, m^3/ton
P: Reservoir pressure, MPa
V_L: Langmuir volume, m^3/ton
P_L: Langmuir pressure, MPa
P_O: Adsorbent saturated vapor pressure, MPa
V_m: BET equation for monolayer adsorption capacity, m^3/ton
C: Constants related to the heat of adsorption and the liquefaction of the adsorbed gas
V_0: Langmuir volume under the standard conditions, m^3/ton
R: Universal gas constant, MPa•m^3/(lb•mole•k)
T: Absolute temperature, k
β: Adsorption gas affinity coefficient, dimensionless
E: Characteristics of the energy, MPa•m^3/(lb•mole)
n: Integer, usually between 1 and 4, dimensionless
V_f: Freundlich coefficient 1, dimensionless
n_f: Freundlich coefficient 2, dimensionless
V_i: Initial volume gas content, m^3/ton
P_c: Critical desorption pressure, MPa
V_c: Volume gas content, m^3/ton
a: Regression coefficient 1, dimensionless
b: Regression coefficient 2, dimensionless
DC: The decision coefficient
b_i: Regression coefficient
r_{ij}: Correlation coefficient.

Data Availability

The data are all original; if you need any data in the article, please send me an email (email address: fengruyong@qq.com).

Conflicts of Interest

The author declares that there are no conflicts of interest.

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