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Gas Distribution and Its Geological Factors in the No.5 Coal Seam of the Weibei Field, Southeastern Ordos Basin, North China

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Abstract: The distribution of gas contents in the No.5 coal seams of the Weibei Field of southeastern Ordos Basin, North China, is highly variable and its mechanism remains unclear. In this study, systematic evaluation of the gas content and its geological control factors are conducted based on the field investigation together with 16 coalbed methane (CBM) wells in the Weibei Field, southeastern Ordos Basin, North China. The gas content variability is determined from the perspectives of gas generation, migration, and preservation. The results indicate that the gas generation is largely relevant with the subsidence and fluctuation of the coal seam during the middle-late Yanshanian orogeny, which controls the gas content variability of the Weibei Field. Besides, gas migration and preservation determine the gas content on a regional scale, significantly related to fault types, roof lithology, burial depth, and hydrodynamic conditions, but scarcely affected by the roof thickness. In the Weibei Field, the geological models controlling gas content are identified as (1) hydrodynamic trapping of gas in the deep burial depth and thrust faults, and (2) gas loss by groundwater flushing and normal faults. Basically, the first mechanism causes the high gas content of the east zone, whereas the other one is responsible for the low gas content in the west zone of the study area.

Keywords: coalbed methane; Weibei Field; gas content; geological control factors; Ordos Basin

Citation: Qiu, Y.; Wang, H.; Guo, G.; Mo, R.; Pan, Z.; Cai, Y.; Abuduerxiti, A. Gas Distribution and Its Geological Factors in the No.5 Coal Seam of the Weibei Field, Southeastern Ordos Basin, North China. *Processes* **2022**, *10*, 659. https://doi.org/10.3390/pr10040659

Academic Editor: Aneta Magdziarz

Received: 30 December 2021
Accepted: 24 March 2022
Published: 28 March 2022

1. Introduction

The exploitation of coalbed methane (CBM) not only benefits mining safety but also has great significance for reducing carbon-dioxide emissions [1]. With the increased demand and gas price in recent years, the increasing interest is exhibited in CBM resources, which requires the accurate estimation of the recoverable reserves of CBM resources [2,3]. Basically, CBM resources are abundant in the Ordos Basin, located in one of the most important fossil-fuel energy areas in China [4–11]. The CBM resources are about 9×10^{12} m^3 in the eastern Ordos Basin, while 10.72×10^{12} m^3 in the entire Ordos Basin, which accounts for ~1/3 to 1/4 of the known total CBM resources in China [4].

The Weibei Field, covering an area of 1530 km^2, lies on the southeastern edge of the Ordos Basin, where thousands of CBM production wells have been drilled, and a CBM production field had been established [4]. Therein, the gas production of each CBM well differs because of the different characteristics of reservoirs. Although the key factors controlling CBM production are various in different geological structures, the gas content is widely accepted to be one of the crucial indicators for CBM reservoir productivity [3,12–14]. However, the difficulty remains in the accurate evaluation on the gas content co-determined by multiple geological factors like hydrodynamic factors and coal heterogeneities [3,15,16]. By discussing the geological and hydrodynamic control factors of gas content in the southeastern Ordos Basin (SOB), Yao et al. [4]. found that there is an intimate relationship between hydrodynamics and gas content in the Basin. Furthermore, an investigation of the gas content of the No.2 coal seam in the Yanchuannan Field of the southern SOB revealed that the high gas content is the integrated result of gas generation, migration, and preservation [3]. The previous achievement also indicated that the geological structure types, burial depth, and the groundwater level in the coal seam are the main factors controlling gas content [3]. Yan et al. [17] conducted a simulation aiming to improve knowledge about the deposition-burial, geothermal, and organic maturation evolution and their influence on gas content in the Weibei field. However, the distribution and geological controls of the gas content in the No.5 coal seam are not yet fully understood for the Weibei Field. Therefore, more investigations are needed.

This study conducts a comprehensive investigation on the gas content in the Weibei Field of the SOB. Based on diverse experimental and statistic data, the distribution of gas content and its geological control factors are discussed, including tectonic and depositional evolution, roof/floor lithology and thickness, burial depth of coal seam, and hydrodynamic conditions. Moreover, two typical geological models controlling gas content are established. This work should be helpful in enhancing the knowledge on the geological control mechanism related to the gas content in the No.5 coal seam of Weibei Field and in guiding the potential CBM engineering operations in this area.

2. Geological Setting

2.1. Tectonics of the Basin

The Ordos Basin, with an area of 2.4×10^5 km^2, lies in the western part of North China (Figure 1A) [18]. This is a large asymmetric Basin including a broad, gently dipping eastern limb, and a narrow, steeply dipping western limb, forming an axis in the Tianhuan Sag [19]. The Ordos Basin is surrounded by the Yin Mountain in the north, Lvliang Mountain in the east, Qinling Mountain in the south, and the Liupan and Helan Mountains in the west (Figure 1B). There is six tectonic domains in Ordos Basin, i.e., the Yimeng and Weibei uplift, the Jinxi fold belt, the Yishan slope, the Tianhuan sag, and the western edge thrust belt (Figure 1B). The studied Weibei Field is situated in the northeastern part of the Weibei uplift (Figure 1B), which contains the Hancheng area in the northeast (east zone) and the Heyang area in the southwest (west zone) (Figure 1C). In the study area, there are three dominant thrust faults, including Xuefeng-Bei (F1), Xuefeng-Nan (F2), and Qingao faults (F3) (Figure 1C), formed during the Late Cretaceous Yanshanian Orogency [20].

2.2. Coal-Bearing Strata in the Weibei Field

The Weibei Field preserved the strata of Cambrian, Ordovician, Carboniferous (Pennsylvanian), Permian, Triassic, and Quaternary-aged sequences [17]. In this field, there are two main coal-bearing strata, including the Carboniferous (Pennsylvanian) Taiyuan Formation and Permian Shanxi Formation, where the No.5 coal seam, one of the most important gas-bearing beds, belongs to the Pennsylvanian Taiyuan Formation (Figure 2). Previous studies have reported that the No.5 coal seam dips gently towards the northwest with an angle of 5–15° [21] and has a thickness of 1.2–8.4 m (avg. 5.5 m) and burial depth of 460–1200 m with a mean of 950 m [4,15]. In addition, the maximum vitrinite reflectance is in the range of 1.6–2.5% (avg. 2.0%), and gas content ranges from 2.69–16.15 m^3/t [4].

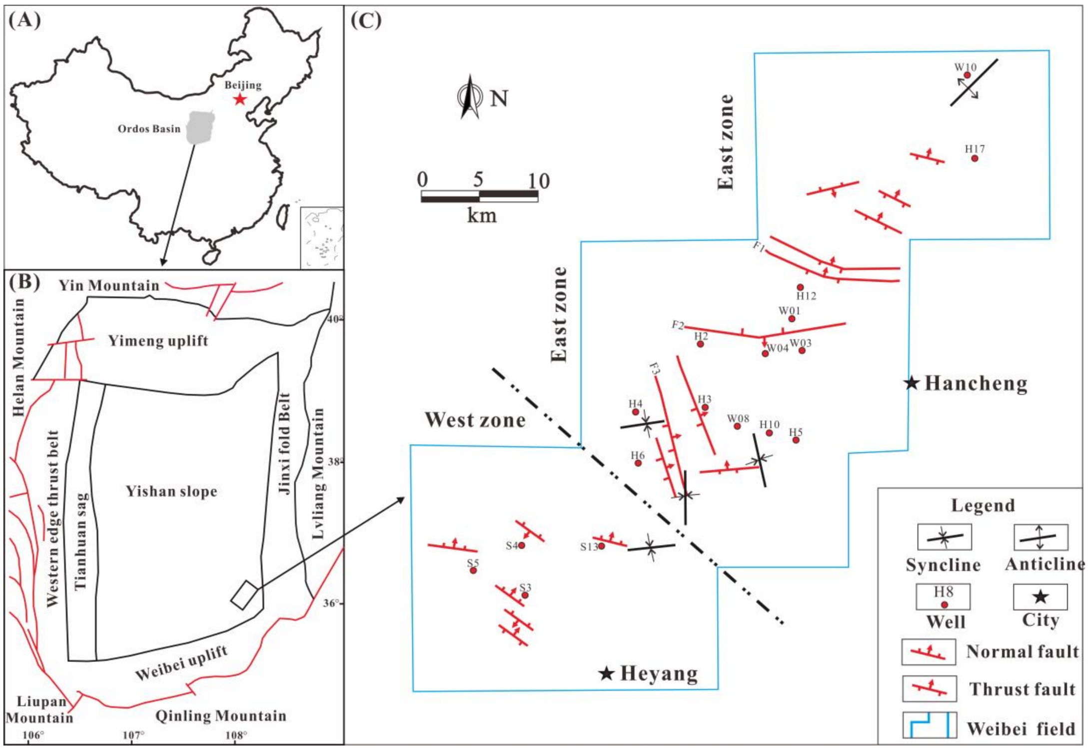

Figure 1. Location of the Ordos Basin in North China (**A**); Location of the Weibei Field (**B**); Geological structures and locations of the exploration wells in the Weibei Field (**C**).

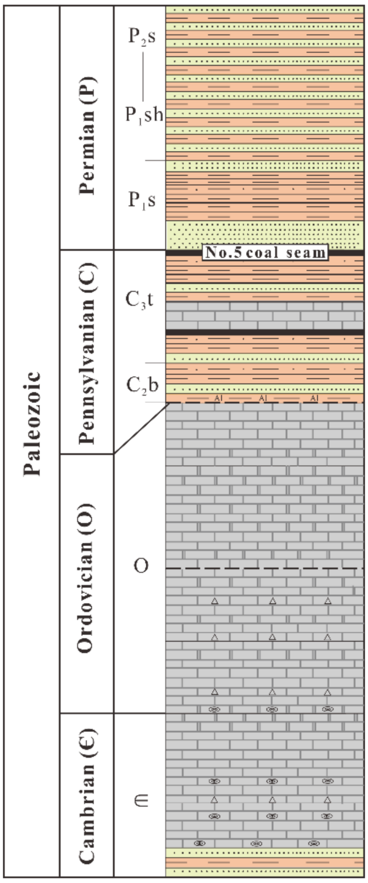

Figure 2. Stratigraphic column in the Weibei Field (Yan et al., 2015 [17]).

3. Methodology

In this study, a total of twenty-two coal samples collected from working coal seams in 18 coal mines were used. The porosity and permeability were measured by the routine core methods following the Chinese Oil and Gas Industry Standard SY/T 5336-1996. Besides, the maceral and vitrinite reflectance were measured by the polished slabs by LABORLUX 12 POL Fluorescence Microscope and Microscope Photometer (MPV-3) following the GB/T 6948-1998 and ICCP system 1994 methods. Isothermal adsorption was carried out on the collected samples following the standard GB/T 19560-2008. Furthermore, the gas content, coal thickness, burial depth, and roof/floor lithology of No.5 coal seam were collected from field test data of 16 exploration wells (Figure 1C). Herein, the measurements of gas content followed the Chinese National Standard GB/T 19559-2004 (2004), and the tectonic characteristics of the No.5 coal seam were interpreted by conventional two-dimensional seismic reflection data. Details regarding the analytical methods are exhibited in our previous study [4]. The burial history, thermal evolution history, and hydrocarbon generation processes were simulated with data of typical wells by BasinMod modeling software. In addition, the microfractures, pore characteristics, permeability, and pressure of the No.5 coal seam are referenced from previous literature [4,21].

4. Results and Discussion

4.1. Gas Content in No.5 Coal Seam

4.1.1. Tectonic and Depositional Evolution Related Gas Generation

The generation of CBM occurred during the coalification process, controlled by various factors, including burial history, tectonic evolution, and paleo-geothermal heating regarding the coal seam [2,22,23]. As for the Weibei Field, it experienced the following four evolution stages: accelerated subsidence (I), fluctuant (II), uplift (III), and terminate (IV) stages (Figure 3).

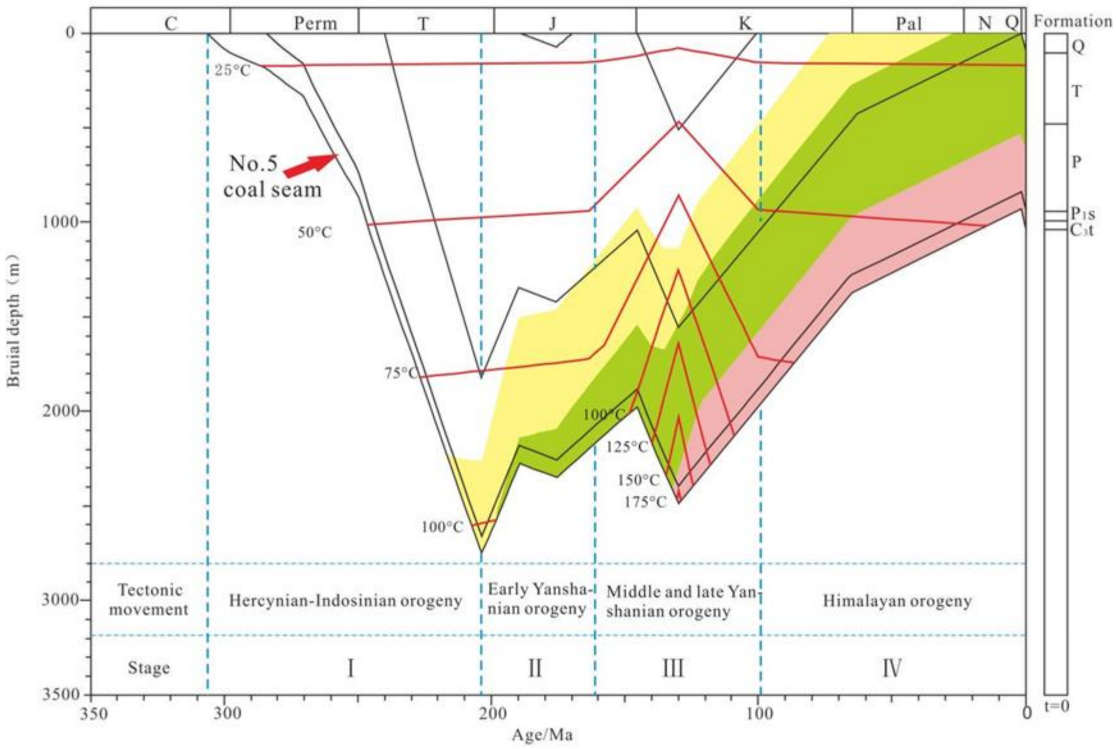

Figure 3. Schematic diagram of tectonic and depositional evolution in the Weibei Field.

The stage I relates to Hercynian-Indosinian orogeny with a gradually increased subsidence speed (Figure 3). In the Weibei Field, the subsidence of coal-bearing strata is approximately 1.5–9 m/Ma and 3–11 m/Ma during the Permian and Triassic, respectively. At this stage, the No.5 coal seam is buried to a depth of ~900 m by the end of Permian and ~2700 m in the Late Triassic (Figure 3). Generally, the temperature of coal reservoir gradually increases with increasing burial depth [2]. In addition, the geothermal gradient in the Ordos Basin was normally ~2.8–4.0 °C/100 m, enabling the maximum temperature of No.5 coal seam to be ~25–36 °C by the end of Permian and to be ~76–108 °C in the late Triassic. Therein, the shallow burial depth of the Permian coal-bearing strata limits the maturation of organic matter, and thus the generated CBM, at this stage, mainly belonged to biogenic gas, which was not well-preserved because of the shallow burial depth [8]. Afterward, the maximum vitrinite reflectance ($R_{o,max}$) of the No.5 coal seam was <0.75% by the end of the Triassic. Due to the relatively strong orogeny during the late Triassic, the CBM migrated at the first adjustment: most of the generated CBM was sealed in place because of the Ordos Basin compressed by the NS trending stress [3].

Stage II relates to the early Yanshanian orogeny with fluctuations in the burial history (Figure 3), where the Weibei Field was compressed by an NS strike stress. In this stage, the uplift and subsidence commonly occurred in the field and resulted in the formation of the EW and SE-NW striking folds and faults [4]. Meanwhile, the temperature of the No.5 coal seam was about 130 °C, and accordingly, the $R_{o,max}$ was up to about 1.0% by the end of Jurassic. Although the coalification was kept more or less stable, rare generated CBM could be preserved in this stage because of thermal fluctuations [3].

Stage III relates to the Middle and Late Yanshanian orogeny. In this stage, the burial depth of the No.5 coal seam reduced rapidly (Figure 3). A magma-heat event resulted in the formation of an abnormal geothermal field as high as 5.5 °C/100 m and some parts were up to 8 °C/100 m. Coalification was significantly affected by the relatively high heat flow from the magmatic intrusions [2]. By the end of the Cretaceous, the $R_{o,max}$ of the No.5 coal seam was about 2.2%, resulting in more gas being generated in this stage.

Stage IV relates to the Himalayan orogeny with the continuously decreasing burial depth of the No.5 coal seam (Figure 3). The No.5 coal seam was uplifted and eroded in the Weibei Field. In addition, the geothermal field reverted to a lower level, and thus the temperature of the No.5 coal seam was continuously decreasing. By the end of the Himalayan orogeny, the gas expulsion of organic matter eventually stopped.

4.1.2. Gas Migration and Preservation

Geological Structures and Related Gas Distribution

The Weibei Field was subdivided into the east and west zones through tectonic complexity, as shown in Figure 1, where mainly thrust faults but few folds existed in the east zone and the faults planes commonly dip south- and eastward. Compared with the east zone, the west zone is extended more intensely with few folds and normal fault development. These faulting and folding activities induce coal deformation, which in turn affects the gas content of the No.5 coal seam. As summarized in Table 1, the gas content of the No.5 coal seam is in the range of 2.69 to 16.15 m^3 /t (avg. 9.95 m^3/t) in the Weibei Field. The gas content is higher (avg. 11.42 m^3/t) in the east zone but lower (avg. 5.56 m^3/t) in the west zone (Figure 4). The compressional deformation is intensified in the east zone and therein the thrust faults are dominated. The compressed stress probably led to the macro- and micro-fractures being close in the coal [21] as well as its roof and floor, creating the seal conditions for gas preservation. On the contrary, extensional deformation is intensified in the west zone, where normal faults and folds are the primary types. The extensional stress caused fractures to develop in the coal as well as its roof and floor, provide open conditions for gas migration. As a result, the CBM content in the east zone is higher than in the west zone in the study area.

Table 1. Coal thickness, burial depth, reservoir pressure, and Langmuir volumes (V_L) data of 16 coalbed methane (CBM) wells in the Weibei Field.

Zone	Well	Burial Depth (m)	Thickness (m)	Reservoir Pressure (MPa)	R_o (%)	Gas Content (m^3/t)	Langmuir Volumes (m^3/t)
East	H3	1013.6	5.6	9.35	1.98	8.99	22.91
	H4	1105.0	4.6	8.51	2.15	12.71	26.12
	H5	587.0	3.2	4.52	2.32	8.91	23.72
	H6	1066.4	5.4	8.22	2.10	11.74	27.77
	H10	715.7	5.0	5.51	2.23	8.59	19.42
	H12	634.1	3.5	4.12	2.32	8.12	23.08
	H17	466.1	2.5	3.72	2.05	11.58	20.63
	W01	638.6	3.1	4.39	2.09	7.42	31.5
	W03	684.3	3.5	6.05	2.15	16.01	28.04
	W04	917.7	4.4	7.06	2.07	16.15	25.83
	W08	883.8	9.0	6.52	2.21	12.38	20.36
	W10	531.6	6.3	4.63	2.23	14.46	24.12
West	S3	607.8	3.8	4.70	2.05	3.22	13.58
	S4	752.2	4.1	6.79	1.73	10.59	22.44
	S5	625.3	2.9	7.43	1.68	2.69	12.43
	S13	854.5	5.3	8.14	1.76	5.72	16.31

Lithology and Thickness Distribution of Roof and Floor

The lithology and thickness of the roof and floor are listed in Table 2, where the floor of the No.5 coal seam is mainly mudstone, while the lithology of the roof varies throughout the entire Weibei Field. In the east zone, the roof of the No.5 coal seam is mainly characterized as mudstone and carbonaceous mudstone, as well as sandstone in some local areas (Table 2 and Figure 5). While in the west zone, the roof is primarily mudstone and argillaceous sandstone, accompanied with silt in some separated areas (Table 2 and Figure 5). Previous studies had reported that the mudstone commonly has a good potential of sealing, which is conducive to CBM storage [3,24], indicating that the floor of the No.5 coal seam has good sealing potential, but variable sealing potential in the roof in the Weibei Field. As a whole, the sealing potential of the roof for generated gas in the east zone is better than that in the west zone.

In addition to lithology, the thickness of the roof and floor directly influences the CBM preservation, where the more thick, the better sealing performance the roof and floor will have [3,24]. In the Weibei Field, it was a shallow marine environment during the Late Pennsylvanian [25], making the thickness of the roof and floor regarding the No.5 coal seam to be stable and within the range of 2.3 to 3.6 m (Table 2), where the mudstone thickness of the floor regarding the No.5 coal seam ranges from 2.3 to 3.5 m (Table 2), representing that there is no significant difference for the floor properties influencing gas content. In addition, the mudstone thickness of the roof for the No.5 coal seam varies from 1.3 to 3.0 m (Table 2). A roof with a mudstone thickness of over 1 m can effectively seal the gas and retain a gas content of over 10 m^3/t [3]. Therefore, there is no obvious relationship between gas content and the roof thickness for mudstone in the Weibei Field (Figure 6). In general, the roof and floor sealing capability of the No.5 coal seam are generally high, which is beneficial to CBM preservation.

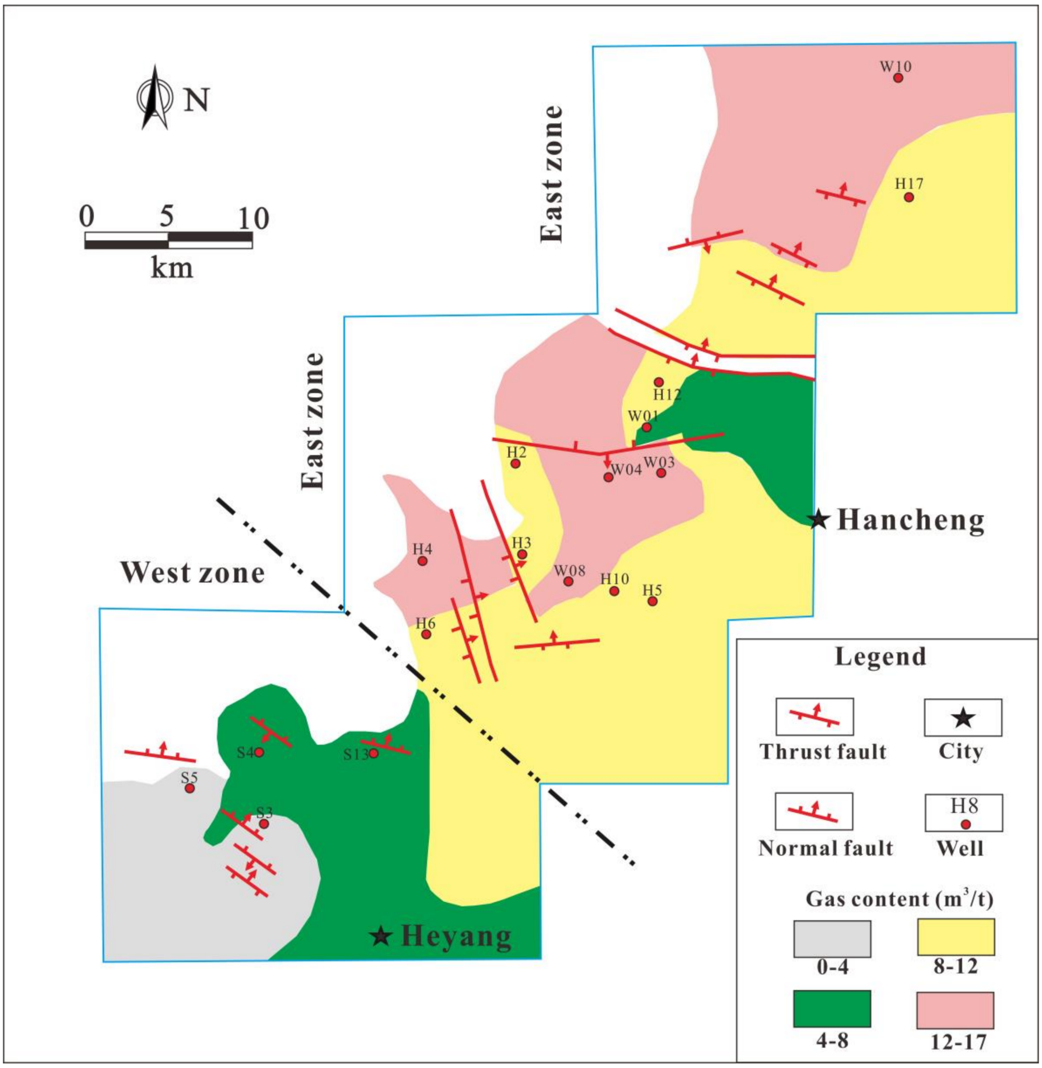

Figure 4. The distribution of gas content of the No.5 coal seam in the Weibei Field.

Table 2. The thickness, roof lithology, and floor lithology of the No.5 coal seam of 16 CBM wells in the Weibei Field. Note: M = Mudstone, S = Sandstone, CM = Carbonaceous mudstone, SM = Silty Mudstone, AS = Argillaceous sandstone.

Zone	Well	Roof			Floor		
		Dominate Lithology	Thickness (m)	M Thickness (m)	Dominate Lithology	Thickness (m)	M Thickness (m)
East	H3	CM	2.7	2.2	M	2.7	2.5
	H4	M	3.2	3.0	M	3.2	3.0
	H5	S	3.6	2.0	M	3.4	3.0
	H6	CM	2.9	2.3	M	2.6	2.2
	H10	CM	3.5	2.8	M	3.2	3.1
	H12	M	3.2	2.9	CM	3.6	3.0
	H17	CM	3.4	2.7	M	2.9	2.8
	W01	M	2.6	2.3	M	3.5	3.3

Table 2. *Cont.*

Zone	Well	Roof			Floor		
		Dominate Lithology	Thickness (m)	M Thickness (m)	Dominate Lithology	Thickness (m)	M Thickness (m)
	W03	M	2.2	2.0	CM	2.8	2.2
	W04	CM	2.5	2.0	M	2.7	2.5
	W08	CM	2.6	2.0	M	3.2	3.1
	W10	CM	3.5	2.7	M	2.8	2.6
West	S3	SM	2.8	2.1	M	2.2	2.0
	S4	AS	2.7	1.3	M	2.5	2.2
	S5	M	2.9	2.6	M	2.6	2.2
	S13	AS	3.2	1.8	M	2.3	2.0

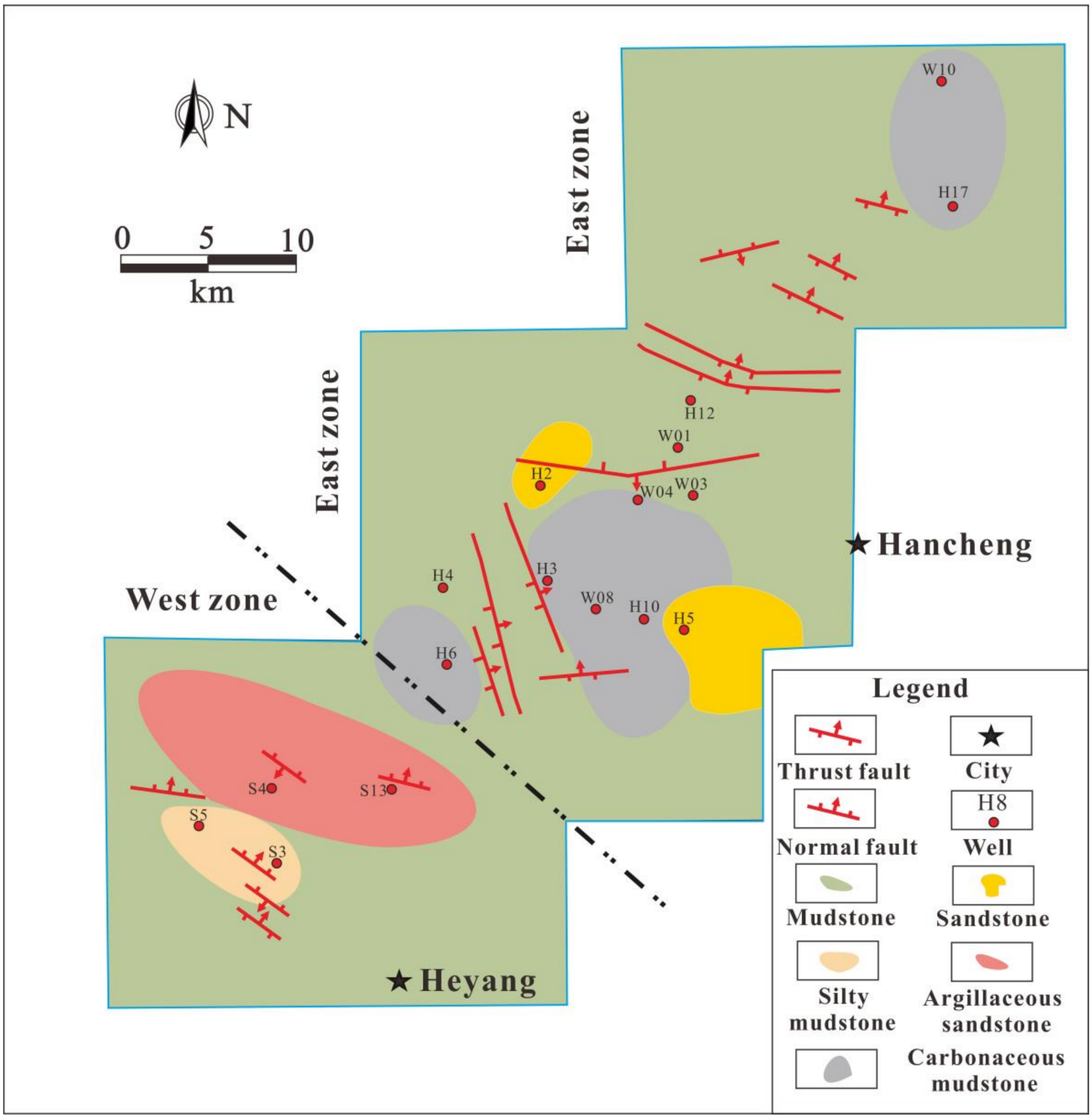

Figure 5. Roof lithology distribution of the No.5 coal seam in the Weibei Field.

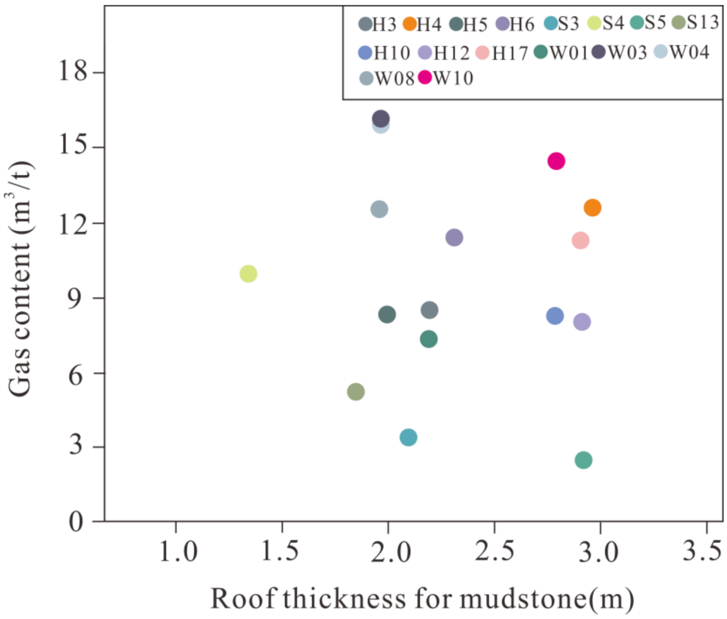

Figure 6. Relationship of roof thickness for mudstone and gas content of the No.5 coal seam in the Weibei Field.

Thickness and Burial Depth

The thickness of the No.5 coal seam ranges from 2.5 to 9.0 m (avg. 4.51 m) and decreases from the center to the margin of the Weibei Field (Figure 7). As listed in Table 1, in the Weibei Field, the No.5 coal seam is generally thicker than 4 m and has a relatively high gas content of over 9 m^3/t. Although coal thickness is not seriously related to current gas content, it can also control gas redistribution during tectonic activities or if magma intrusion occurs [3]. At the margin of the Weibei Field, the thickness of the No.5 coal seam decreases to be less than 4 m, which is a negative factor for gas preservation.

The burial depth of the coal seam has a significant influence on gas content [26,27], because the maximum burial depth during tectonic evolution controls gas generation and coal rank, while the current burial depth affects preservation conditions and gas content [27,28]. To investigate the preservation of the No.5 coal seam, a contour map of current burial depth was illustrated in Figure 8, in which the current burial depth is within 400 to 1200 m in the east zone, and within 500 to 1000 m in the west zone in the Weibei Field. Moreover, the No.5 coal seam burial depth increases from southeast to northwest in the Weibei Field (Figure 8). Besides, it can be observed from Figures 4 and 8 that the gas content of the No.5 coal seam increases with the increase of burial depth. Compared with the west zone, the east zone with a deep burial depth of the No.5 coal seam is favorable for CBM preservation.

Hydrogeological Conditions

Hydrogeological conditions commonly influence the coal properties, gas generation, and gas distribution [4], and are also key controlling factors on the fluid pressure regime and productivity of CBM wells [29,30]. Tectonics, topography, and precipitation are the main factors that affect groundwater migration in the aquifer [4]. According to these conditions, the Weibei Field has three hydrogeological systems, including the Quaternary (Q), Permo-Carboniferous (C–P), and Ordovician (O) aquifers. Previous studies clarified that the Q and O aquifers have no relationship with the No.5 coal seam due to the barrier of one hundred-meter thick strata in the Weibei Field [4]. The groundwater migration in Taiyuan Formation belonging to the C–P aquifer system, however, has an important impact on the No.5 coal seam.

A single C–P aquifer system exists due to a hydrodynamic connection through fractures in the No.5 coal seam, providing abundant produced water for CBM wells in the

Weibei Field [4]. As the thrust fault has a good sealing capability, it can divide a closed local aquifer system in the east zone, for example, thrust faults F2 and F3 in the study area play such a role (Figure 9). In this region, the groundwater with a good hydrodynamic sealing is advantageous for a high gas content in the No.5 coal seam (Figure 4). Compared to the thrust fault, the normal fault commonly has a bad sealing capability. In addition, although the normal fault can interrupt the continuity of the aquifer system, the flow rate of groundwater would significantly accelerate through gravity. These are disadvantages for gas preservation due to the bad hydrodynamic sealing condition as well as some CBM being dissolved in the groundwater and flowing away, for example, well S13 (Figure 9). These phenomena clarify the reasons for the low gas content in the west zone of the Weibei Field.

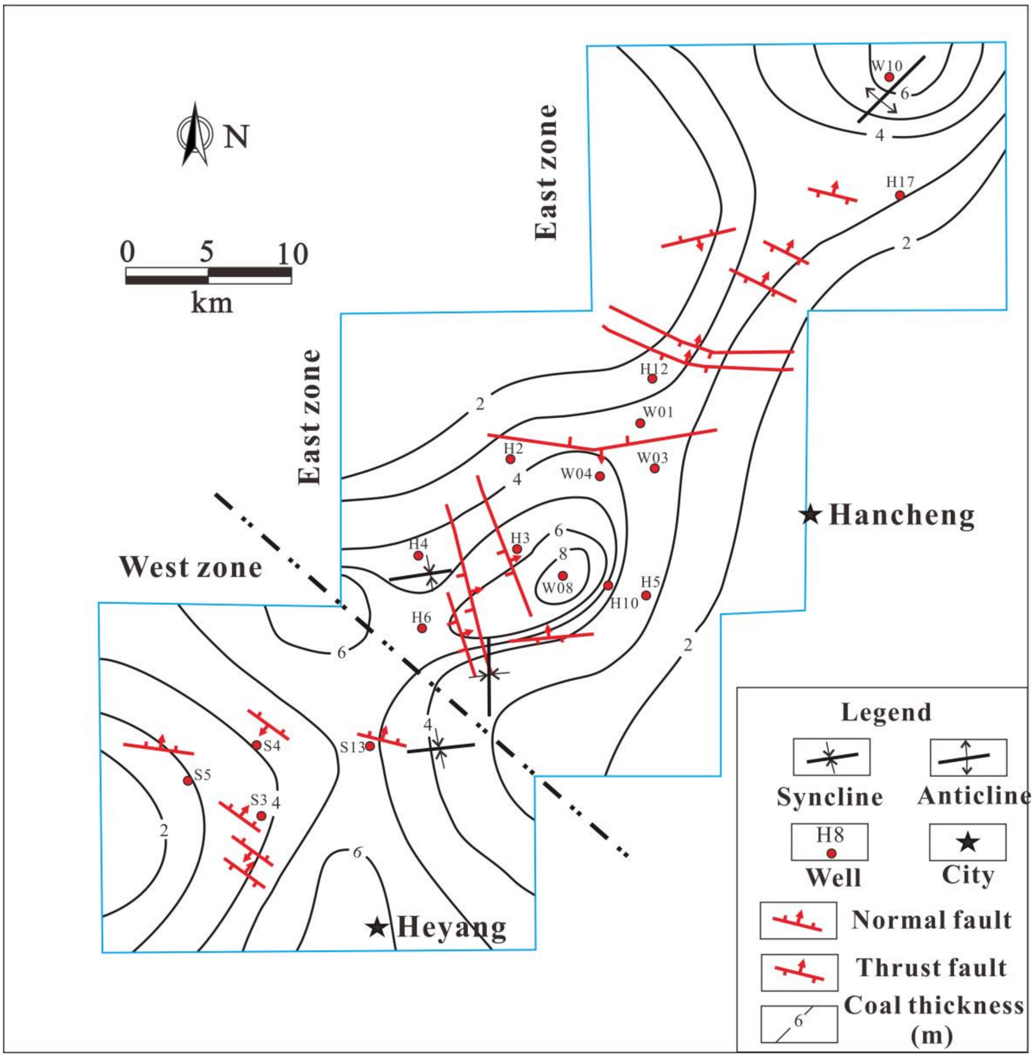

Figure 7. Thickness distribution of the No.5 coal seam in the Weibei Field.

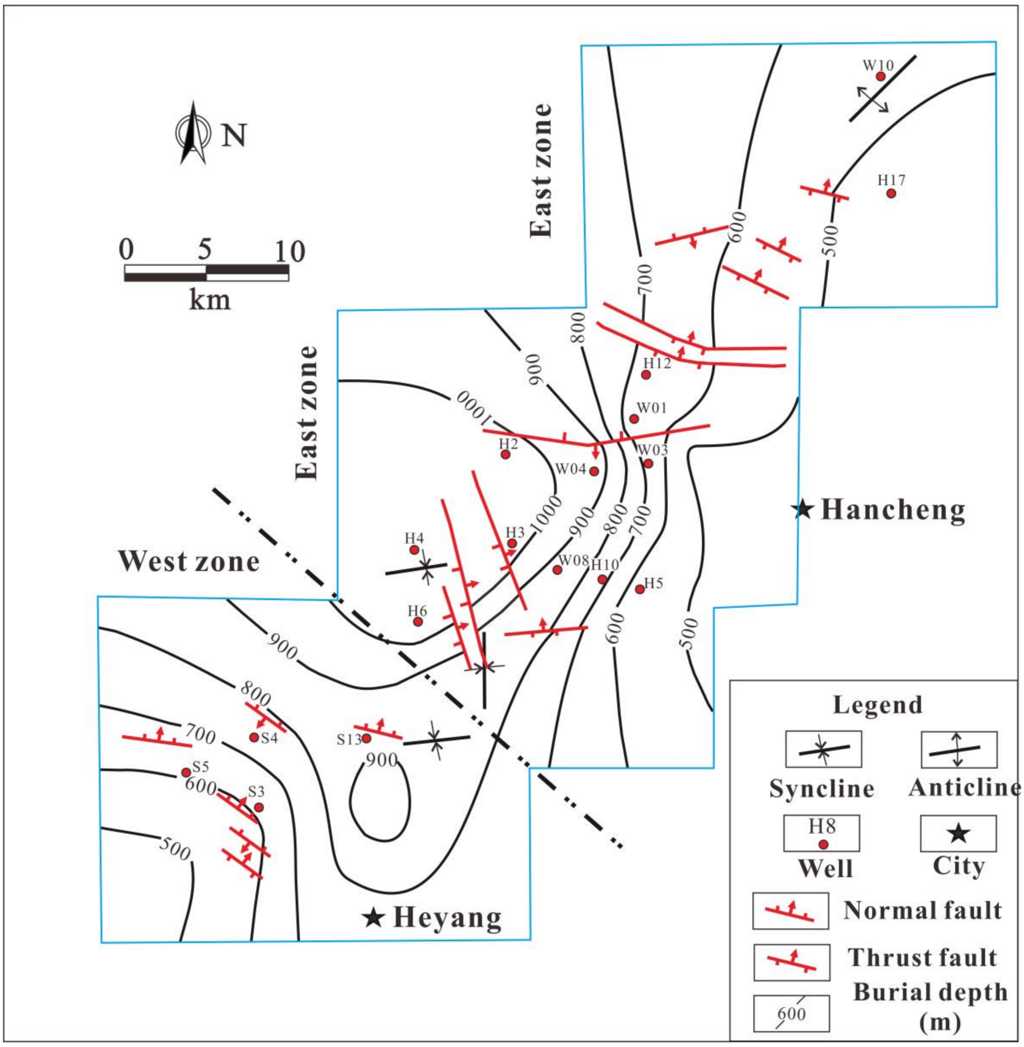

Figure 8. Burial depth distribution of the No.5 coal seam in the Weibei Field.

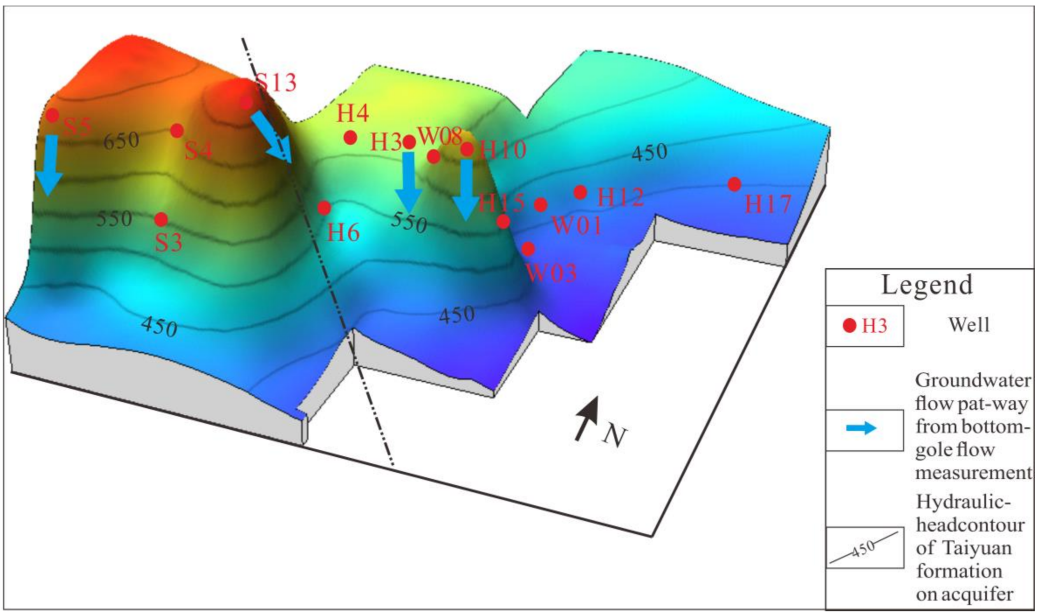

Figure 9. Hydraulic head contour of Taiyuan Formation aquifer.

4.2. Methane Adsorption Capacity of No.5 Coal Seam

CBM is mainly adsorbed on the pore surface of the coal matrix, therefore it is widely accepted that the adsorption capacity has a significant influence on gas content. Table 1 lists the Langmuir volumes (V_L, on an air-dry basis) of the No.5 coal seam in the Weibei Field, suggesting the coal seam has a relatively high methane adsorption capacity revealed by the great V_L varying from 12.43 to 31.50 m^3/t. Moreover, it is lower in the west zone (avg. 16.19 m^3/t) but higher in the east zone (avg. 24.45 m^3/t). These tendencies are consistent with the distribution of gas content in the Weibei Field. Moreover, Figure 10 suggests that the V_L and gas content of the No.5 coal seam exhibits a positive linear relationship in the Weibei Field. Although many factors, such as pressure, temperature, coal composition, ash yield, and pores, affect the methane adsorption capacity of coals, several studies show that the capacity of methane adsorption is related to pore size under the approximate pressure and temperature conditions. Thus, methane is mainly adsorbed on the surface of the pores, which have diameters of <100 nm [3,31].

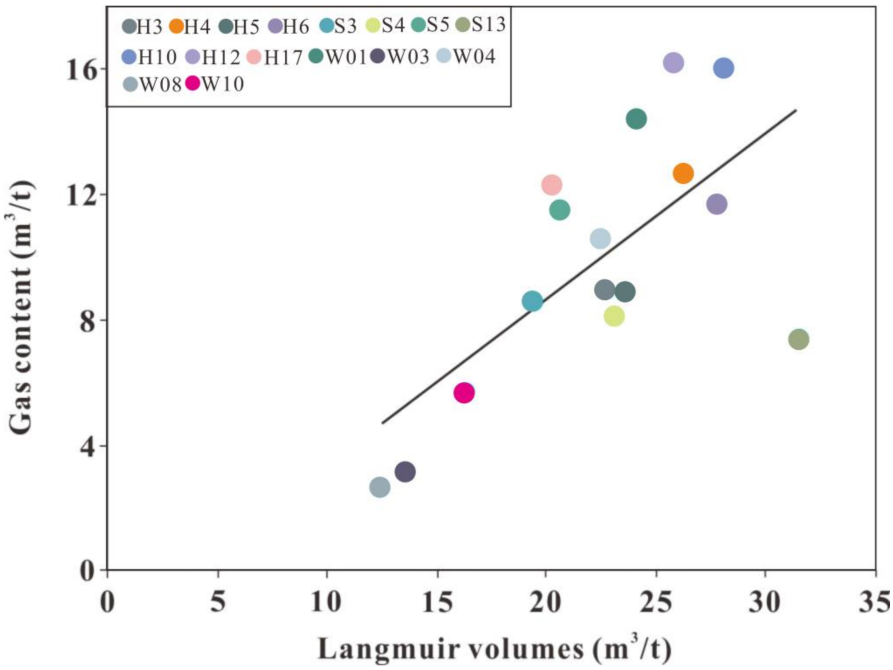

Figure 10. Relationship methane adsorption capacity and gas content of No.5 coal seam in the Weibei Field.

Table 3 lists the pore proportion of the No.5 coal seam in the Weibei Field, showing the proportion of pores with diameters of <100 nm range from 60.31% to 72.04%. Besides, it is higher in the east zone (avg. 67.78%) but lower in the west zone (avg. 62.22%). This situation is consistent with the adsorption capacity distribution characteristics in the Weibei Field. Moreover, the proportion of pores with diameter > 1 μm is lower in the east zone (avg. 5.48%) but higher in the west zone (avg. 24.8%). These phenomena are probably due to the west zone being seriously affected by extensional stress during normal faulting activities, accordingly forming relatively large pores. In contrast, the east zone is seriously affected by compressive stress during thrust faulting activities, which causes the previous large pores to shrink into small ones.

Table 3. The proportion of pores with different diameters of the No.5 coal seam of 16 CBM wells in the Weibei Field.

Zone	Sample No.	Proportion of Pores (%)		
		<100 nm	100 nm to 1 μm	>1 μm
East	E1	72.04	23.61	4.35
	E2	67.06	20.34	8.60
	E3	64.25	32.25	3.50
West	W1	60.31	12.36	27.33
	W2	63.24	13.25	23.51
	W3	63.05	12.40	23.55

4.3. Gas Saturation and Reservoir Pressure

The gas saturation is defined as the percentage of total gas content relative to the maximum capacity of methane adsorption. The gas saturation for a coal sample is determined by reservoir pressure and temperature by comparing the desorption data with an adsorption isotherm [4]. Regarding the calculation of gas saturation, details were exhibited by Pashin [32]. As shown in Figure 11, the gas saturation is in the range of 25% and 94.5% in the Weibei Field. The average gas saturation accounts for ~73% in the east zone, while ~44% in the west zone (Figure 11). This significant difference was affected by secondary processes. For instance, gas migration is related to regional tectonic activities [4]. In the east zone, the compressed stress led to a good sealing capability of the coal seam's roof and floor, resulting in a high gas content; hence, a great gas saturation. In contrast, the extensional stress led to normal faults well development in the west zone, which is negative for gas preservation, resulting in relatively low gas content and gas saturation. In addition, reservoir pressure refers to the fluid pressure acting in the pore-fracture space. The pressure of the No.5 coal seam ranges from 3.72 to 9.35 MPa (Figure 10). A local high-pressure area was formed in the east zone which benefits the occurrence of CBM, while the low-pressure area was formed in the west zone and is a disadvantage for high gas content.

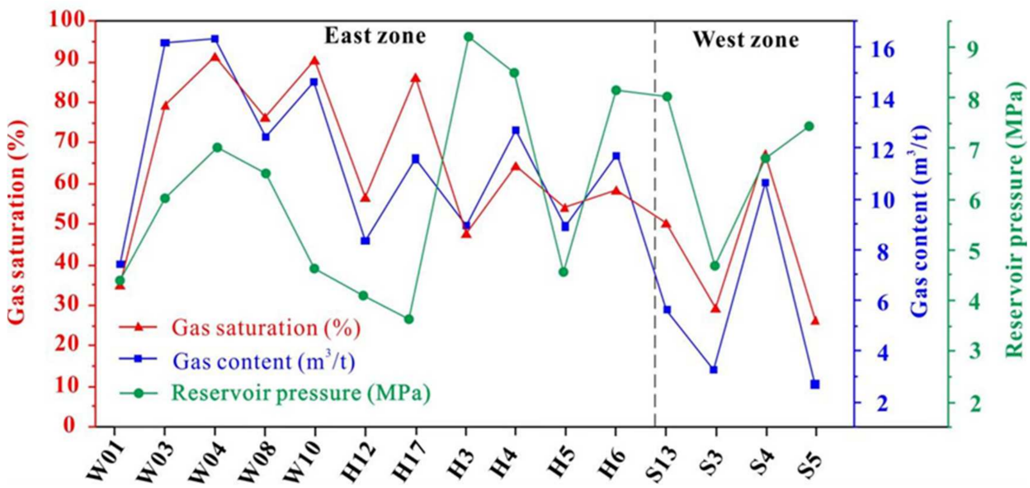

Figure 11. Relationship of gas content, gas saturation, and reservoir pressure of the No.5 coal seam in the Weibei Field.

4.4. Scenarios for Geological Controls on Gas Content

Based on a comprehensive analysis of the effects of geological control factors on gas content in the Weibei Field, the gas content distribution is co-controlled by many factors, including geological structures, roof lithology, burial depth, and hydrodynamic conditions, whereas the coal reservoir properties influence the gas content in a local area. Figure 12 shows two typical geological models, which can give an explanation of the effects of key factors on gas content in the Weibei Field. The first model (Model A) applies to the west zone of the Weibei Field, where the average gas content is <6 m^3/t. Herein, the normal faults are developed, easily allowing the gas to dissipate. Besides, the gas adsorbed in the surface of the coal matrix diffuses into the pore-fracture network and then migrates to the permeable strata by hydrodynamic flushing in the recharge zone.

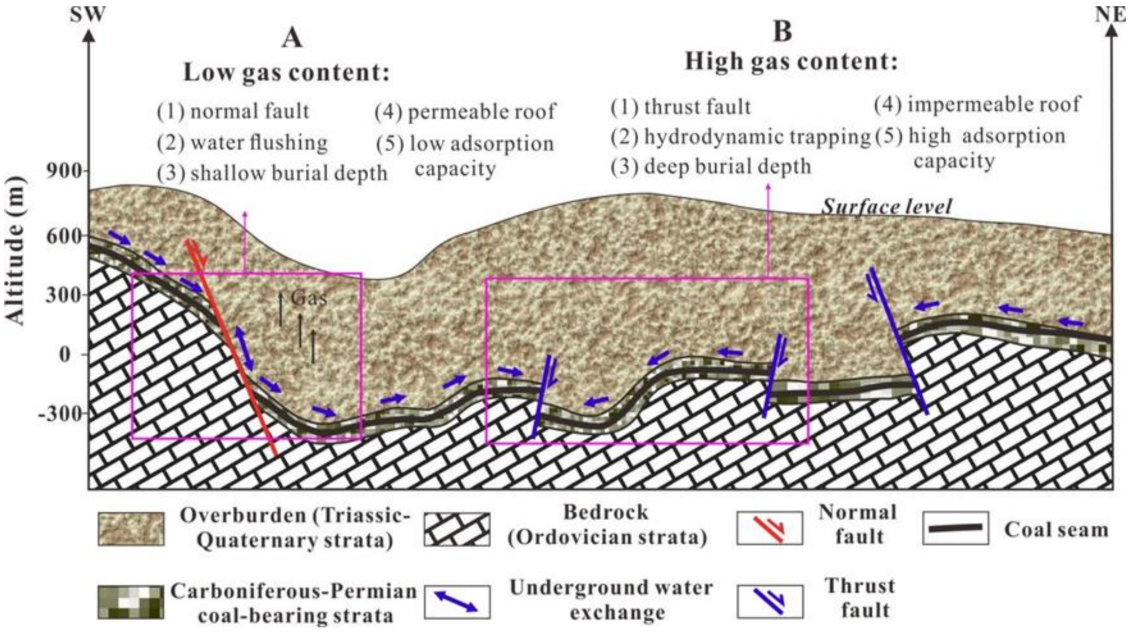

Figure 12. Geological scenarios controlling CBM content of the No.5 coal seam in the Weibei Field. (**A**) shows low gas content model; (**B**) shows high gas content model.

Model B is representative of the east zone in the Weibei Field (Figure 12), where the gas content is high at >11 m^3/t. This model is controlled by the combined effects of hydrodynamic and geological conditions, in which the roof of coal seam developed in the thrust fault zone commonly has an impermeable seal. Moreover, hydrodynamic trapping also increases gas content in the deep burial depth zone, where more gas can be adsorbed in coals with a relatively high reservoir pressure, which is beneficial to CBM preservation.

5. Conclusions

The comprehensive evaluation of gas content and its key controls are conducted based on the working coal seam samples together with 16 CBM wells in the Weibei Field, SOB, north China. The following conclusions are drawn from this study:

(1) The distribution of gas content is directly controlled by the tectonic and depositional evolution, which seriously affects gas generation. In the Weibei Field, the main CBM generation is related to the fluctuation subsidence of the coal seam during the middle and late Yanshanian orogeny.

(2) Highly variable gas contents in the No.5 coal seam of the Weibei Field reflect the combined effects of geological factors, hydrodynamic factors, and the properties of the reservoir. Besides, the fault types, roof lithology, burial depth of coal seam, and hydrodynamic conditions are the key control factors on the distribution of gas content.

(3) In the Weibei Field, the gas production potential for exploration and development is higher in the east zone but lower in the west zone because the recharge and runoff zone of groundwater is located in the west, while the stagnant and weak runoff zone of groundwater is located in the east. According to the analysis of the effects of key control factors on the distribution of gas content, two typical models controlling gas content in the Weibei Field are established.

Author Contributions: Y.Q. and H.W. conceived and designed the experiments; Y.Q. and H.W. performed the experiments and wrote the paper; H.W. and A.A. analyzed the data; Z.P. and Y.C. revised the paper and provided language support; G.G. and R.M. provided technical support. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Natural Science Foundation of China (42102227, 42130806, 41922016 and 41830427), and the Fundamental Research Funds for the Central Universities (2652018280).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Restrictions apply to the availability of these data. Data was obtained from China National Petroleum Corporation and are available from the authors with the permission of China National Petroleum Corporation.

Acknowledgments: We would like to thank China National Petroleum Corporation for providing the exploration well data.

Conflicts of Interest: The authors declare no conflict of interest.

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