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Retraction

Retracted: Influence of Pore Structure Characteristics of Primary Coal on Coalbed Methane Adsorption

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This article has been retracted by Hindawi, as publisher, following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of systematic manipulation of the publication and peer-review process. We cannot, therefore, vouch for the reliability or integrity of this article.

Please note that this notice is intended solely to alert readers that the peer-review process of this article has been compromised.

Wiley and Hindawi regret that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] G. Liu, "Influence of Pore Structure Characteristics of Primary Coal on Coalbed Methane Adsorption," *Advances in Materials Science and Engineering*, vol. 2022, Article ID 3087252, 7 pages, 2022.

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Research Article

Influence of Pore Structure Characteristics of Primary Coal on Coalbed Methane Adsorption

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In order to better discuss the influence of pore structure characteristics of primary coal on coalbed methane adsorption, suburban coal and Zhaozhuang coal in Henan Province were systematically sampled. The analysis method of pore structure characteristics of primary coal is divided into shooting research and experimental analysis. Scanning electron microscope (SEM) was used to analyze the formation reason of coal micropores, pore shape, pore connectivity, pore size, and filling effect on coalbed methane adsorption. Experimental analysis is mainly based on CO_2 adsorption experiments to obtain specific surface, pore volume, and distribution of coal samples. The pore-specific surface area, pore volume, and adsorption-desorption curve of coal samples were obtained by ultralow-temperature N_2 adsorption experiment. Finally, the influence of pore structure characteristics of primary tectonic coal on coalbed methane adsorption was discussed by fusion of phase study and experimental analysis.

1. Introduction

Coal is a porous medium with two-way growth and development of pores. The pore structure of the surface layer of coal cultivation substrate is a reservoir for coalbed methane adsorption, and the penetrating pores inside it are also the primary safe channel for coalbed methane infiltration and spread. The characteristics of pore structure (area, pore size distribution, pore volume) have a very important regulatory effect on the cause, migration (adsorption, spread, infiltration) characteristics, and behavior of coalbed methane. It has a great guiding significance for the comprehensive utilization of coalbed methane and can reasonably ensure the safety factor of coalbed methane mining and discharge. At the same time, the structure of primary coal is the indication of initial chemical substances, accumulation, and conversion of coal and is the key initial characteristic of coal. Therefore, it is of great practical significance to discuss the pore structure characteristics of primary coal for coalbed methane adsorption.

2. Samples and Test Methods

2.1. Experimental Samples. The original coal sample system is taken from the coal mines in the suburbs of Henan Province and Zhaozhuang coal mine. Most coal seams still maintain the original ecological accumulation structure and structural characteristics, and their structures, formation, and endogenous gaps can generally be distinguished from each other. The macroscopic coal and rock types of coal are bright to semibright. The main components of macroscopic coal and rock are dominated by bright coal. Mirror coal accounts for a small part, and sometimes dark coal bands can be seen. The lamellar structure is obviously indigenous, most of which are horizontal layers, and sometimes, the wavy layer and the oblique layer can be seen with strip structure. The coal is hard to break. Fragmentation fracture is mostly shell, serrated, and staircase. Endogenous joints have good growth and development, excellent storage, and smooth and tidy joint surfaces and are dominated by shear joints [1].

2.2. Testing Method. In order to better obtain the pore structure characteristics of two kinds of primary coal samples, this study adopted scanning electron microscopy, CO2 adsorption experiment, and ultralow-temperature N2 adsorption experiment to explore. In the experiment, two kinds of coal samples were ground and broken, 32–60 meshes were selected, and 5–10 g were obtained, respectively.

2.2.1. SEM Experiment. VEGA3 LM tungsten filament scanning electron microscope was used in this test, which has high magnification and can observe the phase under 5 ~ 1000 k sight. High resolution means that pixels are clearer, objects are clearer, and particles are smaller; probe current range is 0.5 pA ~ 5 A, accelerating voltage range is 0.2 ~ 30 KV; the free working distance is 2 ~ 145 mm, which can complete the random transformation of the working distance, so as to observe the actual effect of primary coal micropores.

2.2.2. Low-Temperature N_2 Adsorption Test. Low-temperature N2 adsorption experiment was carried out using the principle of physical adsorption and capillary condensation of nitrogen on a solid surface under saturated temperature standard. In this experiment, Autosorb-iQ analytical instrument from Conta, USA was used for testing at liquid nitrogen saturation temperature (77 K). The relative pressure during the experiment was 0–1. The N2 isothermal adsorption–desorption curve, pore volume, and pore specific surface area value and distribution were obtained by changing the pressure.

2.2.3. CO_2 Adsorption Experiment. The CO_2 adsorption experiment is similar to the low-temperature N_2 adsorption principle, but because of the smaller CO_2 gas molecules and faster diffusion rate, it has higher saturation pressure at saturation temperature (273 K), which can be used to test micropores. Autosorb-iQ analytical instrument from Conta, USA was used for testing at liquid CO_2 saturation temperature (273). The relative pressure was 0–1, and the values and distribution of pore volume and pore specific surface area were obtained.

3. SEM Results and Analysis

3.1. Scanning Results. Through the analysis of coal samples in suburban Henan and Zhaozhuang mines, it is concluded that the homogeneity and integrity of primary structure coal samples are good. There are three types of micropores in coal (Figure 1 and 2), cell cavity pores (Figure 3 and 4), and mold pores (Figure 5 and 6).

Stomatal belongs to a metamorphic pore. In the coal-forming process, coal is subjected to metamorphism and formed by the "gas generation" and "gas accumulation" in the process [2–16]. Stomatals have a variety of shapes, and most of them are round, ellipsoid, and irregular. The pore distribution part presents large area directional production (Figure 1), or relatively concentrated production (Figure 2). The pore size is basically below 10 μm, and the sizes are different. Pores are basically disconnected, and pores are often filled by granular, flake, and other clastic minerals.

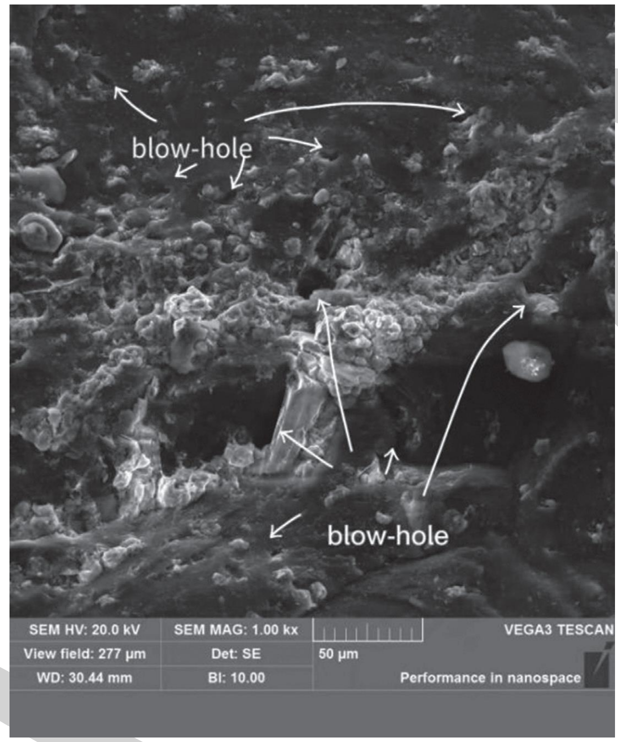

Figure 1: Directional generation of stomata.

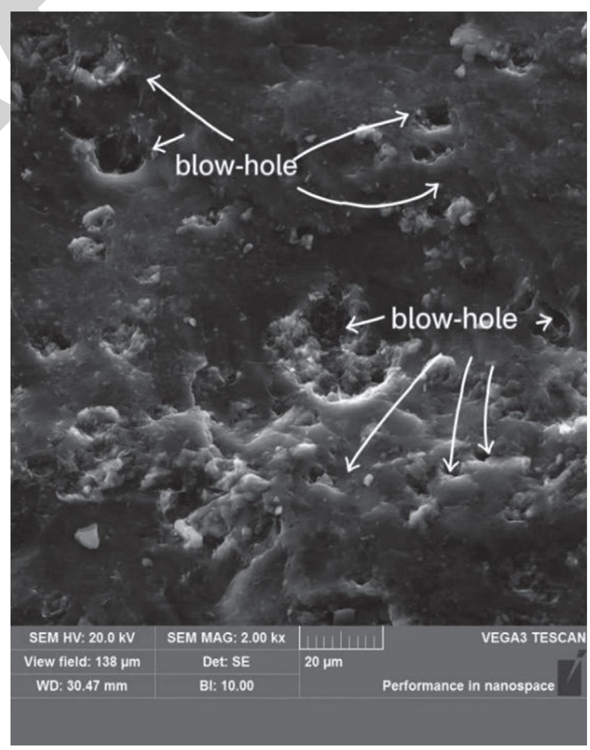

Figure 2: Relative concentration of stomata.

Cavity pores are produced by the structural pores of the cells of coal-forming plants, belonging to the range of primary pores [2–17]. The pores basically exist in an isolated form, and

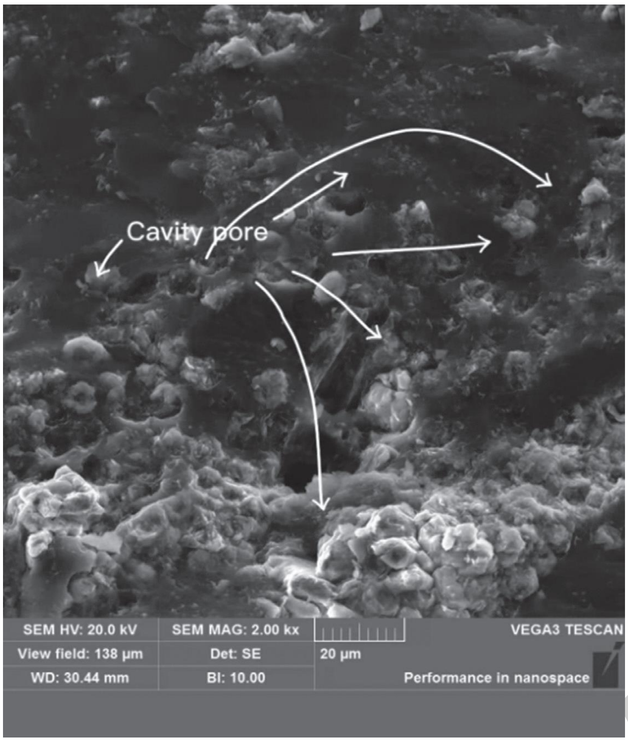

Figure 3: Detrital substances in cell cavity pores 1.

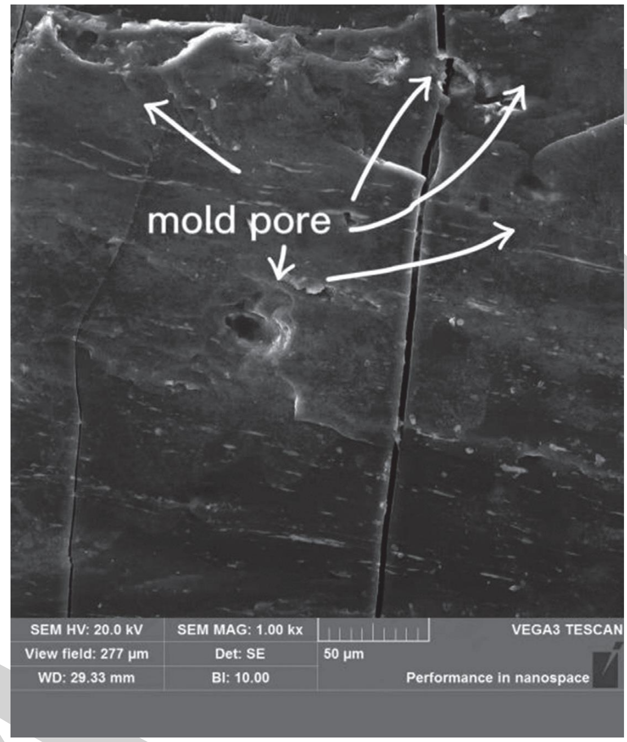

Figure 5: Complex form of mold hole 1.

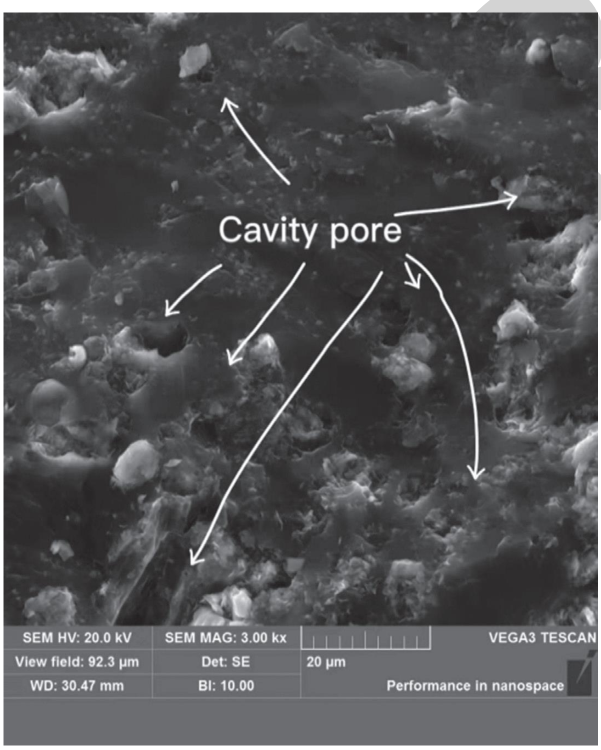

Figure 4: Detrital substances in cell cavity pores 2.

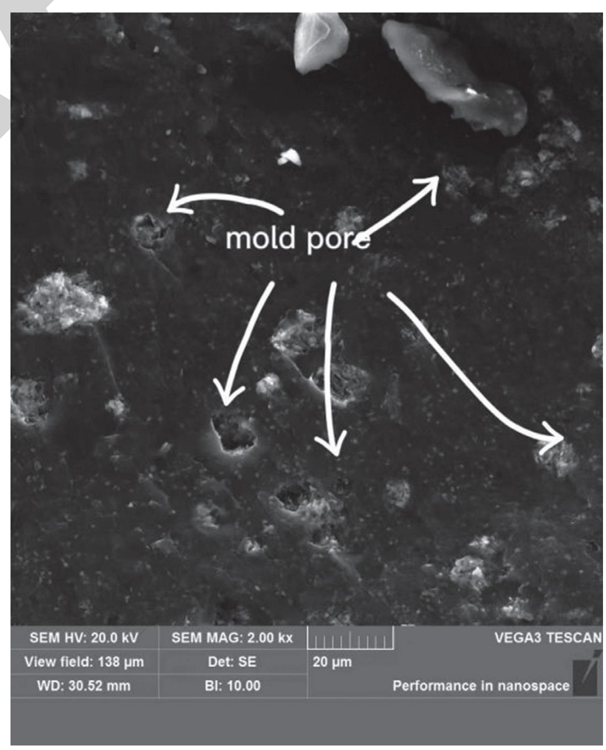

Figure 6: Complex form of mold hole 2.

most of the pores are subcircular. Some pores are deformed due to damage and eventually appear ellipsoid or a small number of irregular shapes. The pore size is different, and most of them are distributed between 1 and 10 μm. It is observed from the figure that most of the pores are independent and disconnected. It can be clearly observed that the pores are filled with granular debris (Figures 3 and 4).

The mold hole belongs to a mineral hole. Due to the difference in the strength of minerals and soil organic matter in coal, some pits are formed due to the compressive stress

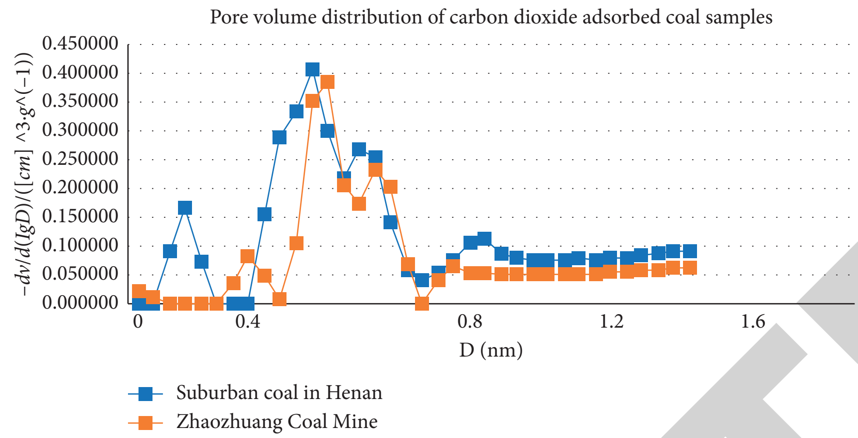

FIGURE 7: The pore volume distribution curve of carbon dioxide adsorption coal sample.

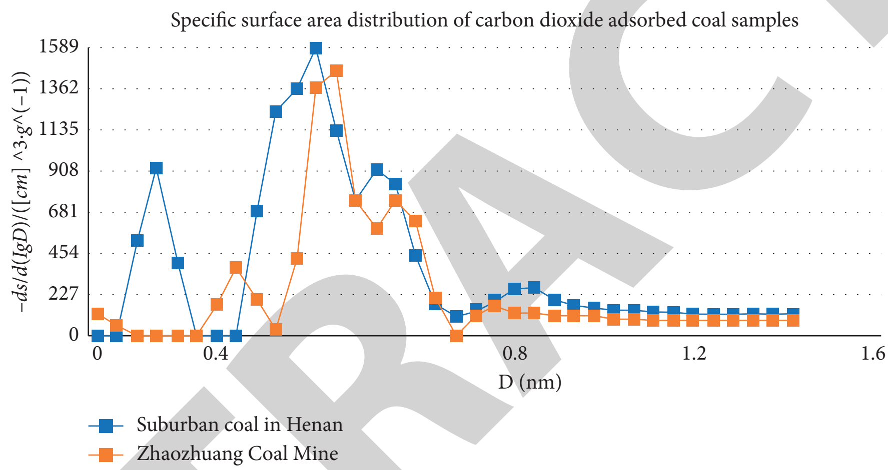

FIGURE 8: The specific surface area distribution curve of carbon dioxide adsorption coals.

during coal formation [2–18]. The shape of the mold hole is extremely complex and changeable, and the pores are not connected, which are called "dead holes" (Figures 5 and 6).

3.2. Result Analysis. IUPAC classification specification is selected. According to the classification method of pores defined by IUPAC, macropores are defined as (pore size more than 50 nm), mesopores are defined as (pore size $2-50$ nm), and micropores are defined as (pore size less than 2 nm). The electron micrographs of two kinds of primary coal from suburban coal mines and Zhaochang coal mines in Henan Province are analyzed. The results show that the pores of primary coal are large and basically disconnected. Many studies have shown that micropores are the primary site for coalbed methane adsorption. The higher the connectivity between pores, the stronger the adsorption capacity of coalbed methane. Therefore, the adsorption capacity of primary coal for coalbed methane is weak, and the adsorption capacity is low.

4. Experimental Results and Analysis of CO_2 Adsorption

4.1. Experimental Results. Literature [19], through a large number of data analyses of three models (DFT, MC, and DA), finally concluded that the DFT model is applied to the CO_2 adsorption experiment to analyze the pore size distribution of micropores in coal is more accurate. In this paper, the adsorption data of CO_2 at low temperature were analyzed by the DFT model, and the pore volume, pore specific surface area, and distribution of the test samples were calculated (Figures 7 and 8, Table 1).

TABLE 1: Numerical values of pore volume and specific surface area of coal samples 1.

Sample	$V/(cm^3{\cdot}g^{-1})$	$S/(m^2{\cdot}g^{-1})$
Suburban coal in Henan	0.083214	281.81
Zhaozhuang coal mine	0.055239	174.0

4.2. Result Analysis. The distribution density function of pore volume and pore specific surface area of primary coal samples, as a whole, increases with the increase of pore size, showing a fluctuation of " increase-decrease-increase-decrease", and finally tends to be stable. The increase of the curves of the two coal samples reaches the maximum between 0.5 nm and 0.6 nm. After that, the pore volume distribution density function gradually decreases and tends to

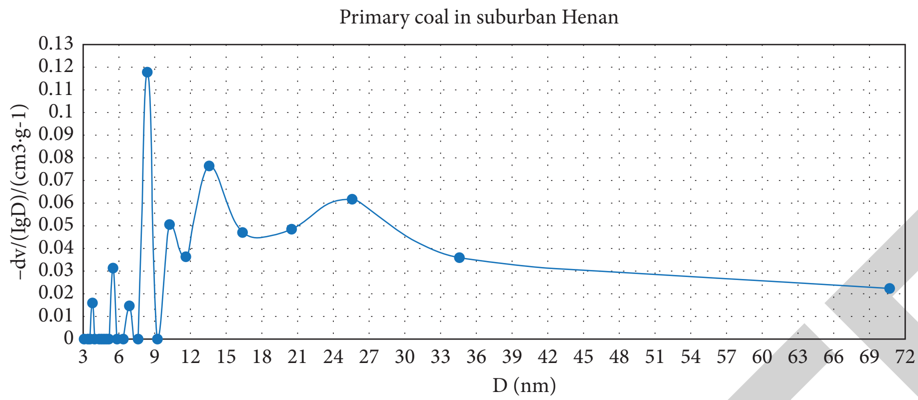

FIGURE 9: Distribution of pore volume of coal.

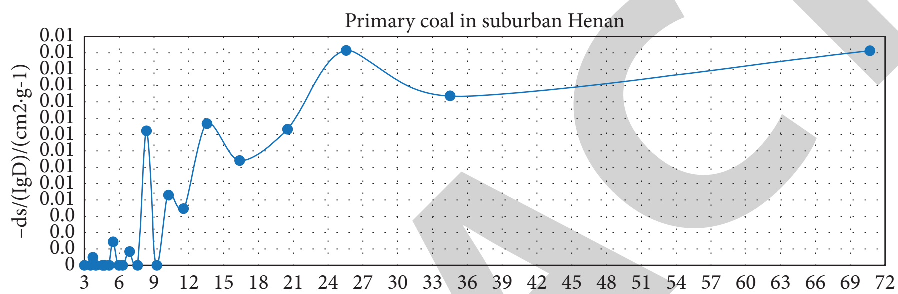

FIGURE 10: Distribution of pore specific surface area of coal.

be stable, indicating that the pore volume corresponding to the pore size of the test coal sample in the range of 0.5–0.6 nm is the largest, with the largest number of pores or the longest pore length. The pore specific surface area distribution of coal samples has a density function similar to the pore volume distribution. On the whole, the pore specific surface area distribution density function of coal samples increases first and then decreases with the increase of pore size, and the maximum increase is obtained at about 0.5 ~ 0.6 nm, followed by a small fluctuation, and finally tends to a very low value. The pore specific surface area corresponding to 0.5 ~ 0.6 nm is the largest. We believe that the dominant pore type of coal pore specific surface area is micropores. The larger the number of micropores, the larger the pore specific surface area of coal.

Combined with the data and distribution, the pore volume and specific surface area of the two coal samples are small, mainly concentrated in 0.5 ~ 0.6 nm. The adsorption of coalbed methane depends on the pore volume and pore specific surface area, and they are positively correlated [20]. The larger the pore volume and pore specific surface area, the stronger the adsorption. On the contrary, the smaller the adsorption capacity is.

5. Experimental Results and Analysis of Low-Temperature N2 Adsorption

5.1. Experimental Results. In this paper, the test data were analyzed, and finally, the traditional BJH model was used to characterize the distribution of micropores and mesopores (Figures 9 and 10).

Reference [21] Chen Ping, Tang Xiuyi according to the adsorption curve and desorption loop shape, the pore morphology of coal is divided into three categories.

The L1 type one-end closed impermeable type (adsorption and desorption curves basically coincide) is mainly formed by the capillary condensation and evaporation pressure is basically the same, so the adsorption curve and desorption loop are basically the same.

The L2 open type (separation of adsorption and desorption curves) is mainly formed by the capillary condensation pressure lower than the pressure required for evaporation. There is a turning point at $P/P0 = 0.5$, and the adsorption curve and desorption loop overlap at low pressure, while separation occurs at high pressure.

According to the adsorption curve and desorption loop shape in reference, the pore morphology of coal is divided into three categories. In the third category, according to the adsorption curve and desorption curve, a steep slope occurs at P / P0 = 0.5, so it is called as slender bottle. The reason for the occurrence of the steep slope is the evaporation effect generated in the early desorption. Due to the different pressures required for evaporation and condensation, the separation of the curve is first caused, and then the liquid is quickly evaporated at P / P0 = 0.5. Finally, the desorption curve is suddenly reduced and the steep slope is generated.

Based on this classification, this paper classifies and analyzes the morphological characteristics of coal pores according to the adsorption curves and desorption loops (Figure 10).

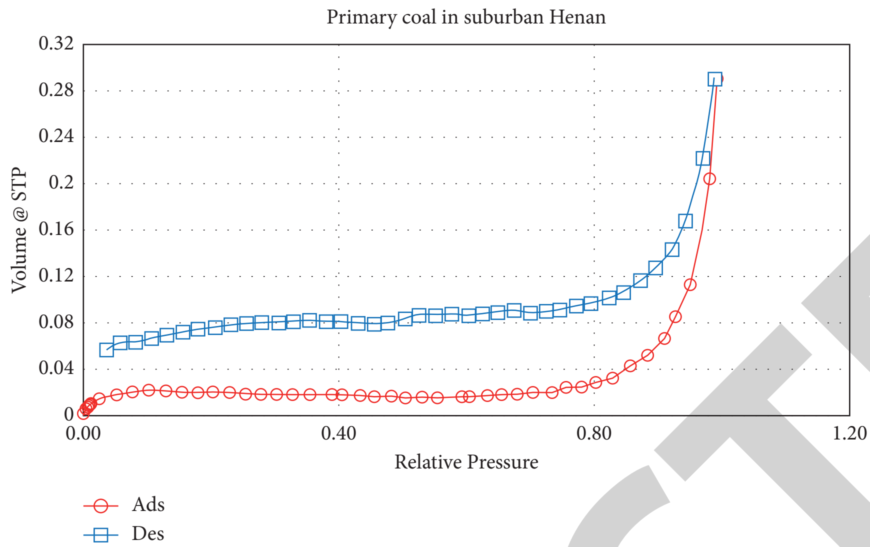

Figure 11: Adsorption and desorption curves of coal.

5.2. Result Analysis. From Figures 9 and 10, the pore volume and specific surface area are almost entirely distributed in the mesoporous phase (IUPAC).

Classification only a small part is distributed in the micropore stage. The number of micropores is very small, resulting in a very small proportion of pore volume and pore specific surface area to total pore volume and total pore specific surface area, and micropores are the primary site for coalbed methane adsorption, resulting in weak adsorption capacity and small intake of primary coal for coalbed methane [22].

By analyzing the adsorption and desorption curve of Figure 11, combined with classification, it is concluded that the adsorption and desorption curve of primary coal in suburban Henan belongs to the L1 type one-end closed impermeable type. Although this pore morphology structure may have good gas content, the permeability is general, which is not conducive to the adsorption of coalbed methane.

6. Conclusion

(1) Through the analysis of the scanning electron microscope, it is concluded that the pores of primary structure coal are large, and there are three types of micropores: pores, cavity pores, and mold pores. The pores are mainly large pores and mesopores, with only a small amount of micropores, and the pores are basically disconnected. Micropores are the main sites for coalbed methane adsorption. The better the connectivity between pores, the stronger the adsorption capacity of coalbed methane. Therefore [2–4], the adsorption capacity of primary structure coal on coalbed methane is weak, and the adsorption capacity is low.

(2) The results of CO_2 adsorption experiments show that the pore volume and specific surface area of the two coal samples are small, and the pore volume and specific surface area are determined by the number of pores, so it can be seen that the distribution of micropores is very small, which is not conducive to the adsorption of coalbed methane.

(3) According to the N_2 adsorption test at ultralow temperature, it is analyzed that the pore volume and specific surface area of primary coal are mostly dispersed in the mesoporous link, and only a small part is in the microporous plate link. The adsorption and desorption curve of primary coal in the suburbs of Henan Province belongs to the closed and impermeable type of L1 end, which is not conducive to the adsorption of coalbed methane.

In general, the pore structure characteristics of primary structure coal, such as pore specific surface area, pore morphology, pore size, and pore volume, are not conducive to the adsorption of coalbed methane.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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