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# Porosity Characteristics of Tectonic Coal and Its Controlling Factors

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## 1 Introduction

The coal, as a special reservoir, has a dual accumulating system of matrix pore and fracture. The pore is the main reservoir space of coalbed methane (CBM) in coal. Generally, pore structure is very complicated and irregularly so that it is hard to be described in the traditional geometry. The fractal theory plays an important role in describing the porous media of the seepage system in recent years. The studies by Pfeifer, Katz and Kroch show the pore distribution in such reservoirs as coal, sandstone, shale and carbonatite is according with the fractal theory.

The previous studies focused on coal reservoir accumulation conditions of CBM in Hegang Basin（Wang Shihui et al, 2012）, but ignored the influences of changes of pore structure on reservoir anisotropy and CBM adsorption capacity in tectonic coal. This paper is intended to study the reservoir of tectonic coal in the northern region of Hegang coalfield, calculating fractal dimensions of pores, exploring the relation of pore fractal characteristic and coal adsorption capacity. It will be of importance to study the formation mechanism of CBM anisotropy.

## 2 Geological Setting and Coal Samples

The Hegang Basin is located in the Hegang fault depression in the Jilin-Heilongjiang fold system as well as Liaoyeling uplift and Qingshan hill uplift zone. The Hegang coalfield is located in the west of the Basin, showing the semi-coverage uniclinal structure inclining to the east.

Based on description of microscopic coal features(Ju Yiwen et al, 2004)，the collected coal samples belong to the brittle deformation series of cataclastic coal and granulated coal. The primary structure of the cataclastic coal is complete relatively with visible banded structure and two groups of cleats. It is felt harder by hand mostly, but some can be crush into small blocks between fingers. The granulated coal has no primary structure and cleat observed, and its blocks have tectonic face striation, like light shining mirror. It becomes fine grains by gently crushing between fingers with its poor hand-feeling intensity. The granulated coal has a diameter of 1—5cm generally.

## 3 Low Temperature Nitrogen Adsorption

The low temperature nitrogen adsorption and desorption curves are classified into type I and II based on testing results of nine samples. For the type I curve, adsorption and desorption curves are always in paralle. This indicates a pore system of open air holes exists in coal. In type II curve, the adsorption and desorption curves are branched reversibly in a relatively low pressure ($P/P_0<0.5$), but in the relatively high pressure ($P/P_0>0.5$), a striking hysteresis loop exists in the branching of adsorption and desorption, and the loops for all coal samples appear near the relative pressure of 0.5. The cause for hysteresis loop is that the coal pore system is more complicated in gas adsorption and desorption. Particularly the bottle pore develops best(Song Xiaoxia et al., 2013). A break point occurs because of desorption of a great deal of gas in the bottle pores with a pressure going down to 0.5 nearby.

The granulated coal indicates the type II curve characters, whose micropores account for 70% or more. It is known by comparison that pore structure changed, micropores increasing in quantity and specific surface area becomes big with deformation intensity.

## 4 Fractal Dimension Feature

The fractal dimension of coal pore is calculated mainly by fractal BET model and fractal FHH model. The FHH model is applied more widely(Chen Ping, Tang Xiuyi,2001; Chen Fuyong et al., 2010; Duan Dong et al., 2009), and the calculating method is based on the

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following two formulas:

$$In\left(\frac{V}{V_0}\right) = cons\tan t + A\left[In\left(In\frac{P_0}{P}\right)\right]$$

*V* is analytical volume of gas absorption in balance pressure P;
*$V_0$* is gas volume of monolayer adsorption;
*$P_0$* is saturated vapor pressure of gas absorption;
*A is slope of* slope of logarithmic curve；
*Constant is a constant;*

$$D = 3 + A$$

*D is fractal dimension.*

By plotting the double logarithmic chart, the fitting straight slope *A* is got to figure out pore fractal dimension *D*. The fractal dimension is resolved by two relative pressure sections. By comparing fractal dimensions $D_1$ and $D_2$, the influence of hysteresis loop on pore system is proved(Table 1). When the relative pressure is less than 0.5, there is no meaning of $D_1$ and curve type; while relative pressure exceeds 0.5, the dimension $D_2$ where hysteresis loop exists is higher than that $D_2$ without hysteresis loop. This indicates the coal samples in different deformation degrees result in their pore system changing, so that it shows different fractal characters. Thus, it is more significant to study the fractal dimension characters in the relative pressure of more than 0.5 for understanding of coalbed pore system.

### 4.1 Relation of coal fractal dimension and adsorption capacity

Methane mainly exists in coal in an adsorption way, so coal pore shape and structure exert a certain influence on adsorption capacity of coal(Jiang Wenping et al., 2011; Qin Yueping, Fu Gui, 2000; Wen Huijian et al., 2007), and the fractal dimension can represent irregularity roughness of coal pores. For this reason, fractal dimension is correlative to adsorption capacity of coal. The relation of fractal dimension $D_2$ and Langmuir volume is shown in Figure 1a. It is known that fractal dimension $D_2$ has a positive linear correlation with Langmuir volume, that is, methane adsorption capacity enhances with fractal dimension. The cause for this phenomenon is believed that with its deformation of coal, the recombination occurs, micropores increase in quantity and specific surface area becomes large in pore structure of coal. At the same time, the fractal dimension becomes big with change of shape and roughness. Coal adsorbs CBM mainly by surface, so coal enhances its adsorption capacity.

### 4.2 Relation of coal fractal dimension and pore structure

The fractal dimension is closely related to pore structure of coal(He Wei et al., 2000; Zhang Ting et al., 2010; Zhao Shurong, 2009). It is shown in Fig. 1 that the fractal dimension $D_2$ has a positive correlation with quantity of micropores in coal, but a negative correlation with average pore diameter.

The fractal dimension is remarkably related to specific surface area, quantity of micropores and average pore diameter. This indicates that the shape of coal pores changes greatly with fractal dimension increasing, that is, its open pores changes into bottle ones, and throat of pores becomes more complicated, with poor connectedness. On the other hand, the smooth pore surface becomes coarse,

**Table 1 Pore fractal dimensions for Hegang tectonic coal**

| Coal | Deformation Degree | $P/P_0$: 0～0.5 | $P/P_0$: 0.5～1.0 | Curve Type | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $A_1$ | $D_1$=3+$A_1$ | $R^2$ | $A_2$ | $D_2$=3+$A_2$ | $R^2$ | |
| HE1-2 | cataclastic | -0. 3924 | 2.6076 | 0.9870 | -0.4129 | 2.5871 | 0.9876 | I |
| HE1-4 | cataclastic | -0. 4630 | 2.5370 | 0.9856 | -0.5414 | 2.4586 | 0.9774 | I |
| HE3-3 | cataclastic | -0. 3689 | 2.6311 | 0.9829 | -0.3988 | 2.6012 | 0.9922 | I |
| HE3-4 | cataclastic | -0. 3932 | 2.6068 | 0.9882 | -0.4040 | 2.5960 | 0.9924 | I |
| HE1-1 | granulated | -0. 4280 | 2.572 | 0.9934 | -0.3234 | 2.6766 | 0.9800 | II |
| HE3-1 | granulated | -0. 3595 | 2.6405 | 0.9861 | -0.3229 | 2.6771 | 0.9920 | II |
| HE3-2 | granulated | -0. 3713 | 2.6287 | 0.9847 | -0.1698 | 2.8302 | 0.9941 | II |
| HE1-3 | granulated | -0. 4402 | 2.5598 | 0.9845 | -0.3646 | 2.6354 | 0.9838 | II |
| HE3-5 | granulated | -0. 3924 | 2.6076 | 0.9899 | -0.3067 | 2.6933 | 0.9801 | II |

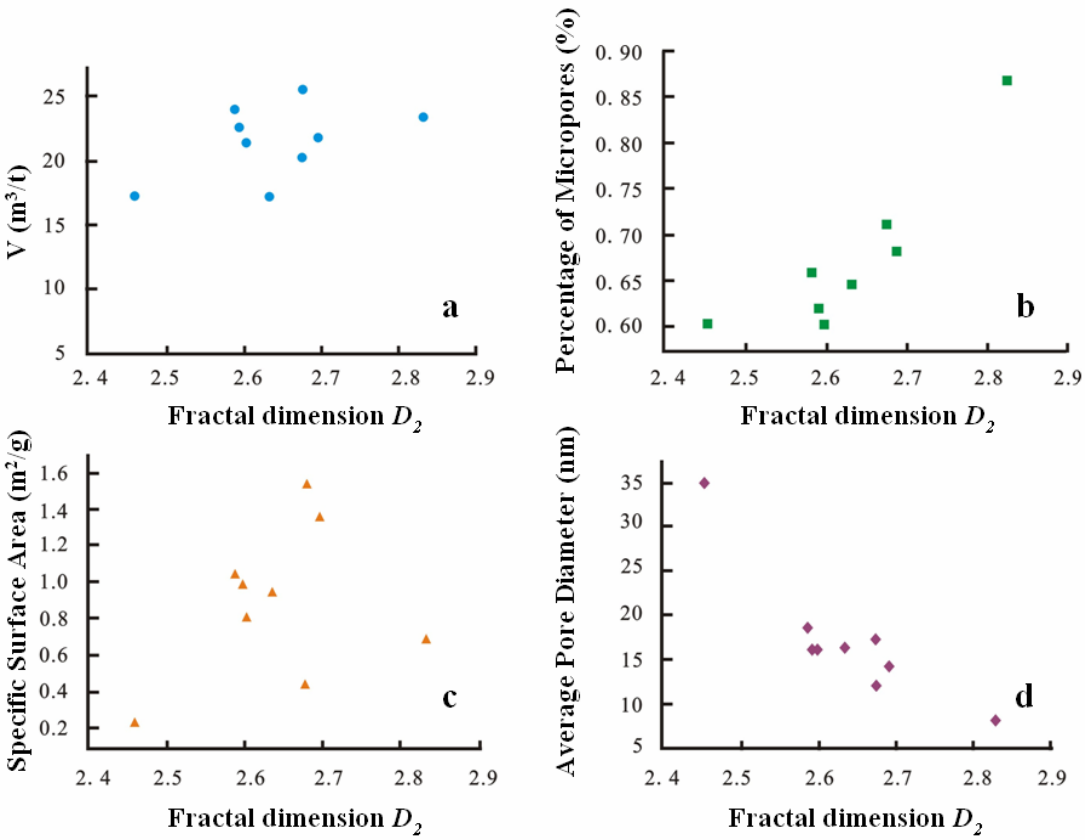


Fig.1 Relationships between the fractal dimension adsorptive capacity and pore structure

specific surface area increases, and attached methane molecules arrange in a more space. To sum up, the fractal dimension can reflect characters of pore structure and adsorption of coal accurately in different deformation degrees.

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