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Comparison of flotation performances of intruded and conventional coals in the absence of collectors

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HIGHLIGHTS

- Intruded coal surface has more pores, holes and cracks than conventional coal.
- Surface roughness of intruded coal is much higher than that of conventional coal.
- Surface morphology plays a significant role on coal natural floatability.
- Magmatic intrusion has a negative effect on coal natural floatability.
- Flotation performance of conventional coal was better than that of intruded coal.

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ABSTRACT

Magmatic intrusion creates many intruded coals whose properties are different from the conventional coals. It is well known that the surface hydrophobicity and wettability of coal surface are the primarily factors determining the flotation behavior of fine coal particles in coal preparation industry. This paper was to investigate the difference in the flotation behavior between intruded and conventional coals from Yongcheng Coalfield. Brunauer–Emmett–Teller (BET), scanning electron microscopy (SEM), and Fourier transform infrared spectroscopy (FTIR) were used to indicate the surface properties of intruded and conventional coals. The results showed that magmatic intrusion not only changed the functional groups on coal surface but also changed the pore structure of coal particles. The flotation performance of conventional coal was better than that of intruded coal in the absence of collectors. Magmatic intrusion has a negative effect on the natural floatability of coal particles. The natural floatability of coal particle is not only determined by the types of functional groups on coal surface but also affected by the surface morphology of coal particles.

1. Introduction

In China, there are many intruded coal beds produced by magmatic intrusion [1]. Yongcheng Coalfield in Henan province of China is a representative case [2]. Yongcheng Coalfield has rich natural coke resources. In Yongcheng Coalfield, magmatic intrusion is the primary condition for the formation of natural coke. The other condition for the formation of natural coke is coal spontaneous combustion underground coal mines [3]. Therefore, natural coke in Yongcheng Coalfield can be also named as magma contact metamorphic coal. In this investigation, intruded coal was used as a general term. The reserves of intruded coal accounts for about 20% of total coal reserves in China [2].

The physicochemical properties of coal are greatly changed by magmatic intrusion as well as oxidation processes [3–6]. Obvious changes include elemental compositions, molecular structures and physical properties, such as pore and fracture on coal surface [7,8]. These changes have great effect on pyrolysis, liquefaction and gasification behavior of coal [9,10]. The washability of coals affected by magmatic intrusion is the main attention for coal preparation researchers. Gravity separation of coarse intruded coal particles from coarse gangues can be achieved since the density of coal particles is not significantly changed by magmatic intrusion. But for fine particles, gravity separation is difficult to achieve. Flotation is one effective method for the separation of fine particles. The surface hydrophobicity/wettability determines the flotation behavior of coal fines. It is urgently that the flotation of intruded coal should be investigated since there are little literatures about intruded coal flotation industry.

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In this paper, we attempted to investigate the comparison of flotation behavior of intruded and conventional coals from Yongcheng Coalfield in the absence of collectors. Throughout this paper, the conclusions may provide useful information concerning the separation of fine intruded coal and give some evidence for the difference in flotation performance between the two coals.

2. Experimental

2.1. Materials

Intruded and conventional coal samples were provided by Juji Coal Preparation Plant in Yongcheng Coalfield in Henan province of China. The lump coal samples were selected by density fluid with less than 1.6 kg/L. Then, lump coal samples were crushed and screened to several size fractions. In this investigation, 0.125–0.074 mm size fraction was used as experimental samples in order to ensure the accurate comparison of surface properties of two coal samples using BET, SEM, FTIR, and flotation tests. Table 1 is the proximate analysis of intruded and conventional coal samples on air dried basis, where *Mad* is the moisture content, *Vad* the volatile matter content, *FCad* the fixed carbon content, and *Aad* is the ash content.

2.2. BET measurement

Specific surface area measurements (BELSORP-max ver 2.1, Bel, Japan) of intruded and conventional coal particles were made by the Brunauer, Emmett and Teller (BET, BELSORP-max) method of adsorption of nitrogen gas. Surface area, pore volume and average pore diameter were obtained from the experimental data.

2.3. SEM measurement

Quanta 250 SEM (FEI, USA) was used to analyze the surface morphology of intruded and conventional coal particles. The magnification times were fixed at different values in order to obtain several pictures in the same area. The coal samples were prepared by surface cleaning using absolute ethyl alcohol. After surface cleaning, the coal samples were dried in air. Before SEM tests, the coal samples were sputter-coated with a layer of gold.

2.4. FTIR measurement

FTIR spectrums of intruded and conventional coals were obtained with KBr pellets prepared with two coal samples ground with KBr in a mortar. For the FTIR analyses, a Fourier Transform Infrared Spectroscopy Vertex 80v (Bruker, Germany) was used and the spectrum was obtained at 2 cm^{-1} resolution, between 4000 and 400 cm^{-1}.

2.5. Flotation tests

This paper was to investigate the natural floatability of intruded and conventional coals. The collector was not used, but the frother (2-Octanol) was used to ensure the stability of bubbles. The dosage of frother was 0.2 kg/t coal. The flotation tests were conducted in a 1.5 L XFD flotation cell. The impeller speed of flotation machine was 1900 r/min and the airflow rate was 4.33 L/min in each flotation test. First, 0.1 kg coal was added into flotation cell with 1.5 L water and agitated for 1 min. Second, the frother of 0.2 kg/t was added into flotation pulp and conditioned for 30 s. Third, the flotation process begun and the froth products were collected as the concentrate. The tailings were also collected. The flotation products were collected, dried, weighted and forward to ash content tests.

Table 1
Proximate analysis of intruded and conventional coal samples (air dried).

Coal samples	*Mad* (%)	*Vad* (%)	*FCad* (%)	*Aad* (%)
Intruded coal	1.35	6.78	73.85	18.02
Conventional coal	1.04	7.56	74.63	16.77

3. Results and discussion

3.1. BET analysis

As shown in Table 2, BET results of surface area, pore volume and average pore diameter for intruded and conventional coals are presented. The surface area of intruded coal is 8.26 m^2/g whereas that of conventional coal is 3.72 m^2/g. Intruded coal has larger surface area than conventional coal, and it also has larger pore volume (1.90 cm^3/g) than conventional coal (0.85 cm^3/g). However, the average pore diameter of intruded coal is 2.85 nm whereas that of conventional coal is 4.69 nm. It indicates that intruded coal should have more pores than conventional coal. Intruded coal should also have many smaller pores than conventional coal. Because intruded coal suffers a high temperature heating process by magmatic intrusion, many micro pores are created.

As shown in Table 1, some volatile matters will evaporate under high temperature heating process, and hence the volatile matter content of intruded coal is a little lower than that of conventional coal. In addition, the pores are easy to hold the water and hence the moisture content of intruded coal is a little higher than that of conventional coal. The feature of surface morphology on coal surface will be indicated by using SEM measurement in Section 3.2 SEM analysis.

3.2. SEM analysis

The pictures about the surface morphology of intruded and conventional coal particles are presented in Figs. 1 and 2. Fig. 1 indicates that intruded coal surface looks like countless ravines. There are many holes and pits on intruded coal surface. In addition, many scales are found on intruded coal surface. The surface morphology of intruded coal is similar to the surface morphology of heated coals or unburned carbon found in fly ash [11–15]. Magmatic intrusion creates an oxygen deficient and high temperature environment, and hence the properties of coals can be changes greatly. Coal will be expanded during the high temperature heating process and will be constricted while the temperature is reduced. Many holes and cracks are produced by magmatic intrusion. However, Fig. 2 indicates that conventional coal surface is flat and smooth. There are nearly no holes and cracks on conventional coal surface. The results of SEM show that the surface morphology of coal particle is changed greatly by magmatic intrusion. The results of SEM are consistent with the results of BET.

3.3. FTIR analysis

Fig. 3 indicates the difference in chemical properties between intruded coal and conventional coal. The peak near 3400 cm^{-1} represents —OH group which is a hydrophilic functional group.

Table 2
BET results for intruded and conventional coals.

Coal types	Surface area (m^2/g)	Pore volume (cm^3/g)	Average pore diameter (nm)
Intruded coal	8.26	1.90	2.85
Conventional coal	3.72	0.85	4.69