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Coalbed methane sorption related to coal deformation structures at different temperatures and pressures

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HIGHLIGHTS

- Different tectonically deformed coals have different adsorption isotherms and adsorption capacities.
- Strong-ductile deformed coal has a higher adsorption capacity at low temperature.
- At high temperatures, the coal samples do not show significant differences in coal methane adsorption capacity.

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ABSTRACT

Coal methane adsorption capacity is related to coal deformation structures. Due to different deformation properties and deformation degrees, tectonically deformed coals have different adsorption isotherms and adsorption capacities. In this work, adsorption capacity investigations are performed using three types of tectonically deformed coal (weak brittle deformed coal, strong brittle deformed coal and strong ductile deformed coal) with vitrinite reflectance of about 0.9% at different temperatures and pressures. The results indicate that the methane adsorption capacity in coal has a decreasing relationship with temperature. At a constant temperature, the methane adsorption of different tectonically deformed coals also varies. For example, the strong-ductile deformed coal has a significantly higher adsorption capacity than the weak-brittle deformed coal and the strong-brittle deformed coal at a constant temperature of 30 °C. At low pressures, the strong-brittle deformed coal has a higher adsorption capacity than the weak-brittle deformed coal; as the pressure increases, the adsorption capacities of both types of coal become equal. The findings show that the methane adsorption capacity of different types of tectonic coal is mainly affected by temperature and pressure. At high temperatures (i.e., 50 and 70 °C), the coal samples do not show significant differences in coal methane adsorption capacity, and their adsorption isotherms are similar.

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1. Introduction

Coal methane adsorption capacity is influenced by many factors, including degree of coal metamorphism [1], coal composition [1–8], moisture content [9,10], and temperature and pressure [11–15]. Coal adsorption studies have been carried out by many researchers. For example, Zhong and Zhang [1] conducted an isothermal adsorption experiment using 56 dry coal samples with vitrinite reflectances between 0.46% and 7.1% at a temperature of 30 °C and the maximum pressure of 4 MPa. Their results showed that the methane adsorption presents a declining-rising-declining trend with increasing metamorphic degree. Pratik et al. [16] selected dry coal samples with vitrinite reflectances between 0.64% and 1.3% and preformed an isothermal adsorption experiment at a temperature of 30 °C and the maximum pressure of 7.8 MPa. They found that the methane adsorption capacity of coal presents a "U" trend as the coal ranks increase. At present, controversy remains between adsorption capacity of coal and maceral composition; most scholars [4–8] believe that the adsorption capacity of vitrinite-rich coals is higher than that of inertinite-rich coals, while others [3] consider that the relationship between adsorption capacity of coal and maceral composition is not obvious. Some research experiments [1,2] have shown that the inertinite has the greatest adsorption capacity. The effect of moisture in coal on methane adsorption capacity shows an inverse relationship: the higher moisture of coal, the lower its saturated adsorption [10]. In an isothermal adsorption experiment by Xie and Chen [12], four kinds of coal samples with different metamorphic

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series showed decreasing adsorption with increasing temperature but the variation tendency was not obvious. Based on the results of isothermal adsorption experiments on 184 middle-rank coal samples with equilibrium moistures, Fu et al. [13] discussed the effects of pressure and temperature on middle-rank coal adsorption capacity and analyzed differences in the isothermal adsorption characteristics between middle-rank and low- and high-rank coals. In isothermal adsorption experiments using coal samples with different metamorphic degrees at different temperatures, a composite adsorption model, showing the effects of temperature and pressure on coal methane adsorption, was discussed by Zhang et al. [14]. At the equilibrium moistures, Cheng et al. [15] found that the variation tendency of saturated adsorption is not obvious with increasing temperatures, but, in general, decreases slightly.

The isothermal adsorption experiments performed thus far are very relevant but most are based mainly on uniform coals. The methane adsorption capacity of the tectonic coal, deformed by changes in the tectonic stress, has been discussed [17] but only to a limited extent. The most disastrous gas outbursts have occurred in the areas of tectonic coal development in China, where coalbed methane exploitation remains as a technological bottleneck. Therefore, the study on the adsorption capacity of tectonic coal and determination of its controlling factors are of utmost importance to supplement the theoretical foundation for gas outburst mechanisms and CBM exploration and development in the areas of tectonic coal. In the present paper, the results of the isothermal adsorption experiments performed on different types of the tectonic coal samples at different temperatures and high pressures are discussed. The aim of this work is to determine the effects of varying deformation degrees and deformation properties on the tectonic coal methane adsorption.

2. Sample selection and experiments

2.1. Sample selection

To avoid influences from other factors during the investigation of the influence of the tectonic coal deformation structures on methane adsorption capacity at different temperatures, all experimental samples were selected from the same area (Xutong Coal Mine in the Huaibei mining area). Low-rank coals with a vitrinite reflectance of about 0.9% were used. Three kinds of tectonic coal with different deformation degrees and deformation properties were selected; i.e., weak-brittle deformed coal, strong-brittle deformed coal, and strong-ductile deformed coal (Fig. 1). The features of the experimental samples are shown in Table 1.

2.2. Experiments

Three blocks of coal samples were obtained and all had equilibrium moisture. Isothermal adsorption experiments were performed at a maximum pressure of 10 MPa and temperatures of 30, 50, and 70 °C. The high-pressure adsorption testing system (IS-300) used in the experiment was manufactured by TenaTec. In this study, the testing procedure was performed in accordance with the national standard of "Experimental method of high-pressure adsorption isothermal to coal-capacity method" (GB/T 19560-2004). The analytical results of equilibrium moisture values, ash contents and particle size of the coal used in the sorption tests were listed in Table 2.

3. Results and discussion

3.1. Influences of temperature and pressure on coal methane adsorption

The experimental results of the experiments are shown in Figs. 2–4. At a constant temperature and low pressures, methane adsorption showed an almost-linear relationship with increasing pressure. The rate of coal methane adsorption continuously decreased with further increases in pressure. Methane adsorption then reached a saturation point, and after this point, no further increases were observed with further increases in pressure.

The adsorption isotherms indicate that the temperature has a significant influence on coal methane adsorption capacity. Regardless of the types of coal (Figs. 2–4), methane adsorption capacity demonstrates an inverse relationship with temperature. At a constant pressure and increasing temperature, coal methane

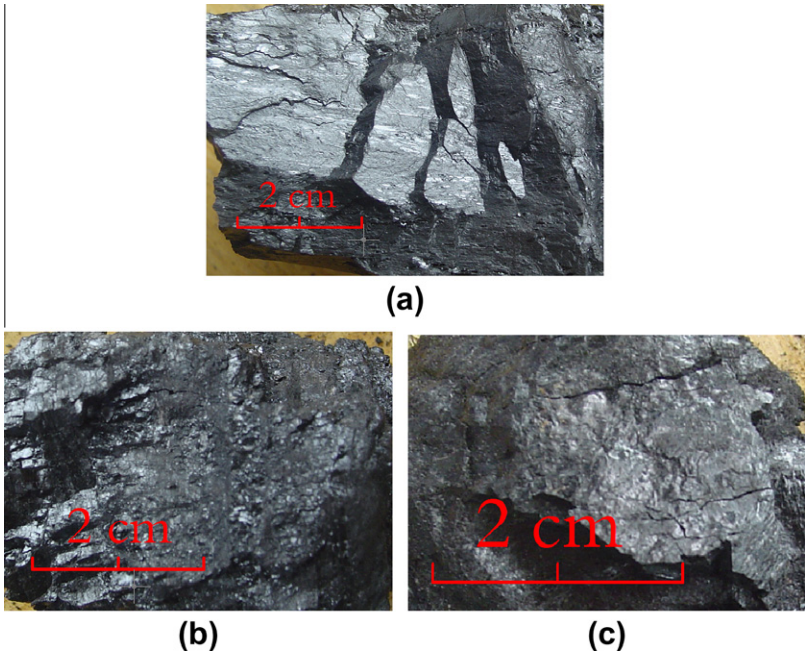

Fig. 1. (a) Weak-brittle deformed coal, (b) strong-brittle deformed coal, and (c) strong-ductile deformed coal.

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