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Ashing temperature of lignite and mineral transition sequence

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ABSTRACT

To investigate the effect of non-mineral inorganics on the degree of ashing and determine the minerals in lignite, we performed selective leaching of amorphous materials in coal. Three kinds of lignite ash samples were prepared at < 200 °C, 500 °C and 815 °C, and the minerals and ash products were analyzed by X-ray diffraction, ash composition analysis and statistical modelling. The results suggest that the mineral types of the main coal seams of three sags in the Erlian Basin mainly comprise of clay minerals and quartz, of which clay minerals are mainly kaolinite, followed by mixed illite/smectite and illite. The increase in ashing temperature below 500 °C was found to not affect the mineral species, but it damages the clay minerals to various degrees, mainly kaolinite. Based on principal component analysis and multiple regression analysis, a prediction model was established for medium-temperature ash to obtain the low-temperature ash mineral composition. Erlian Basin lignite contains a large amount of alkali or alkaline earth elements (AAEMS), among which Ca, Na, and Mg cations react with organic oxygen-containing functional groups or other organic functional groups, whereas K is mainly hosted in clay minerals. The positive effect of AAEMS in non-mineral inorganics on the ash yield is higher than the negative effect of the increase in ashing temperature. Ca is an important element that controls the degree of ashing in low-temperature ashing below 500 °C. The effect of Mg on the degree of ashing is enhanced with increasing ashing temperature, but does not exceed that of Ca.

1. Introduction

Minerals are present in coal, which makes knowing the minerals in coal essential for coal processing and coal dressing (Li et al., 2017a, 2017b). The mineral content in coal is low, and its relation to the organic matter is complex, which complicates mineral identification in coal. Usually, the first step is to perform coal ashing to remove the organic matter and then analyze the residue. Currently, low-temperature ashing is the best method to separate minerals without changing the mineral species; furthermore, the lower the degree of metamorphism is, the easier the ashing (Ward, 1978; Harvey and Ruch, 1984; Harvey and Ruch, 1986; Ward, 1991; Ward, 1992; Ward and Taylor, 1996; Song, 2011). However, low-temperature ashing is complex and time consuming (24 to 50 h); moreover, oxygen plasma low-temperature ashing is inapplicable to lignite and peat because the non-mineral inorganics in coal can form NH_4SO_4 with organic sulfur and organic nitrogen as well as other substances that affect ashing. In addition, the proportion of non-mineral inorganics in low-rank coal is high (Benson and Holm, 1985; Cao and Li, 1994; Shang et al., 2016). Currently, the mechanism by which non-mineral inorganics affect the ashing of coal needs to be analyzed, and the methods to efficiently and accurately measure the minerals in lignite need to be determined.

Many studies have dealt with the role of temperature in mineral phase transitions (Querol et al., 1994; Bryers, 1996; Ward et al., 2001; Ma et al., 2014; Zhang et al., 2015; Tao, 2015; Wen et al., 2016). For instance, calcite decomposes at 650 °C, gypsum transforms to anhydrite at 400 °C, illite decomposes at 900 °C, and kaolinite changes to metakaolinite at 325–450 °C and decomposes into amorphous SiO_2 and Al_2O_3 at 1000–1400 °C. The increase of ashing temperature mainly leads to a decrease in the crystal mineral content, an increase of amorphous mineral, and a transition of ash samples to the molten state. The changes in mineral and coal ash composition, focusing on the effects of coal combustion characteristics, ash melting characteristics, slagging and ash deposits, have been studied at different ashing temperatures (Nel et al., 2014; Li et al., 2017a, 2017b). However, little is known about the characteristics of the original mineral formation obtained by observing changes in the specific mineral species and content through rising ashing temperature. Coal with different substances will

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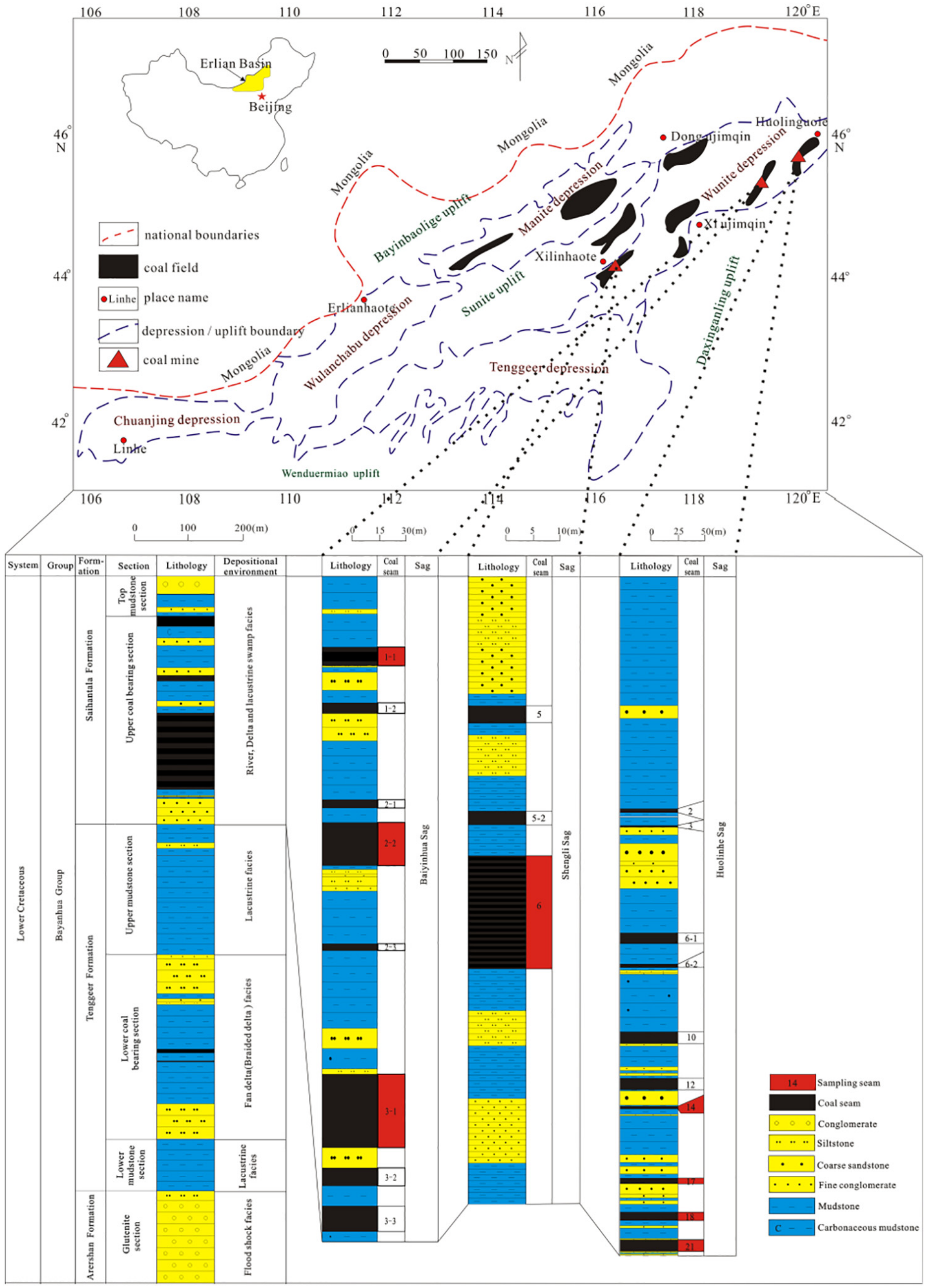

Fig. 1. Sampling locations and coal stratigraphy.

also affect the degree of ashing. For example, coal with high fixed carbon content and small volatile content, its peak temperature and activation energy are higher, coal combustion performance is poor, and the ashing time is longer, often increasing the loss rate of clay minerals (Ma et al., 2015). In view of this, It is necessary to study the mineral loss in the process of ashing coal with different substances, and then a prediction model suitable for coal with different substances was established for medium-temperature ash to obtain the low-temperature ash mineral composition.

For minerals that decompose easily, the ashing temperature affects analytical accuracy (Yang et al., 2016). For example, Na begins to escape at temperatures ranging from 400 °C to 600 °C. Ca precipitates slowly at temperatures below 600 °C, but precipitates faster after 1000 °C (Tao, 2015). At the same time, the change of ash temperature may also cause changes in the occurrence of elements. For example, Nacl is the main existence form in the ash fired at temperatures between 500 °C and 600 °C. With the increase of ash temperature, there will be sodium feldspar at 700 °C and nepheline at 800 °C to 900 °C. The chemical composition of coal ash is one of the main factors affecting the sintering characteristics and ash fusion characteristics of coal ash (Wang et al., 2010). Therefore, understanding the variation characteristics of ash composition and the change of element occurrence state under different ashing temperatures are the basis for rationally solving the problem of ash accumulation and slagging.

Based on this problem, typical lignite samples from three coal mines in the Erlian Basin were selected. The raw coal of low- and middle-temperature ash were selectively leached, excluding the raw coal of high-temperature ash, and then ashed at different temperatures (< 200 °C, 500 °C, 815 °C). The minerals and ash products were analyzed by XRD, ash composition analysis, and mathematical methods to