

Chemistry of thermally altered high volatile bituminous coals from southern Indiana

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Abstract

The optical properties and chemical characteristics of two thermally altered Pennsylvanian high volatile bituminous coals, the non-coking Danville Coal Member ($R_o=0.55\%$) and the coking Lower Block Coal Member ($R_o=0.56\%$) were investigated with the purpose of understanding differences in their coking behavior. Samples of the coals were heated to temperatures of 275 °C, 325 °C, 375 °C and 425 °C, with heating times of up to one hour. Vitrinite reflectance ($R_o\%$) rises with temperature in both coals, with the Lower Block coal exhibiting higher reflectance at 375 °C and 425 °C compared to the Danville coal. Petrographic changes include the concomitant disappearance of liptinites and development of vesicles in vitrinites in both coals, although neither coal developed anisotropic coke texture. At 375 °C, the Lower Block coal exhibits a higher aromatic ratio, higher reflectance, higher carbon content, and lower oxygen content, all of which indicate a greater degree of aromatization at this temperature. The Lower Block coal maintains a higher CH_2/CH_3 ratio than the Danville coal throughout the heating experiment, indicating that the long-chain unbranched aliphatics contained in Lower Block coal liptinites are more resistant to decomposition. As the Lower Block coal contains significant amounts of liptinite (23.6%), the contribution of aliphatics from these liptinites appears to be the primary cause of its large plastic range and high fluidity.

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1. Introduction

Indiana's coal resources are dominantly high volatile C bituminous in rank (Mastalerz and Harper, 1998). On this basis, their rheological properties are generally considered unsuitable for use in commercial coking.

Medium volatile bituminous rank coals usually have the best coking properties; coals of lower rank are less effective (Taylor et al., 1998). Consequently, Indiana's steel industry imports coals from other states, including Illinois. However, as premium quality coking coals are consumed, alternate supplies need to be identified. There is a paucity of research on the use of lower rank coals in coking blends, although several have been successfully utilized in steel production (Akamatsu et al., 1978; Valia and Hooper, 1994). Coals from the Pennsylvanian Brazil

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Formation of southern Indiana, particularly the Lower Block Coal Member, have been noted to possess the potential to produce a stable coke when used in blends. Laboratory and industry scale tests of blends containing up to 50 wt.% of Brazil Formation coals produced commercially viable, high-quality, strong and stable cokes (Valia and Hooper, 1994; Mastalerz and Padgett-Alano, 1999). The potential for use of Indiana coals in the steel industry is discussed in a recent paper by Valia and Mastalerz (2004). Most critically there is a need to identify the specific physical and chemical properties associated with the Lower Block coals that create commercially viable coking behavior.

Previous work on the coking properties of the Danville and Lower Block Coal Members found the Lower Block coal to have lower total sulfur and ash yields, higher carbon content, lower O/C ratios, and higher organic sulfur content than the Danville coal. There are notable differences in the maceral compositions of the seams; the Lower Block coal contains considerable amounts of inertinite (14.8 wt.%) and liptinite (23.6 wt.%), whereas the Danville coal is dominated by vitrinite (85 wt.%; Walker et al., 2001). Vitrinites in the Danville and Lower Block coals were similar in elemental composition, whereas the inertinite and sporinite in the Lower Block coal possesses relatively higher carbon, lower oxygen, and lower sulfur contents than the Danville coal (Walker and Mastalerz, 2004). FTIR analysis showed that liptinites contribute long-chain aliphatics to the overall

kerogen composition of the Lower Block seam, which might require higher cracking temperatures during coking (Walker and Mastalerz, 2004). An increase in cracking temperature could allow liptinites of the Lower Block coal to maintain coherency further into the coking process.

The objective of this paper is to detect and characterize physical and chemical changes in the Danville and Lower Block coals as they undergo heating, with the aim of furthering understanding of the differences in the coking behavior of these two coals.

2. Geologic setting

The Illinois Basin is a cratonic basin covering approximately 155,000 km² across Indiana, Illinois, and Kentucky (Fig. 1). During the Pennsylvanian coal-forming period, the basin climate was tropical and humid (Mastalerz et al., 2000). Although the Danville and Lower Block coals are both largely fresh water coals, there are significant differences in their depositional environments. The Danville Coal Member (Dugger Formation; Fig. 2) is a laterally continuous seam deposited in tree-fern dominated rheotrophic coastal-plain mires (Mastalerz and Padgett, 2002). It has moderate sulfur and ash contents (av. 2.9 wt.% sulfur, av. 12.6 wt.% ash), and an average vitrinite reflectance of 0.54%, corresponding to a high volatile C to A bituminous rank (Mastalerz and Harper, 1998; Mastalerz and Padgett-Alano, 1999).



Fig. 1. Map showing the Illinois Basin as defined by the extent of Pennsylvanian strata in grey.

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