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Microstructures and microtextures of natural cokes: A case study of heat-affected coking coals from the Jharia coalfield, India

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Abstract

In Jharia coalfield, nearly 1250 Mt of coking coal has been devolatilized due to igneous intrusives and ~ 1900 Mt due to mine fires. This paper is an effort to investigate the effect of carbonization in two intrusive affected coal seams of Ena (seam XIII) and Alkusa (seam XIV) collieries of this coalfield. Through petrographic studies by microscopy, characterization of normal and heat-affected coals was carried out. The microstructures and microtextures produced due to extraneous heat have been related to nature and extent of heat, location of heating source, and quality and quantity of natural coke produced. Based on the results of this study and earlier studies, an effort has been made to study the classification scheme for microtextures of natural cokes generated through in-situ carbonization of the coal seams. It has been observed that in case of such heat effects under overburden pressure, the anisotropy is much more pronounced as compared to laboratory-carbonized cokes. In the mildly carbonized coals (pre-plastic phase, < 300 °C) the vitrinite attained higher reflectance than normal vitrinite, liptinite started disappearing, and inertinite remained unaffected. In the moderately affected coals (plastic phase, 300–500 °C), mesophase spheres and fused natural cokes were generated from the reactives (vitrinite and liptinite maceral groups), the liptinites disappeared, and structurally, the inertinites remained almost unchanged with slight increase in the reflectance value. In the severely heat-affected coals (post plastic phase, > 500 °C) the identified microtextures were mesophase spheres, different shapes and sizes of natural cokes, graphitic sphaeroliths, pyrolytic carbons, inerts with morpho-structural changes and slightly higher reflectance values, and altered and unaltered mineral matters. A gradual change in the heat-affected coals with increasing temperature was observed with respect to location of intrusive body.

It has been concluded that, barring the effect of pressure, the changes due to heat effect on coking coals, whether in situ or laboratory carbonization, are almost similar. Organic and inorganic constituents undergoing changes at a particular temperature are nearly similar in both conditions. In case of pronounced overburden pressure, flow structures develop in the natural coke groundmass. Higher reflectance and very strong anisotropy, as evidenced in completely baked coking coals with fine to very coarse mosaic structures, may be a good criterion to explore these heat altered coals for the carbon artifact industry and further efforts are required to be made in this line.

Keywords: Heat-affected coal; Natural coke; Anisotropy; Microtextures; Microstructures; Mesophase spheres; Graphitic sphaeroliths; Pyrolytic carbon; India

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1. Introduction

Mine fires and igneous intrusives in coalmines frequently cause huge loss to the property and environment. In the Jharia coalfield nearly 18 km^2 is on fire, which has blocked ~ 1900 Mt of coking coal and has burnt ~ 40 Mt of coal in different parts of the coalfield. Igneous intrusives have baked ~ 1250 Mt coking coal and produced natural coke (jhama). The petrography of heat-affected coals has been attempted by some workers. In this regard, the works of Stach (1952a, b), Chandra (1963), Ghosh (1970), Teichmüller (1973, 1974) and Chandra and Taylor (1975) may be mentioned. Chandra and Bond (1956) and Chandra (1965, 1975) have studied the impact of heat on coals under artificial conditions. Ferrari (1938) conducted experiments related to the oxidation of coal. The work on heat-affected coals of the Jharia coalfield has been carried out by Chandra and Srivastava (1979, 1980a,b), Singh (1998) and Singh et al. (2003). Chandra (1953, 1954, 1963, 1965) has shown the effect of oxidation on the reflectance of coal. The investigations of coal microstructures and microtextures derived from heat affection have been made by Mookherjee et al. (1967), Chatterjee et al. (1968), Patrick et al. (1973), Sanada et al. (1973), White and Price (1974), British Carbonization Research Association (1974, 1975a,b), Goodarzi and Murchison (1977), Rumsey and Pitt (1978), Jasienko (1978), Mochida et al. (1979), Grint and Marsh (1979), Forrest and Marsh (1982), Grint et al. (1979, 1983), Hays et al. (1983), Gray and Devanney (1986), Bourrat et al. (1986), Johnson et al. (1986), Coin (1987), Suchy et al. (1997), Ross and Bustin (1997), Chaudhuri et al. (1997), Petersen (1998), Singh (1998), Singh et al. (2003), and Kwiecinska and Petersen (2004). Several workers have studied changes in the petrographic and chemical characteristics of coal due to igneous activity in many coalfields. Kisch and Taylor (1966) have shown alterations in coal due to heating up to 1000 °C. Petersen (1998) and Kwiecinska and Petersen (2004) have described organic particles (natural char) derived from coal influenced by fire. Seyler (1948) has observed stepwise changes in reflectance of heat-affected coals but Chandra (1963) and Brooks and Taylor (1968) differ in their observations claiming no significant changes. In this paper, an effort has been made to detect the probable impact of heat on coal leading to different alteration products, by characterizing the heat-affected coal seams of the Ena (seam XIII) and the Alkusa collieries (seam XIV) of the Jharia coalfield (Table 1, Figs. 1, 2). An attempt to classify the microtextures of natural cokes generated through in situ carbonization of the coal seams and update the existing knowledge has also been made.

2. Geological and tectonic setting

Jharia coalfield lies within the Dhanbad district of Jharkhand state. The Dhanbad Township is located in its northeastern margin. The coalfield is named after the chief mining centre Jharia, which is situated in the eastern part of the field. The field is roughly sickle-shaped, with its longer axis running northwest–southeast (Fig. 1). The coal basin extends for about 38 km in an east–west direction and a maximum of 19 km in north–south direction, and covers an area of about 450 km^2. Geologically, it consists of Archaean Metamorphics at the base, which is succeeded unconformably by the Talchir (Upper Carboniferous) and Barakar Formations (Lower Permian), Barren Measures (Middle Permian) and the Raniganj Formation (Upper Permian). The Barakar Formation (with 18 persistent seams) and Raniganj Formation (with 12 persistent seams) are coal bearing. In addition, these two formations are providing good quality coking (prime coking) coals in India. Jharia basin is structurally disturbed with series of step faults and folds. Mica peridotite sills and dolerite dykes have baked the coals at several places and probably are responsible for the enhancement of rank of coal seams in several parts of the basin.

3. Methods of study

Pillar coal samples from opencast mines at Ena (seam XIII) and Alkusa (seam XIV), both from Barakar Formation, were collected and examined macroscopically. Seam profiles (Fig. 2) were prepared and each

Table 1
Macroscopic seam description of seams XIII and XIV, Jharia coalfield

Formation	Seam number and thickness (ft)	Colliery	Description
Barakar Formation (Damuda group, Gondwana)	XIII (45′)	Ena opencast	The lower part of the seam is composed of bright-banded coal, while the upper part is dull due to severe heat affection. The overburden consists of jointed sandstones and the floor consists of fire clays.
	XIV (60′)	Alkusa opencast	The lower part of the seam shows dominance of banded bright coal, while the upper part gradually becomes more dull. The lower part of the seam is less heat affected as compared to upper part.