International Seminar on Mineral Processing Technology (MPT-2008), April 22-24, 2008
Jointly Organized by Indian Institute of Mineral Engineers & National Institute for Interdisciplinary Science & Technology, CSIR, Trivandrum.

Petrographic investigation of selected natural cokes from Damodar Valley coalfields

Mamta Sharma, #Ashok K Singh, #N. K. Shukla ,#S. K. Srivastava, K. K. Bhattacharya**
#Central Institute of Mining and Fuel Research, Dhanbad-828108
*National Metallurgical Laboratory, Jamshedpur, Jharkhand
(Corresponding author: mamtasharma17@rediffmail.com)

Abstract

The natural coke is a kind of fossil fuel and its reserves are scattered in almost coalfields covering approx. 2600 Km^2. In Indian coalfields, the igneous intrusion varies, causing regional in-situ burning of coal seams. The intrusion process itself is quite complex and does not follow any fixed trend everywhere. The chemical composition of the intrusion also varies from place to place. Petrographic, physical and chemical characterizations of some selected natural coke samples of Damodar Valley coalfields were done. The comprehensive study on above samples helped a lot in differentiation of natural cokes, slightly heat affected coal and normal coals obtained after washability at different specific gravities. The yield of the samples after washability varied from sample to sample. Through petrographic studies by microscopy, an effort has been made to decipher the new classification schemes for microtextures and microstructures of natural coke, which are generated through in-situ carbonisation of coal seams. Isotropic, anisotropic components and mineral matters were differentiated. Some selected natural coke fractions were explored for value addition in different studies. The study was helpful in establishing industrial use of natural coke in Power, Cement and Carbon Artifact industry.

Key words: Natural coke (jhama), petrography, anisotropy, anisotropy, industrial use.

Introduction

Damodar Valley coalfields occur along Damodar River as outlier in the shield area. The entire Gondwana sequence is well preserved in the basin, where some important coalfields such as Raniganj, Jharia, Bokaro, Ramgarh and Karanpura are located. These coalfields are the store-house for good quality coals suited for Steel and Power industries. Some coalfields of this basin are affected by igneous intrusions. Apart from igneous activity, spontaneous combustion and accidental causes, leading to coal seam fires, have damaged considerable part of the coal occurrences.

The intrusives are dolerite or basaltic, basic mica peridotite and lamprophyre dykes and sills. Mica peridotite dykes are generally less than 1 m in thickness, but sometimes the width may exceed even 10 m. Most of the intrusives are characterised by an irregular habit. In certain areas, the intricate pattern of veins has completely spoiled the coal seams. At places, the coking coals are converted into natural coke, and char has been produced if the coal is non-coking. The dolerite dykes are characterised by their great thickness. The mica peridotite sills are more wide spread in the Barakar Coal Measure than in the overlying Raniganj coal bearing horizons. Adjacent to peridotite intrusion, even the shale and sandstone beds have also been affected and some times produced para-lava. Raniganj coalfield (Figure 1) has been selected for this case study. The This Coalfield is scattered in about 1603 km^2 area. There are three coal seams (Damagoria, Laikdih and Ramnagar seams) in Barakar Formation and one workable seam (Dishergarh seam) in Raniganj Formation. The Lower Gondwana formations are succeeded by Panchet and Mahadeva formations. This coal-belt has witnessed two episodes of fold tectonics. One during Permian to Lr. Cretaceous Period giving rise to two sets of early folds trending NW-SE. Another during Palaeocene Period forming cross - folds along E-W axes. The two folds were accompanied by large scale fractures.

Thermal metamorphism of coal due to igneous activity has been described from various parts of the world (Amijaya and Littke, 2006, Blanford, 1861, Dutcher, et. al, 1966, Fox, 1930, 1934, Gee, 1932, Ghose, 1967). Such metamorphosed coals are also known by various names such as natural coke, geological coke, cinder coal or jhama (Taylor et al., 1998; Kwiecinska and Petersen, 2004, Singh, 1998, Singh et al. 2003, 2007). In India, among the Lower Gondwana coalfields, plenty of reserves of this kind are found in the Damodar Valley coalfields (Ghosh, et al, 1977, Greenwell, 1912-1913, Chatterjee and Ghosh, 1970). In this paper an attempt has been made to carry out the organic petrographic and geochemical characteristics of coals from Raniganj coalfield. Since the effects of heat derived from the igneous intrusion are mostly local and occur over short span of time (Taylor et al., 1998, Amijaya and Littke, 2006) the macerals are projected to be coalified with a different path as compared to normal coalification path. Due to its heterogeneity, its judicious industrial utilization could not be planned. Therefore, this study would focus on genesis of natural cokes keeping in view the typical examples. The igneous rocks causing thermo-contact effect on coalification were mica-peridotite and dolerite type and erupted at the beginning of the Lower Cretaceous Period (Dapples, 1939, Kisch, 1966). They appeared in the form of veins and apophyses, which are either cross- or fissure-type veins tearing up the coal seams, or bed veins which, ramifying along the fault planes, and filling in the faults, intruded into the rocks of the lowest resistance on the boundary-line of the different rock beds and caused destructive impact. Near the intrusive contact coals became coked and also partition rocks underwent alterations. As a consequence of the interaction of coals exposed to thermo-contact effects, however, the dark-coloured lamprophyre turned grayish-white, and pyrites and calcite appeared in it. This change is characteristic of thinner bed veins only; the bulk of the thicker cross-veins amounting to some meters did not change, at the most their 2-3 m thick marginal parts underwent changes. The contact impact exerted on coal is generally of varying extent depending upon whether the veins had come into direct or indirect contact with the coal seams. Changes are influenced by vein thicknesses, their distances from the coal seams and the heat capacity (Kwiecinska et al, 1992). Intrusive veins punctured the coal seams and induced a large scale baking effect in addition to mechanical destruction. The ash content of the coked coals increased due to varying degree of distillation (Golab, 2003, Golab, et al, 2007, Kwiecinska and Petersen, 2004, Merritt, 1990, Pascoe, 1959, Sanyal, 1986, Querol et al, 1997, Jennifer et.al, 2006).

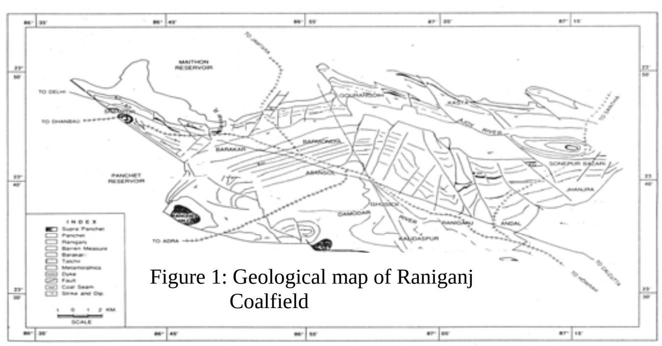

Figure 1: Geological map of Raniganj Coalfield

Methodology

In the present investigation, jhama samples were collected from the Laikdih Salanpur "A" Seam of Damagoria Colliery. Since no working faces were available, the sample was collected from a nearby big dump comprising mined out jhama ()>20000 tonnes) from same mine. Three tonnes of samples of top size about 50 mm were carried in a truck from colliery site to CIMFR for laboratory investigations. The samples were initially air dried and crushed to 50 mm in a continuously operated single roll crusher. The crushed samples were thoroughly mixed and after proper mixing divided into four parts. Out of these, one part was considered as head sample and characterized for proximate, ultimate, petrographic, HGI, GCV and ash analysis etc following BIS procedures. The second part was subjected to size analysis at 50, 25, 13, 6, 3 and 0.5 mm standard screens. The third part was used for float and sink studies as per BIS-13810 (1993).The fourth part was kept as a reserve. The samples were further processed and sub sampled for different laboratory investigations as per required sizes, and subjected to various studies such as proximate, ultimate, petrography, characterization of the heat affected coal through: petro-chemical examination, XRD, real density, microtexture and microstructure studies through high resolution petrological microscope, SEM), anisotropy studies, etc following standard procedures.

Results

Head sample was characterized (air dried basis) through proximate and ultimate analyses, GCV, ash analysis, ash fusion temp., HGI, AI, real density etc. On air dried basis the natural coke of study area contained moisture 2.6%, Ash 44.0%, VM 10.1% (18.9% daf), FC 43.3% (81.1% daf), Elemental carbon

46.6% (87.3% daf), Hydrogen 1.3% (2.9% daf), Sulphur 0.4% (0.7% daf), Nitrogen 0.9% (1.6% daf), CO_2 2.4%, GCV 3840 kcal/kg and real density ~1.99. It is indicative of considerable conversion of coaly material into natural coke after baking. This is also depicted through very low hydrogen 1.3% (2.9% daf), very less reactives 12.8% (18.4% vmmf) and moderate heat altered maceral constituents 27.6% (39.8% vmmf).

Micropetrographic characterization of the head sample as well as gravity fractions were also carried out in the laboratory to characterize reactives (unaltered macerals - vitrinite, semivitrinte, liptinite), inertinite (fusinite, semifusinite, macrinite and micrinite), altered products of reactives and mineral matters. In the head sample the reactive/unaltered macerals (vitrinite, semivitrinte, liptinite) were 12.8% (18.4% vmmf), inertinites (fusinite, semi fusinite, macrinite, micrinite, sclerotinite etc.) 29.0% (41.8% vmmf), heat altered products/anisotropic constituents 27.6% (39.8% vmmf) and mineral matter 30.6%. Petrographically, the size fraction 25-13mm depicted the distribution of unaltered macerals (reactives) 43.3%-2.7% (51.3% - 3.7% on vmmf basis), inertinites 31.9% to 15.3% (37.2%-26.3% on vmmf basis), liptinite 4.0%-0.7% (4.6%-1.3%), mineral matter 14.2% to 45.3% and the heat altered maceral components with different mosaic and flow structures (very fine to very coarse and flow structures) varied between 36.0% and 41.3% (44.9 and 65.8% on vmmf basis). The size fraction 06-03mm depicted the distribution of unaltered macerals (reactives) in meager quantity i.e. up to 5.2% (8.5% on vmmf basis), inerts up to 24.1% (33.7% on vmmf basis), mineral matter up to 51.6% and the heat altered maceral components up to 45.1% (65.2% on vmmf basis). The size fraction 03-0.5mm depicted the distribution of unaltered macerals (reactives) in meager quantity 9.2%-0.4% (11.7% -1.0% on vmmf basis), inertinites 31.4% to 17.8% (39.6%-42.8% on vmmf basis), mineral matter 20.7% to 58.4% and the heat altered macerals varied between 38.7% and 23.4% (60.4% and 40.3% on vmmf basis).

Discussion

Microscopically, it was observed that due to intense heat and pressure conditions even some of the inerts have generated anisotropic carbon. The anisotropy in the case of generated natural cokes was higher than the corresponding coke (generally generated in laboratory) due to intense overburden pressure and higher temperature of the intruding magma giving rise to intrusive bodies. Most of the seams of Damodar valley coalfields are considered to be containing high amount of reactives (vitrinite mostly) and good coking propensity, but due to intense underground heating, causing carbonization due to intrusives, the reactive macerals have been converted into coke like mass with high reflectance/anisotropy and development of different microtextures and microstructures (fine to very coarse mosaics, flow structures and micropores). It has been established that the fractions having anisotropic carbon in significant amount show good trend of graphitization, the property, which is of immense use for carbon artifact industry. Other fractions having unaltered petrographic components, with higher V.M. and GCV values (>5000 kcal/kg) may be recommended to be used as blend with high to moderate V.M. coal for consumption in power plants.

Overall, it appears that the ash content is not a major problem and it can be taken care through washability studies and bulk of the actual natural coke may be considered for consumption in carbon artifact and power industries.

Reference

1. Amijaya, H., Littke, R., 2006. Properties of thermally metamorphosed coal from Tanjung Enim Area, South Sumatra Basin, Indonesia with special reference to the coalification path of macerals. International Journal of Coal Geology, 66, 271-295.

2. Blanford, W.T., 1861. On the geological structure and relation of the Raniganj coalfield, Bengal. Mem. Geol. Surv., Ind, III, pt.1, 146-149.

3. Chandra, D., Srivastava, G.P., 1980. Petrology of burnt coals. Trans Min. Geol. Met.Inst.,77,No.1and2,75-100,

4. Chatterjee, G.C., Ghosh, P.K., 1970. Tectonic framework of the Peninsular Gondwanas of India. Rec. Geological Survey of India, 98(2) 1-15.

5. Dapples, E.C., 1939. Coal Metamorphism in the Anthracite-Crested Butte quadrangle Colorado. Economic Geology, 34, 369-398.

6. Dutcher, Russell, R., Campbell, D.L, Thornton, C.P., 1966. Coal Metamorphism and Igneous Intrusives in Colorado. American Chemical Society, Advances in Chemistry Ser., no. 55, 708-723.

7. Fox, G.S. 1934. The Lower Gondwana Coalfields of India. Geological Survey of India, Mem., 59, 386 pp.

8. Gee, E.R., 1932. The geology and coal resources of the Raniganj coalfield. Mem. Geol. Surv. Ind., LXI, 343pp.

9. Ghose, T.K., 1967. A study of temperature condition at igneous contact with certain Permian coal of India. Economic Geology, 62, 109-117.

10. Ghosh, S., Chatterjee, C.N., Mallik, P.C., 1977. Regional metamorphism of coal in major coalfields of Damodar valley region, India. In proceeding of IV International Gondwana symposium, 1977, Calcutta, India. Hindustan Publishing Corporation (India), Delhi-110007, 286-298.

11. Golab, A., 2003.The impact of igneous intrusions on coal, cleat carbonate, and groundwater composition. Ph.D. thesis, School of Geosciences, University of Wollongong, Australia.

12. Golab, A. N., Hutton A.C., French D., 2007. Petrology, carbonate mineralogy and geochemistry of thermally altered coal in Permian coal measures, Hunter Valley, Australia. International Journal of Coal, 70,150-165.

13. Greenwell, G. H., 1912-1913. The Jharia coalfield (India) and its future development. Transactions of the Institute of Mining Engineers, Vol. XLV, 88-106.

14. Jennifer, R.C., Crelling J.C., Rimmer S.M., Whittington A. G., 2006.Coal metamorphism by igneous intrusion in the Raton Basin, CO and NM: Implications for generation of volatiles. International Journal of Coal Geology, 71, 15-27.

15. Kisch, H.J., 1966. Carbonization of semi-anthracitic vitrinite by an anthracite basanite sill. Economic Geology 61, 1043-1063.

16. Kwiecinska, B., Petersen, H. I., 2004. Graphite, semi graphite, natural coke and natural char classification- ICCP system, International Journal of Coal Geology 57, 99-116.

17. Kwiecinska, B. K, Hamburg G., Vleeskens J.M., 1992. Formation temperature of natural coke in the lower Silesian coal basin, Poland. Evidence from pyrite and clays by SEM-EDX. International Journal of Coal Geology 21, 217-235.

18. Merritt, R. D., 1990. Thermal alteration and rank variation of coals in the Matanuska field, south-central Alaska. International Journal of Coal Geology 14, 255-256.

19. Pascoe, E.H., 1959. A manual of the geology and Burma. Govt. of Ind. Publication, 909-1016.

20. Querol, X., Alastuey, A., Lopez-Soler, A., Lana, F., Fernandez-Turiel, J.L., Zeng, R., Xu, W., Zhuang, X., Spiro, B., 1997. Geological controls on the mineral matter and trace elements of coals from the Fuxin Basin, Liaoning Province northeast China. International Journal of Coal Geology 57, 99-116.

21. Sanyal, S.P., 1984. Petrology of natural coke associated with igneous intrusives in parts of the Raniganj Coalfields. Geological Survey of India, Memoirs, vol.117. 75 pp.

22. Singh, A.K., 1998. Petrology of coals from the fire affected areas of Jharia coalfield, Damodar valley Bihar. Ph. D. thesis, Department of Geology, Banaras Hindu University, Varanasi, U.P., India

23. Singh, A.K., Singh, M.P., Sen, K., 2003. New Classification Scheme for Microtextures of Natural Cokes: A Case Study from Heat Affected Coking Coals of Jharia Coalfield, India. 20th International Pittsburgh Coal Conference, USA.

24. Singh, A.K., Singh, M.P., Sharma, M., Srivastava, S.K., 2007. Microstructures and microtextures of natural cokes: A case study of heat-altered coking coals from the Jharia coalfield, India. International Journal of Coal Geology 71, 153-175

25. Taylor, G. H., Teichmüller, M., Davis, A., Diesel, C.F.K., Littke, R., Robert, P., 1998. Organic petrology. Gebrüder Borntraeger, Berlin-Stuttgart. 704 pp.