

Petrochemistry and Depositional Environment of Permian Coals of Basundhara Block, Ib-Valley Coalfield, Orissa, India

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Abstract. This paper deals with the characteristics of coals of Basundhara block of Ib-valley. The aim of this study is to reconstruct the paleo-environment condition of coal formation. A large number of pillar coal samples from Basundhara block were collected and subjected to detailed petrographic and geochemical studies. The results show that the Basundhara block (Rampur seam) coals are rich in inertinite group macerals. The rank of Basundhara block coals as per ASTM system and according to the mean of random vitrinite reflectance has been found to range between sub-bituminous 'A' and high volatile bituminous 'B'. The proximate analyses exhibit that coals belong to semi-coking to weakly coking range. The ultimate composition shows hydrogen ranges between 4.87 and 6.20%, carbon from 78.7 to 86.3% and oxygen between 7.26 and 13.78%. The nitrogen ranges from 0.71 to 0.76% and sulphur is between 0.53 and 0.96%. The quantitative study of macerals, microlithotypes and mineral matter indicate that these coals originated from the plant communities of highly fluctuating oxic and anoxic moor to oxic (dry) moor with sudden high flooding conditions. Low value of Tissue Preservation Index (TPI) and high value of Gelification Index (GI) indicate peat formation in dry condition.

Introduction

The Ib-valley coalfield occurs in the northeast-south-west trending Son-Mahanadi basin belt. The Basundhara block occupies northwestern part of Ib-valley coalfield. This block is situated in the Sundergarh district of Orissa state. The name of the study area is derived from the name of river Basundhara, a tributary of Ib-river. Ball (1875) prepared the first geological map of the area. Other workers including King (1881) and Reader (1901) remapped the area, but detailed petrographic and geochemical studies of these coals were still lacking.

The litho-stratigraphy of the area comprises of two distinct broad lithounits i.e. Precambrian Metamorphics and Lower Gondwana Group of rocks separated by an unconformity. The Talchir Formation, unconformably rests over Archaean Basement, which is overlain by Karharbari and Barakars, Barren Measures and by Kamtlus, the top most formation of Lower Gondwana in the study area (Rao, 1982). The Barakar Formation is the main coal-bearing horizon. In the Basundhara block (Rampur seam), thick or thin interbanding of carbonaceous shales are frequently noticed. The coal seam of the study area strikes N 60° W- S 60° E and dips at low angles of 5 to 8° towards SSW. Two normal faults F_1 and F_2 traverse the area, while fault F_3 demarcates the southern boundary.

Materials and Methods

About 100 coal samples were collected from open cast mine of Basundhara block, Ib-valley coalfield. The vertical face of coal seam section was examined and macroscopic seam profile was made by using the method pro-

posed by Diessel (1965). The coal samples were crushed to 72-mesh size for proximate and ultimate analyses. For microscopic investigations, coal samples were crushed to < 1 mm size fraction (-18 mesh size) and were mounted. In total, 23 polished particulate mounts and powdered samples were prepared for both analyses. The coal microscopic investigations have been made by using Leitz MPV II reflected microscope. The identification of microscopic constituents was according to guide lines of International Committee for Coal and Organic Petrology (1971). For maceral analysis, a mechanical stage and a point counter were used and for each polished particulate block, 500 points were counted. Reflectance measurements were taken in monochromatic light (546 μ m) produced by a Leitz monochromator S-546-19. For calibration a leuco-sapphire optical standard with reflectance in oil (DIN 58884 of 1.519 refractive index at $23 \pm 1^\circ$ C at 546) of 0.59% was used. Using 20-point cross-line graticule, the microlithotype analysis was done. The 5% rule and 50x50 μ m band width for each count were followed. For every particulate mount, minimum of 500 points were counted.

Chemical Characteristics and Rank

Proximate Analysis

In the coal of Basundhara block, moisture content ranges from 4.0 to 6.0%, volatile matter from 21.0 to 39.0%, ash from 5.0 to 33.0% and fixed carbon from 33.0 to 59.0% (Table 1).

Ultimate Analysis

In the coals of Basundhara block, hydrogen content ranges from 4.87 to 6.20%, carbon from 78.7 to 86.3% and

oxygen between 7.26 and 13.78%. The nitrogen content is in the range of 0.71 and 0.76% and sulphur ranges between 0.53 and 0.96% (Table 2).

Rank

The mean random value of vitrinite reflectance (0.52%) shows that the coals of Basundhara block, Ib-Valley coalfield are between sub-bituminous 'A' and high volatile bituminous 'B'.

Petrography

Megascope Characters

The Basundhara block coal shows greyish black to dull black appearance with some reddish inclusion. According to Stopes (1935), the four lithotypes namely vitrain, clarain, durain and fusain are found in varying amounts, depending on depth and rank of the coal seam. According to Diessel (1965), the coal of Basundhara block, Ib-Valley coalfield is dull to bright in nature. Dull coal is more abundant in Basundhara block.

Table 1. Results of proximate analysis (dry basis and dry ash free basis) of Basundhara block coals

No.	Dry basis				Dry ash free basis	
	Moist. %	Ash %	Volatile matter %	Fixed carbon %	Volatile matter %	Fixed carbon %
1	4	15	26	55	32.10	67.90
2	5	14	30	51	37.04	62.96
3	4	24	28	44	38.89	61.11
4	5	14	39	42	48.15	51.85
5	5	23	23	49	31.94	68.06
6	5	07	37	51	42.05	57.95
7	4	32	31	33	48.44	51.56
8	5	19	24	52	31.58	68.42
9	5	17	26	52	33.33	66.67
10	6	5	31	58	34.83	65.17
11	4	16	36	44	45.00	55.00
12	5	14	23	58	28.40	71.60
13	6	15	32	47	40.51	59.49
14	6	13	38	43	46.91	53.09
15	4	14	31	51	37.80	62.20
16	4	18	28	50	35.90	64.10
17	4	16	33	47	41.25	58.75
18	4	27	28	41	40.58	59.42
19	4	16	21	59	26.25	73.75
20	5	20	32	43	42.65	57.33
21	4	27	28	41	40.54	59.46
22	5	33	21	41	33.87	66.13
23	4	24	34	38	47.22	52.78

Microscopic Characters

Vitrinite: The most dominating maceral in this vitrinite group is collotelinite. The colours of vitrinite group maceral are light grey to moderately dark grey. The collotelinite macerals are found separately or in association with inertinite group macerals. At some places, it is highly oxidized and also associated with clay minerals. The vitrinite ranges between 1.7 and 73.1% (2.17 to 81.13% mmf basis).

Liptinite: Liptinite group maceral is different from vitrinite and inertinite due to its hydrogen contents and heterogeneous origin. The common structured liptinite macerals are sporinite, cutinite and resinite, which were found in these coals. In this coal, sporinite is more dominating maceral of liptinite group. The sporinite occurs as elongated thread like bodies. Cutinite is less common in these coals, which appears dark grey to black under white light. The rounded to sub-rounded resin bodies occur very rarely. The concentration of liptinite group macerals ranges between 0.5 and 8.7% (0.55 and 12.0% mmf basis).

Inertinite: Inertinite group macerals have higher reflectance value than vitrinite and liptinite group macerals. The inertinite group macerals are commonly

Table 2. Ultimate analyses of Basundhara block coals

No	Hydrogen %	Carbon %	Oxygen %	Nitrogen %	Sulfur %
1	5.20	84.8	8.30	0.75	0.95
2	5.42	83.0	9.96	0.76	0.86
3	5.61	82.2	8.30	0.72	0.84
4	6.04	79.9	9.96	0.73	0.93
5	5.17	83.6	10.63	0.71	0.76
6	5.68	82.2	10.56	0.74	0.82
7	6.20	78.7	13.78	0.71	0.59
8	5.13	84.1	9.38	0.72	0.68
9	5.22	83.8	9.37	0.74	0.89
10	5.23	83.8	9.70	0.74	0.53
11	5.93	81.2	11.48	0.75	0.65
12	4.94	85.4	8.08	0.75	0.83
13	5.57	81.4	11.57	0.71	0.75
14	5.92	79.8	12.78	0.71	0.79
15	5.52	83.3	9.63	0.73	0.82
16	5.42	83.5	9.59	0.75	0.74
17	5.71	82.2	10.64	0.72	0.73
18	5.72	81.4	11.31	0.72	0.85
19	4.87	86.3	7.26	0.72	0.85
20	5.76	80.9	11.67	0.74	0.93
21	5.72	81.4	11.19	0.73	0.96
22	5.32	82.2	10.89	0.72	0.87
23	6.09	79.8	12.60	0.75	0.76

found in these coals. In inertinite group maceral the semifusinite, fusinite, secretinite, macrinite, micrinite and inertodetrinite were observed. The semifusinite shows light grey to white colour and occurs in thick and thin micro bands. The maceral fusinite dominantly occurs and shows a well-preserved cell structure, where the cell lumens are partially or completely filled up with mineral matter. Under white incident light, it shows white to yellowish white colour and high reflectance. The macrinite, micrinite and secretinite concentrations are very rare and occur as small rounded to irregular amorphous bodies without any structure and show pale grey to white colour. Inertodetrinite is commonly occurring maceral, which is mainly derived as detritus particles. Inertinite group maceral concentration ranges between 16.5 and 72.1% (18.30 and 92.08% μm^2 basis).

Mineral Matter: The clay minerals dominate with subordinate amount of arenaceous material. Sulphides are in very low concentration. In these coals, the mineral matter ranges between 6.4 and 38.0% (Table 3).

Microolithotype Study

The microolithotype analysis demarcates the presence of monomaceral as vitrite and inertite, bimaceral as clarite, vitrinertite, durite and trimaceral as duroclarite. Collotelinite is the main constituent of vitrite and is dominating microolithotype in this coal. Inertinite consists of

fusinite and semifusinite. In the study area, vitrite ranges nil to 2.0%, vitrinertite from 3 to 23%, clarite from 2.0% and duroclarite from nil to 2.0%. The carbominerite in these coals ranges from 32.0 to 80.0% (Table 4).

Reflectance

Reflectance measurements help to find out the rank of maturity of coal. The reflectance value of measured samples range between 0.40 and 0.58% ROM (mean = 0.52%).

Scanning Electron Micrography

The different lithotypes of coal have been analysed for their mineral matter association. The lithotypes formation depends upon the mechanism of subsidence and subsequent flooding of the coal-forming basin (Stach et al., 1982). The Basundhara block coals show diversity in mineral matter distribution. The massive impregnation and cavity-filling interrelationships are more commonly seen, while superficial mounting is seen in clarain, whereas argillaceous matter is distinct in durain. The cell cavity of fusain is sporadic. The decreasing order of their association with different lithotypes are reported as vitrain > durain > clarain > fusain, as observed in scanning electron micrographic study.

Table 3. Contents of macerals microolithotypes and mineral matter of Basundhara block coals

No.	Telmitite	Vitrinite				Liptinite			Inertinite							Mineral matter MBt
		Collo-telmitite	Collo-detrinite	Vitro-detrinite	Corpo-gelinite	Sporinite	Cutinite	Resinite	Semi-fusinite	Fusinite	Fungi-nite	Secre-tinite	Macri/Micrinite	Inerto-detrinite		
1	N	2.2	3.0	0.2	N	6.2	N	N	30.2	23.2	N	N	0.2	11.0		23.5
2	N	25.6	4.0	1.0	N	2.6	N	N	23.2	13.8	0.2	N	0.6	11.6		17.4
3	N	8.2	0.5	N	N	6.5	N	N	35.2	N	N	N	0.7	25.2		23.5
4	N	39.7	10.0	N	N	2.0	N	N	29.5	8.2	N	N	0.2	2.5		7.7
5	N	4.2	1.2	N	N	8.7	N	N	31.0	6.2	N	N	0.5	20.7		27.2
6	N	47.6	7.4	0.2	2.0	1.8	N	N	18.0	7.6	N	N	0.2	3.2		12.0
7	N	1.0	0.7	N	N	4.5	N	N	42.7	14.7	N	N	0.2	14.5		21.5
8	N	16.7	4.5	N	4.2	3.7	N	0.2	31.7	9.5	N	N	0.2	10.0		19.0
9	N	9.2	4.5	N	N	4.2	N	N	42.5	10.5	N	N	0.2	12.7		16.0
10	N	70.2	0.4	N	0.8	1.0	1.8	N	17.2	2.2	N	N	N	N		6.40
11	0.2	18.2	3.5	0.5	0.9	1.2	N	N	7.0	26.7	0.2	N	0.2	19.0		22.0
12	N	35.2	7.4	0.4	N	3.8	0.2	N	18.0	12.0	0.6	N	0.6	7.6		14.2
13	N	16.0	12.2	N	N	5.0	N	N	33.7	15.7	0.5	N	N	4.2		12.5
14	N	57.7	13.7	0.2	1.5	0.5	N	N	9.5	5.5	N	N	1.0	0.5		9.70
15	N	15.6	12.4	N	N	6.0	N	N	30.2	12.0	0.2	N	0.8	8.2		14.6
16	N	6.7	10.2	N	N	4.0	N	N	25.0	4.2	N	N	0.2	13.0		36.5
17	N	15.7	25.7	N	N	7.7	N	N	22.0	9.7	N	N	0.2	3.7		15.0
18	N	4.0	3.5	N	N	7.2	N	N	34.7	10.5	N	N	N	11.5		28.5
19	N	21.2	3.6	0.2	0.2	5.4	0.4	N	23.2	13.2	0.4	N	0.4	10.6		21.2
20	N	30.8	4.0	0.4	N	4.6	N	N	14.6	8.2	N	N	0.8	12.6		24.0
21	N	8.2	10.2	N	N	7.7	N	N	26.2	9.2	0.5	N	0.5	14.5		22.7
22	N	2.2	0.7	N	N	4.5	N	N	18.7	21.2	N	N	N	14.5		38.0
23	N	14.5	8.7	N	N	7.0	N	N	30.0	10.2	0.2	N	N	10.5		18.7

Table 4. Frequency distribution of microlithotype and carbominerite (in volume percent)

No.	Monomaceral		Bimaceral			Trimaceral	
	Vitrite	Inertite	Clarite	Durite	Vitrinerite	Duroclarite	Carbominerite
1	10	23	01	-	08	-	58
2	29	17	-	01	10	-	43
3	04	13	-	02	03	-	78
4	49	09	01	02	04	-	35
5	04	11	-	01	04	-	80
6	48	09	02	01	07	-	34
7	07	15	-	-	04	-	76
8	36	13	-	-	11	-	38
9	13	17	02	01	07	-	60
10	50	06	01	01	06	-	36
11	31	15	-	-	06	-	48
12	38	15	02	-	05	-	40
13	20	19	02	02	07	-	49
14	47	08	01	02	09	01	32
15	28	09	-	-	11	01	41
16	10	21	02	-	12	01	55
17	29	03	01	-	05	-	62
18	11	20	-	-	13	-	56
19	42	17	-	-	05	-	36
20	54	07	-	-	05	-	34
21	23	07	-	01	07	-	62
22	11	19	02	-	15	-	53
23	23	14	02	02	04	01	54

Petrographic and Chemical Constituents

There is no particular trend of distribution of vitrinite, liptinite and inertinite from top to bottom. The quantitative occurrence of maceral and mineral matter in a facies of diagram proposed by Singh and Singh (1996) suggests that the coals of Basundhara block were formed in highly fluctuating oxic and anoxic moor to oxic (dry) moor with sudden high flooding conditions (Fig. 1).

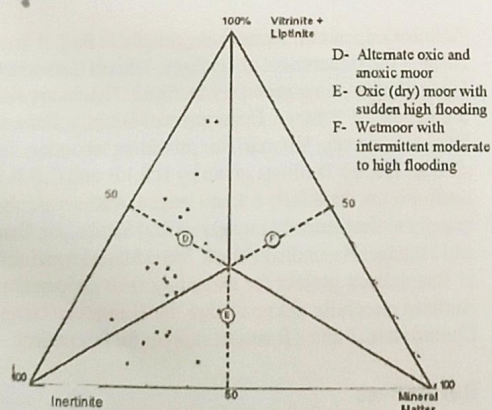


Fig. 1. Depositional conditions of coals based on maceral and mineral matter contents.

On the basis of quantitative analysis of macerals and microlithotype, an attempt has been made to find out the paleo-depositional history of the Basundhara block coals using models proposed by earlier workers. On the basis of facies model by Mukhopadhyay (1986), the maceral composition suggests the development of peat in forest swamp under mildly oxic to anoxic conditions with tissue preservation (Fig. 2).

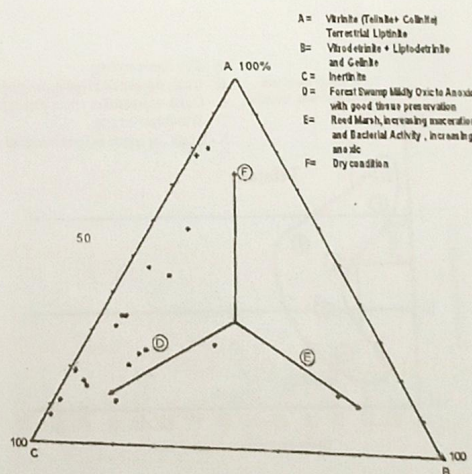


Fig. 2. Diagram of facies-critical maceral association of coal and suggested peat forming environments.

Further, the microlithotype compositions on the basis of facies model of Smyth (1979) indicate the development of peat under fluvio-lacustrine conditions, along with the development of upper deltaic and lower deltaic conditions near the fresh water lakes (Fig. 3).

Using Gelification Index (GI) and Tissue Preservation Index (TPI), Diessel and Mc Hugh (1986) have deciphered coal facies depicting the depositional environment and the type of mire. Diessel (1965) suggests that a high GI and telovitrinite dominated TPI results due to wet condition of peat formation, while a low GI and TPI indicates a dry peat condition (Fig 4).

This is further supported by the occurrence of inertodetrinite in higher concentration (nil to 33.03%). As a result of periodic drier conditions, the biochemical activity gets reduced which, in turn impedes the process of gelification or humification (Singh et al., 2003). This results in a rapid fall of the water table leading subsequently

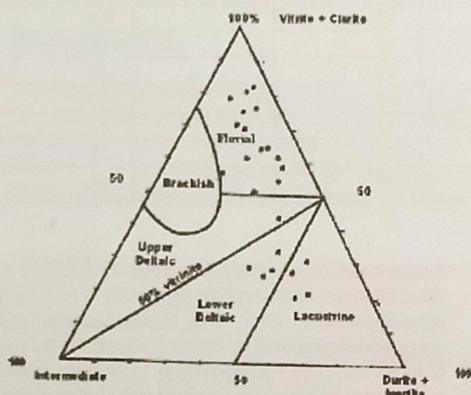


Fig. 3. Environments of coal deposition based on microlithotype composition (modified after Smyth, 1979).

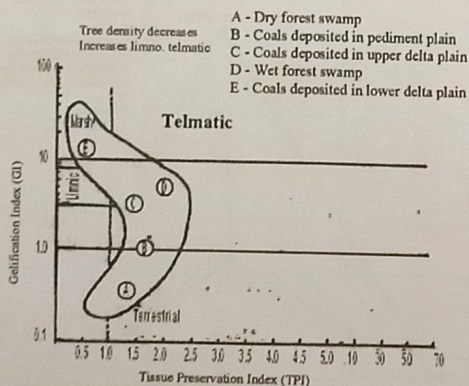


Fig. 4. Coal facies indicating relation with depositional setting and type of mire (Diessel and McHugh, 1986).

to the disintegration of structured inertinites. According to Calder et al. (1991) such type of coal forming environment is typical of ombotrophic condition (Fig. 5).

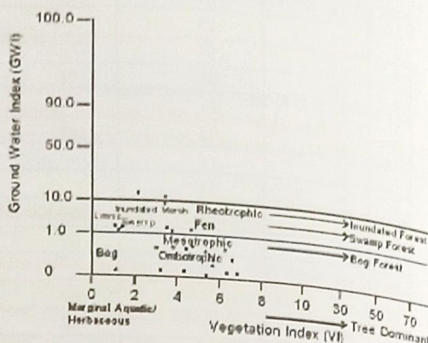


Fig. 5. Paleo-environment of mire based on GWI vs VI.

Conclusion

On the basis of proximate and ultimate analyses results, the studied coals fall in the category of non-coking to weakly coking and sub-bituminous to high volatile bituminous group. The maceral composition suggests the peat development in forest swamp under mildly oxic to anoxic conditions with tissue preservation. Microlithotype composition suggests development of peat under fluvio-lacustrine condition along with the development of upper deltaic condition near fresh water lakes. The coal forming environment is typical of ombotrophic hydrological condition.

Moreover, the Basundhara coals are suitable for thermal power plants, brick and fertilizer industries and for domestic uses. Though, high mineral matter supports the environmental disorder, which can be minimized by taking necessary precautions.

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