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Physico-chemical and petrographic characters of coal of Langrin coal field occurring in Borsora area, Meghalaya (India)

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Abstract

The Borsora area lying just on the Indo-Bangladesh border where sandstones are found with a number of thin coal seams within the Shella Formation of the Jaintia Group. The coal seams are associated with Lakadong (Sylhet) Sandstone Member of the Shella Formation. The coals are generally soft and friable with brown to black colour and at places bottom part of the seams show increasing order of lustre and hardness. They possess mostly conchoidal to uneven fractures. The coal is having low moisture (3.23-5.30wt%) and ash (2.92-10.23wt%), high volatile matter (38.83-42.42wt%), relatively high calorific value (6722-7926 Kcal/Kg) with comparatively low fixed carbon (43.72-55.02%) content. Total sulphur is high (2.40-4.61wt%). Calculated carbon and hydrogen content varies from 72.39-81.47wt% and 5.17-5.51wt% respectively. Collinite type of vitrinite (81.5wt%) constitutes the bulk of the macerals present in the coal and vitrinite reflectance (0.68wt%) confirms the rank as HVB stage.

High sulphur of the coal is genetically related to the mode of formation of the coal seams in paralic basin. Collinite and framboidal pyrite in the coal indicate a marine environment. High concentration of Ba, V, Cr, Zr and Cu also indicate a marine influenced environment of deposition of the coal. Presence of Mo, V and Co with Mn and Cu indicate a reducing condition of deposition.

The coal can be used to produce a diverse type of by-products, in thermal power projects and in hydrogenation products. It can also be used as fuel for cement, paper mechanised brick industry and domestic purposes.

Key Words : Physico-chemical, petrography, Langrin coal field, Borsora, Meghalaya.

Introduction

The Langrin Coal field of West Khasi Hills is the important coal field of Meghalaya. The coals of this coal field occur with a few number of thin coal seams (six) within the Lakadong Sandstone Member of Shella Formation, Jaintia Group. These coal seams are mostly of Eocene age of Tertiary period.

The Tertiary coals of Meghalaya were studied by different workers[1,2,3,4,5,6,7,8] covering different aspects of coal.

The present studies deal with the physico-chemical and petrographic characters of the coals for their usefulness and also determination of depositional environment.

The study is mainly represented by Tertiary rocks of Shella Formation, Jaintia Group. Lakadong limestone and coal bearing Lakadong Sandstone Members occur in Borsora area where Langrin coal field is present. The coal field is represented by Lakadong Sandstone with thin coal seams.

The rocks associated with the coal seams are bedded and fine grained sandstones and shales. The present study was carried out in Langrin coal field covering an area of about 1 sq. Km. within the 25°12/N and 25°15/N Lat. and 91°5/E - 91°8/E Long. in Borsora area. (Fig.1a,b).

Materials and Methods

Samples of coals were systematically collected in the field from exposures of coals. There are 6 (six) coal seams in the area with varying thickness nearly 1.5m to 2m. Altogether 20 samples were collected from the field for laboratory analysis. Amongst these 11 (eleven) representative samples were selected for laboratory analysis. In the laboratory, samples were grounded and passed through 72 B.S. test sieve and used for proximate and ultimate analyses. Some samples were also analysed in the coal laboratory of Regional Research Laboratory (now Neist), Jorhat. The chemical properties were determined by proximate and ultimate analyses using conventional methods described by Chandra[9]. In the laboratory, proximate and ultimate analyses were carried out following the Indian Standard Specification[10,11,12,13].

Trace element and petrographic studies were done and methods were incorporated in the respective places.

Physical properties :

The coals are commonly soft and

friable with brown black colour and at places bottom part of the seam show increasing order of lustre and hardness. They show conchoidal to uneven fractures. The range of hardness is from 1.5 to 3 in Moho's hardness scale. The coals are devoid of any banded nature. The specific gravity of the coal samples ranges from 1.25 to 1.40 with average 1.31.

Chemical properties :

Chemically coal consists of a mixture of complex organic compounds along with small amount of inorganic mineral matter and moisture. The chemical properties of coals are determined by proximate and ultimate analyses using conventional methods[9]. The proximate analyses include the determi-nation of moisture, ash, volatile matter and fixed carbon. The carbon, nitrogen, hydrogen, oxygen and sulphur are considered to be the dominant constituents of coal and the ultimate analyses were determined of the above constituents.

For proximate analyses, the powdered coal samples of 100 mesh size were taken on air dried basis for the determination of proximate analyses. The results of the proximate analyses are shown in Table - 1. The calorific value of the coal calculated from proximate analyses data using Goutal's formula varies from 6721.98 to 7971.65 Kcals/kg. (Table - 2).

Carbon, hydrogen, nitrogen, oxygen and sulphur are the essential elements of chemical compound made up the organic components of coal. The ultimate analysis involves the determination of each of these elements in the coal samples. The ultimate analysis of total sulphur, hydrogen and carbon determined by chemical analysis and by using Seyler's formula[14]. The result is shown in Table - 3.

The plotting of carbon against hydrogen on Seyler's chart, coal is found as perlignitous and Bituminous type. (Fig.-3).

The fuel ratio of the different coal seams of the study area were calculated and shown in the following Table (Table - 4).

Trace elements study :

The study of trace elements in coal and bearing sediments has gained importance in recent years. Although India has fairly large resources of coal, no systemic and comprehensive study has so far been carried out on their trace element content. Trace element study of Indian coals was made by Rishi[15], Mukherjee[16,17,18], Singh[19], Lahkar and Das[7].

Samples were systematically collected from the field exposures of coal-seams. The collected samples used for laboratory studies. Of these, 6 (six) representative samples (one from each seam) were selected for chemical analysis. In the present analysis Atomic Emission Spectrometer was used for the determination of trace elements in the coal samples after ashing at 500°C temperature and treated with acids. ($HF + HCl + HNO_3 + HClO_4$). The concentration of trace elements determined from the present samples are expressed in part per million (ppm) along with their crustal abundances,[20] are shown in Table-5 and frequency distributions are shown in

Fig-4.

Nicholls[21] classified the trace elements of coal into (i) associated with organic fraction (ii) associated with inorganic fraction and (iii) elements associated with both fractions. The present study reveals that the most elements are confined to organic fraction. According to him the high concentration of Co, Ni, Cu, V, Ba and Zr and low concentration of Ge in the coal samples indicate marine influences during the coal formation. Elements like Cu, Mo, V, Co etc. are accumulated frequently in reducing environment[22]. Moreover, Ge is significantly low in concentration as trace element. This indicates that the coal of the study area were deposited in paralic basin[22]. Thus from trace elements study, it can be interpreted that the coal of the Langrin coal field of Borsora area were deposited under marine influenced transitional environment.

Petrography:

In the present paper an attempt was made to carry out the petrographic characterization of coals from Borsora area. For this purpose, collected coalsamples were subjected to detailed petrographic examination after preparation of pellets (polished blocks) from the coal samples by standard procedure.

The petrographic studies were done under reflected light with oil immersion lens using polished blocks[9]. A point counter was also used for counting the volume percentage of the macerals.

Study of coal under microscope can show necessary industrial properties for appropriate characterization and utilization[23]. Mukherjee[24,25] have already used a pattern recognition based technique to classify the different macerals of coal.

The coal samples collected from the study area are megascopically found rich in vitrain and are devoid of any banded nature.

Microscopic characters :

The microscopic constituents that are present in the coal of the study area consist of all the three groups of macerals *viz*. vitrinite, liptinite and inertinite. Every maceral groups consist of the different sub-groups of macerals which exhibit their respective morphological features and reflectivity that are considered as the basis of identification. Moreover, the coals also consist of some organic matters with a few inorganic matters as fissure filling, in oxidation cracks, voids and patches. The macerals and the mineral matter found in the coal of the study area are represented as volume percentage and shown in Table-6.

Vitrinite group :

The coal samples of the study area consist mostly of the macerals of vitrinite group and it is found that it occurs about 79% and sometimes more. Other macerals are composed of exinite, inertinite with some mineral inclusions.

The most abundant maceral of the vitrinite group is collinite with minor amount of tellinite fragments have been observed as inclusions in collinite. The collinites are identified as structureless constituents and is found in common in all the coals of the study area. (Fig.-5) Mineral matters are also present as inclusions in vitrinite as cell fillings and sometimes even replaces the vitrinite as patches, framboides of pyrites. (Fig.-6).

Liptinite group :

This group of maceral includes sporinite, cutinite, resinite, alginite and liptodetrinites which were originated from spores, cutines, resins, waxes and fats and oil vegetal matters.

Sporinite is the most common constituent recorded in the liptinite group, which are distributed sparsely in the coal of the study area. Sporinites in these coals are spores and pollens with high relief and golden yellow colour (Fig.-7). Bands of cutinites are distinctly observed in the coals, it shows low relief and light yellow colour. Cutinite bands formed by layers of cuticles. Resinite and alginite are rarely observed in the coals. Some fragments of exinitic materials are found to occur as detritus in the coal samples and are counted as liptodetrinite. Sporinites in the present area are found to occur in two types namely microspores and megaspores and are associated with vitrinite showing dark grey and brownish colour in reflected light.

Inertinite group :

Inertinite consists of macerals fusinite, semifusinite, funginite, macrinite, micrinite and inertodetrinite. This group of maceral shows a higher reflectance compared to the other two groups. The colour of maceral ranges from grayish white to white and yellowish white. Inertinite group of maceral are found to occur in a very less amount in the coal of the area.

Fusinite originated due to oxidation and charring of plant tissues. They show the highest reflectance of all the macerals. Some dark rounded mineral inclusions are seen in fusinite. The transitional stage between fusinite and vitrinite is semi-fusinite. (Fig.-8).

Funginites are observed as oval to elliptical shaped bodies in the collinite mass having white, grey to grewish white colour. They appear brighter than the groundmass and both unicellular and multicellular bodies are found. They scattered almost everywhere in the vitrinite mass and are mostly observed as fungal spores and sclerotia (Fig.-9).

Some inertinite fragments are found to occur as detrial macerals in the vitrinite which are counted as inertodetrinite, micrinites and macrinite are rarelyobserved in the coals of the area.

Mineral inclusions (Matter) :

Mineral matters are associated with coal of the study area through various processes during different stages of its formation.

The mineral matters can be originated from the original plant materials or introduced by water or wind into the coal deposits during its formation or by descending or ascending solution in cracks and fissures in consolidated coals. They are controlled by the nature of the basin nature of the parent plant materials and geology and geomorphology of the hinterland. Depending upon the time of inclusion of the mineral matters they may be divided into syngenetic and epigenetic.

The epigenetic one are deposited in the cleats cracks and fissures of the coals after the consolidation of the coal. Whereas syngenetic mineral matter are intimately mixed with the coal and with the organic substances in coal.

The microscopic study of the coals of the area shows that they have a relatively larger proportion of mineral matters (Fig.-10). The most abundant mineral inclusions occur in the coal are pyrites. They are also found as large masses or band within the vitrinite. Moreover, some other organic mineral matters are observed scattered and large masses in vitrinite.

Classification:

The following classifications were made to classify the coal of the study are on the basis of Triaxial diagram, ASTM classification and ISI classification.

Triaxial diagram :

The values of proximate analysis (moisture content, volatile matter content and fixed carbon content) were plotted in a Triaxial diagram (Fig.-11), (modified after Ahmed[26]) and it has been observed that the coals of the Borsora area, Langrin coalfield fall within the range of semi to weakly caking coal and non caking coal.

American (ASTM) classification :

The classification of coal by American System (ASTM) is based on the volatile matter, calorific value and reflectivity of the coal. But in the present study only the volatile matters and calorific values are found out and are used in the present classification. The volatile matter and calorific value are plotted as shown in the Table-7. The coal types of the study area show that they belong the sub-bituminous and high volatile bituminous stage. (HVB).

Indian classification (Indian Standard Institute) :

The Standard coal classification system adopted by the Indian Standard Institute is mainly based on the yield of volatile matter and calorific vale (d.a.f) together with the moisture content and caking nature of the coal (Table-8). According to this classification, the Borsora coal ranges within the high volatile bituminous to sub-bituminous coal mostly under B_5 and B_6 stage.

Discussion and Interpretations

The present area of investigation Borsora is a part of the Langrin coalfield, located in the Indo-Bangladesh border of West

Khasi Hills District, Meghalaya. It formed part of the Southern slope of Shillong Plateau facing the plains of Bangladesh towards South. From the above study, it can be summarised as :

Megascopically the coal of Borsora area of Langrin coal fields is bright in nature and does not show any banding appearance. It shows conchoidal to uneven fractures. The dominant rock type of the coal is vitrain. Shales are found to occur above and below the coal seams.

From the proximate analysis it has been observed that the coals are having moderately high moisture content ranging from 3.23wt% to 5.30wt%, low to moderately high ash ranging from 2.92wt% to 10.23wt%, high volatile matter content from 38.83wt% to 42.42wt% and fixed carbon content ranging from 43.72wt% to 55.02wt% on air dried basis. The ultimate analyses of coal show high sulphur content ranging from 2.40wt% to 4.51wt%, hydrogen content from 5.17wt% to 5.51wt% and carbon content from 72.39wt% to 81.47wt%. Calorific values from 6721.98 Kcal/Kg to 7971.65 Kcal/Kg. Most of the coal samples are of low to moderately high ash content and moisture content, which indicates that the coal are having better utilization prospects. The percentage of ash content indicates that the plant debris has not been transported from a long distance. The coal contains high volatile matter, which indicates the absence of any igneous intrusion in the area during or after the formation of the coal matter. As volatile percentage of the coal decreases with the increase of temperature it can be said that the coals are thermally less metamorphosed i.e., tectonically less disturbed. The calorific values indicate medium grade of the coal.

It has been observed that the coal consist of a large amount of sulphur content upto 4.51wt%. The presence of high amount of sulphur indicates that the coals were deposited in the marine influenced transistional environment. Due to the presence of high sulphur, these coals cannot be used for metallurgical purpose.

The Trace element analysis shows that the coal composed of high concentration of Ba, V, Cr, Zr, Cu and little concentration of Ge, which indicates that the coal has been deposited under marine influenced environment[27]. Low concentration of Ge again indicates that they were deposited in Paralic basin. The presence of Mo, V and Co with Mn and Cu indicates that they were deposited under reducing environment[22].

Petrographically, coal shows that vitrinite is the dominant maceral followed by inertinite and liptinite group. Collinite is the most common and abundant maceral of the vitrinite group. A small amount of telinite is found in some samples. The exinite and inertinite group of macerals are very few in the coal. The coal consists of fusinite and semi-fusinite patches and sclerotinite bodies of inertinite group and sporinite, cutinite with rare alginite, resinite and

Table 1. The results of proximate analysis of the samples (Air dried basis)

Locality	Quarry No.	Sample No.	Seam	Moisture Content (%)	Volatile Matter Content (%)	Ash Content (%)	Fixed Carbon Content (%)
West Bank of Borsora Nala	1	1	Upper	3.51	39.24	3.18	54.07
		2	Middle	5.14	40.15	6.15	48.56
		3	Bottom	4.23	41.33	8.91	45.44
	2	4	Upper	3.23	38.83	2.92	55.02
		5	Middle	4.91	39.62	6.31	49.16
East Bank of Borsora Nala	3	6	Upper	5.30	41.54	4.18	48.98
		7	Middle	4.81	40.35	10.23	44.98
		8	Bottom	4.50	42.42	9.36	43.72
	4	9	4th Seam (upper)	4.31	41.75	8.56	45.38
		10	3rd Seam (middle)	4.61	40.55	9.84	45.00
		11	2nd Seam (bottom)	5.20	41.83	4.59	48.38

Table 2. The calorific values of the coal samples

Seam	Sample No.	Fixed Carbon D.A.F %	Volatile Matter D.A.F %	α	Calorific Values Kcals/kg
Upper	1	57.94	42.05	75.5	7925.85
	4	58.62	41.37	76.5	7971.65
Middle	2	54.74	45.26	63.5	7362.69
	5	55.37	44.62	65.5	7462.95
Bottom	3	52.36	47.63	57.5	7032.25
	6	54.11	45.89	62.5	7305.15
Upper	11	53.63	46.37	61.0	7226.23
	7	52.50	47.49	59.0	7106.91
Middle	10	52.60	47.39	60.0	7156.60
	8	50.75	49.24	52.0	6721.98
Bottom	9	52.08	47.91	56.0	6953.52

Table 3. The results of ultimate analysis of the coal samples

Seam	Sample No.	Total Sulphur	Hydrogen %	Carbon %
Upper Seam	1	2.51	5.51	81.05
	4	2.40	5.49	81.47
Middle Seam	2	3.42	5.34	77.03
	5	3.22	5.36	77.76
Bottom Seam	3	4.61	5.27	74.57
Upper Seam	6	3.82	5.34	76.56
	11	3.60	5.32	75.99
Middle Seam	7	4.51	5.32	75.04
	10	3.82	5.34	75.36
Bottom Seam	8	4.30	5.17	72.39
	9	4.10	5.24	74.05

Table 4. The fuel ratio of the coal samples

Seam	Sample No.	Fixed Carbon Content (wt%)	Volatile Matter Content (wt%)	Fuel Ration C/V
Upper Seam	1	54.07	39.24	1.37
	4	55.02	38.83	1.41
Middle Seam	2	48.56	40.15	1.20
	5	49.16	39.62	1.24
Bottom Seam	3	45.44	41.33	1.09
Upper Seam	6	48.98	41.54	1.17
	11	48.38	41.83	1.15
Middle Seam	7	44.61	40.35	1.10
	10	45.00	40.55	1.11
Bottom Seam	8	43.72	42.42	1.03
	9	45.38	41.75	1.08

Table 5. The Trace element in some coal samples

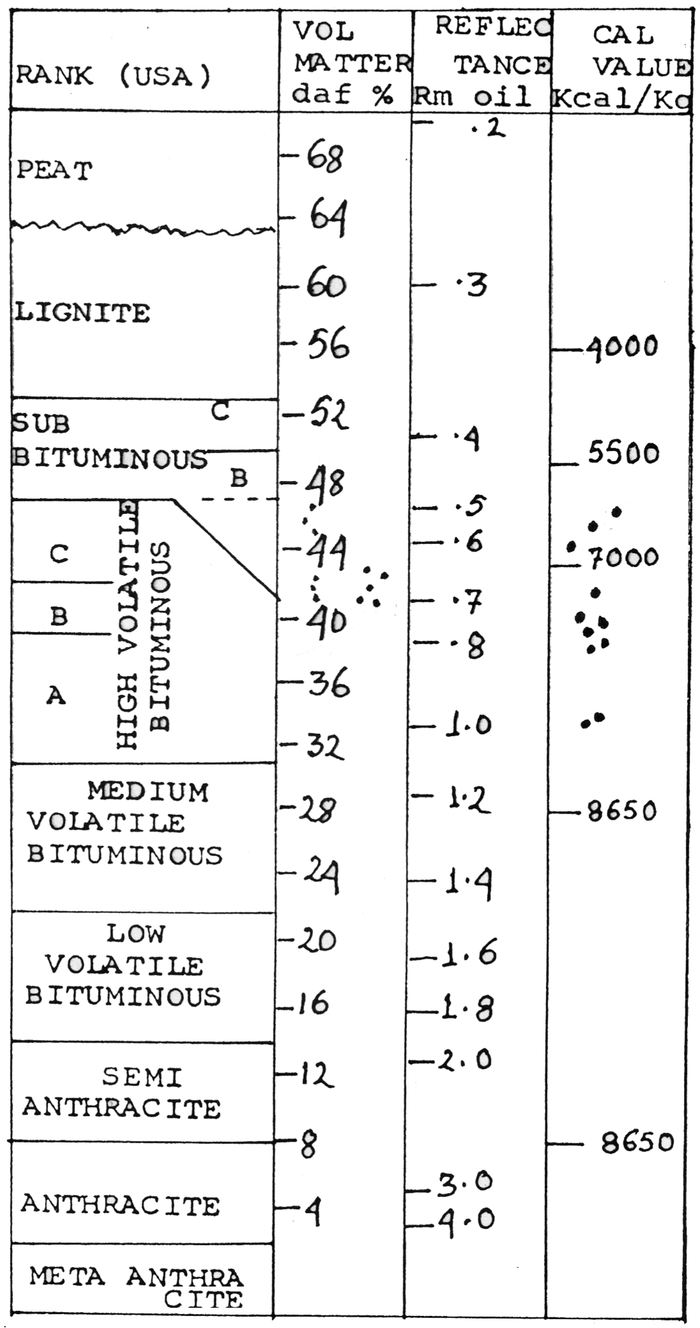
Sample No	ASH %	Mo ppm	V ppm	Cr ppm	Sn ppm	Ag ppm	Ge ppm	Ga ppm	Zn ppm	Zr ppm	Mn ppm	W ppm	Ba ppm	S ppm	Co ppm	Ni ppm	Pb ppm	Cu ppm	Y ppm	Yb ppm	In ppm
S-1	2.3	20	140	150	20	1.1	1-10	30	< 20	250	1000	< 50	100	6	80	100	1-10	160	60	10	1-10
S-2	5.83	< 10	250	10	15	1.1	1-10	1-10	1-20	350	250	< 50	30	4	60	1-10	1-10	40	80	5	1-10
S-3	8.68	10	275	100	25	1.0	1-10	200	1-20	400	300	< 50	150	1	70	50	1-10	100	100	10	1-10
S-4	2.75	15	100	80	20	1.1	1-10	15	1-20	180	1000	1-1	100	6	80	40	150	130	160	30	1-10
S-5	9.40	10	250	20	25	1.1	1-10	20	1-20	100	75	1-50	40	< 1	40	1-10	1-10	75	120	15	1-10
S-6	8.22	10	300	150	30	1.0	1-10	175	1-20	300	350	1-50	300	4	60	60	60	200	130	25	1-10

Table 6. Showing volume percentage of the macerals of the coal of the Borsora area (Langrin coal field) (Mineral matter free basis)

	Vitrinite Group				Liptinite Group						Inertinite Group							Mineral Matter		
Pellet No.	Telinite	Collinite	Vitrodetrinite	Total	Sporinite	Cutinite	Resinite	Alginite	Liptodetrinite	Total	Fusinite	Semifusinite	Micrinite	Macrinite	Sclerotinite	Inertodetrinite	Total	Pyrite	Organic Matter	Total
1	[illegible]	81.5	[illegible]	81.5	3.1	1.05	[illegible]	[illegible]	[illegible]	4.2	[illegible]	1.4	[illegible]	[illegible]	3.8	[illegible]	5.2	3.8	[illegible]	9.05
2	1.5	78.2	[illegible]	79.7	1.91	-	-	-	[illegible]	1.91	4.6	3.4	-	-	1.91	[illegible]	9.9	3.4	5.0	8.4
3	1.5	77.2	-	78.7	2.9	0.7	-	-	-	3.6	3.6	4.2	-	-	2.9	-	10.7	3.2	3.9	7.1
4	-	80.5	-	80.5	1.7	5.1	-	-	-	6.8	-	-	-	-	1.7	-	1.7	4.23	6.7	11.0
5	1.2	78.2	-	79.4	2.7	-	-	-	-	2.7	4.6	2.3	-	-	3.1	-	10.0	3.1	5.0	8.1

Table-7

American (ASTM) classification on the basis of different rank parameters (After Stach et. al, 1982)



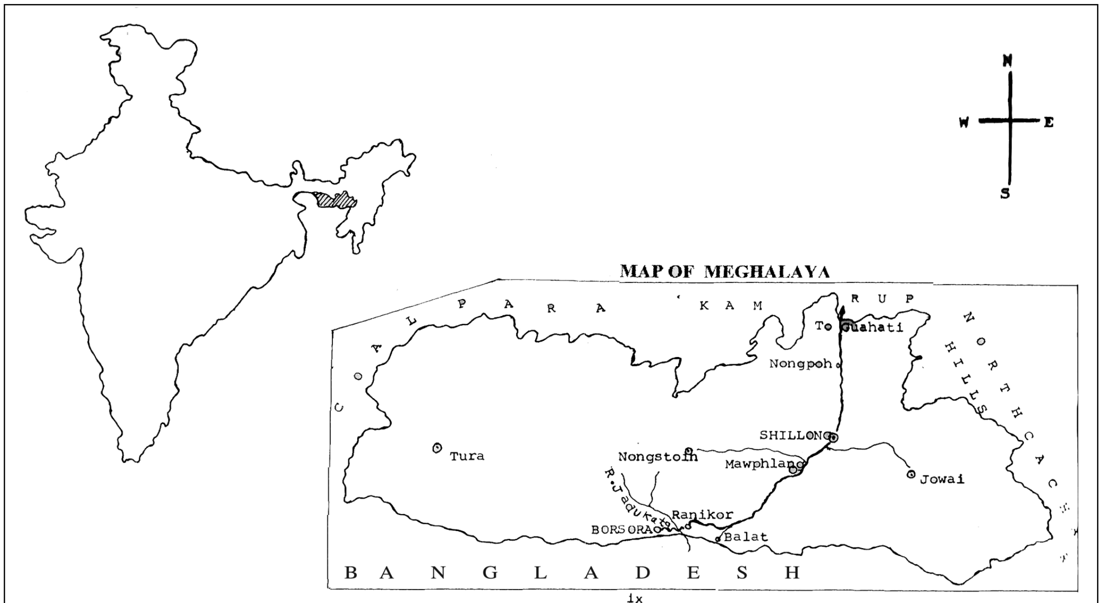


Fig. 1(a) : Location Map

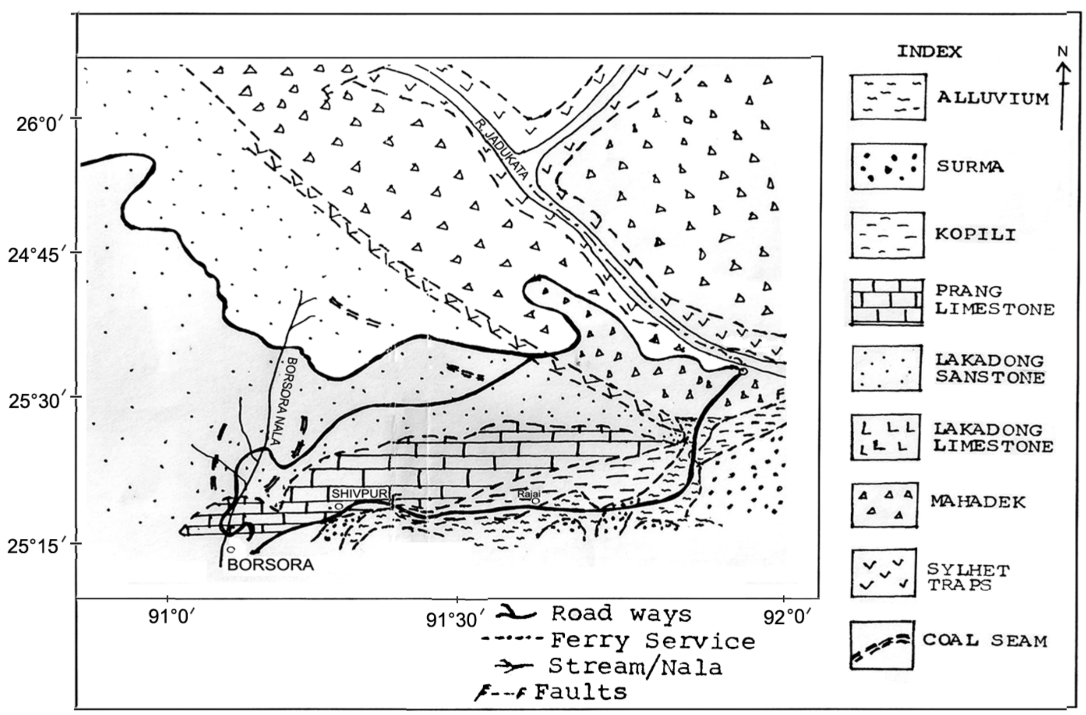


Fig. 1(b) : GEOLOGICAL MAP OF THE AREA AROUND BORSORA (Modified after, G.S.I., 1974)

Fig. 2 : Photograph showing the different coal seams in the Borsora area.

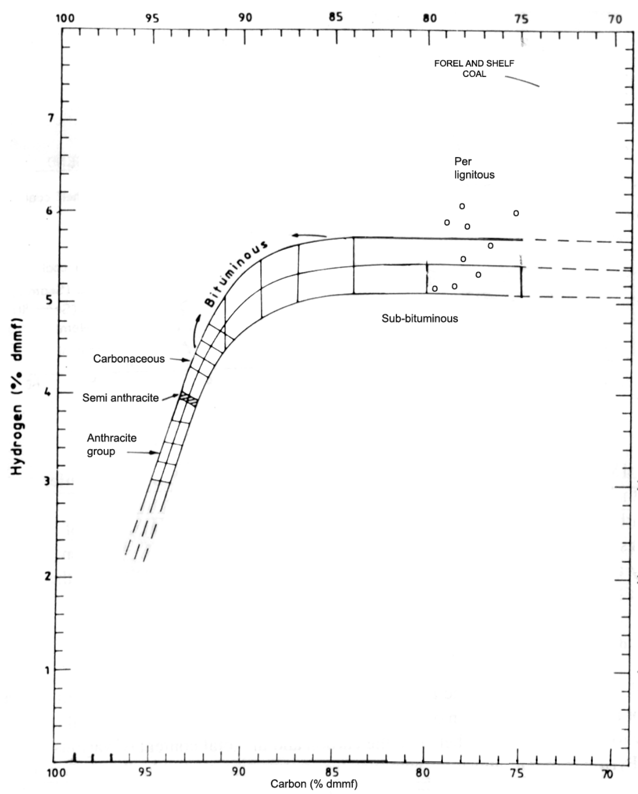


Fig.3 : Position of coal of the study area on Seylers Chart

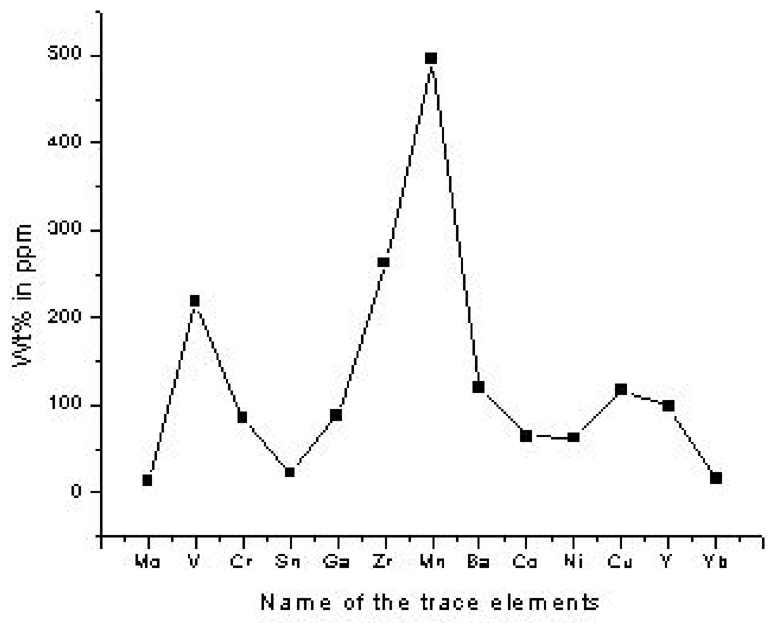


Fig.4. Distribution trace element

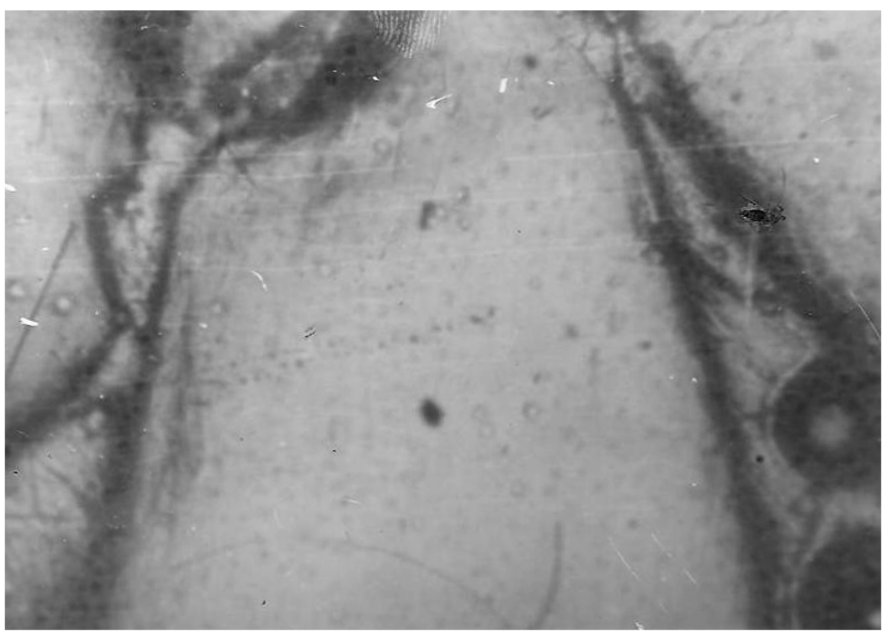


Fig. 5 : Photomicrograph showing Collinite (Vitrinite). (10x)

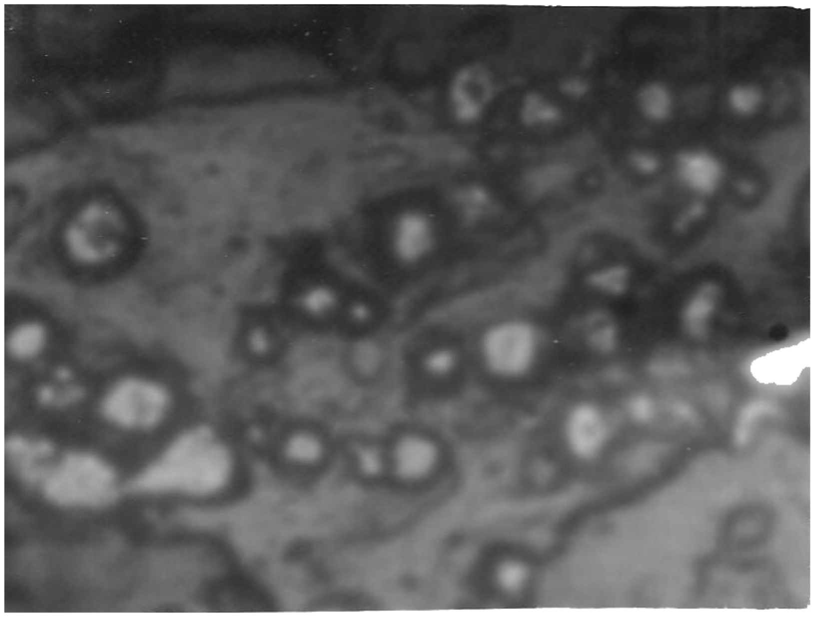


Fig. 6 : Photograph showing framboidal pyrites (10x)

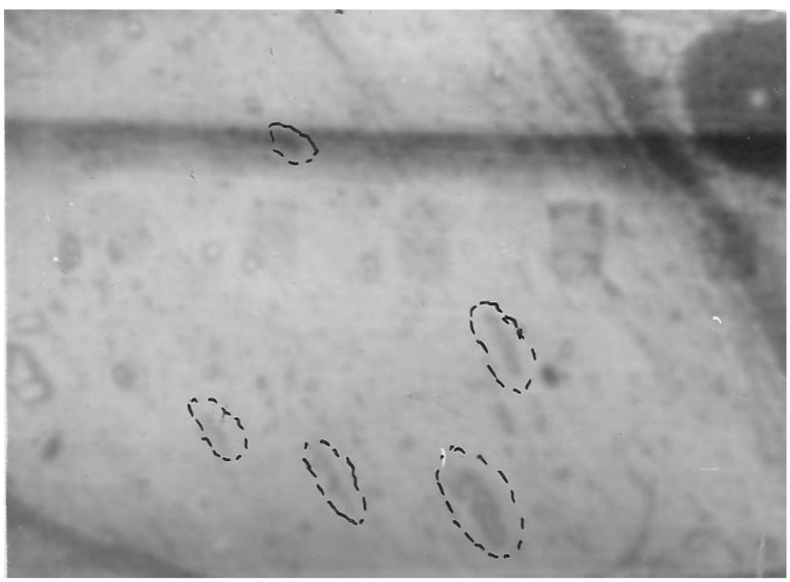


Fig. 7 : Photomicrograph showing sporinites in Vitrinite (10x)

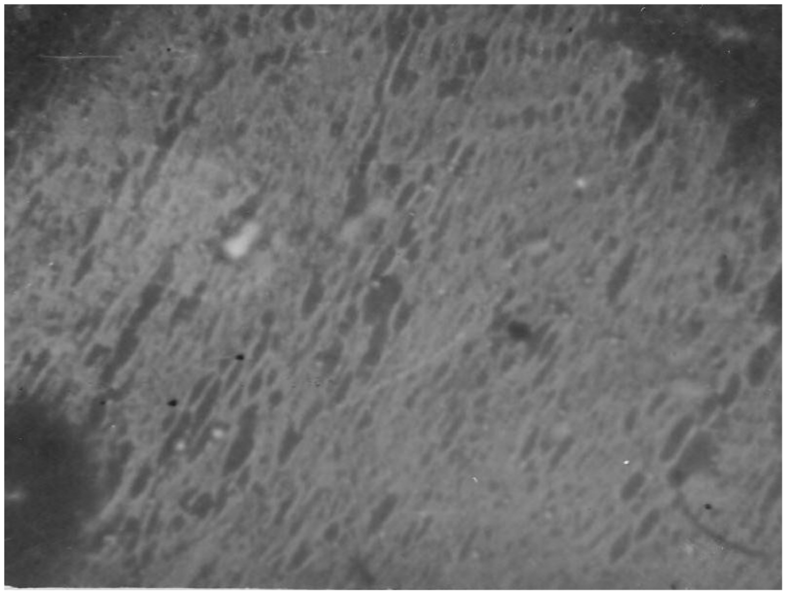


Fig.-8 : Photomicrograph showing fusinite. (10x)

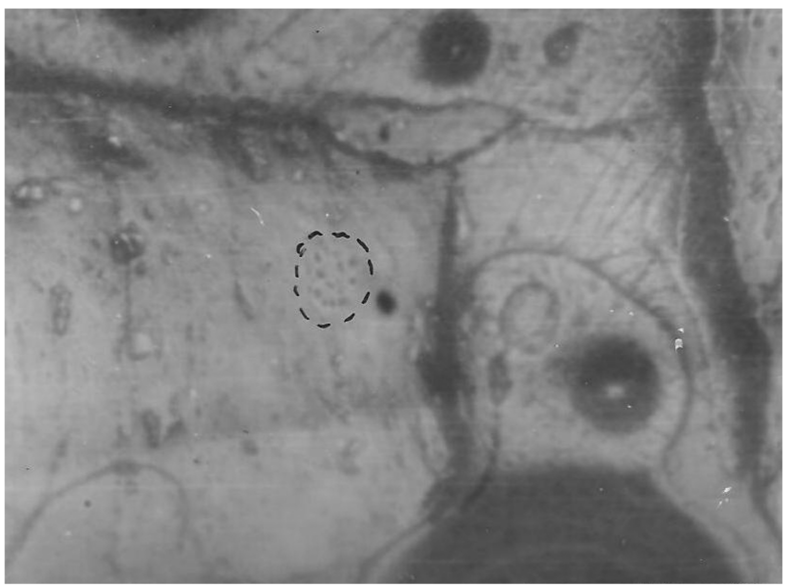


Fig. 9 : Photomicrograph showing sclerotinite in vitrinite. (10x)

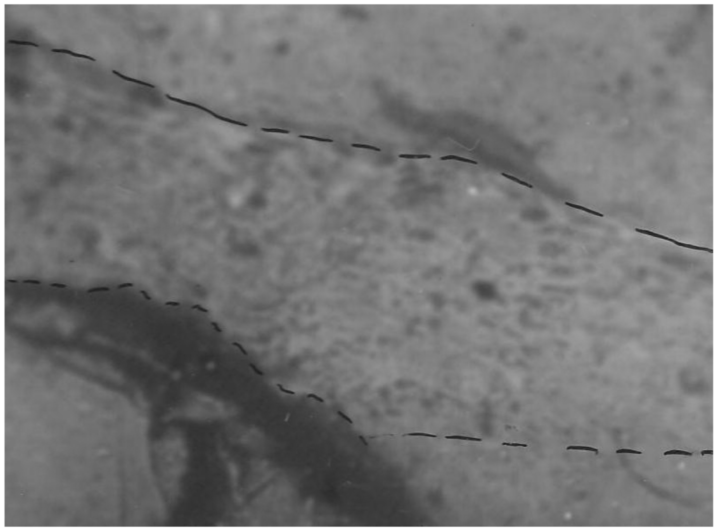


Fig. 10 : Photomicrograph showing fusinite band with mineral matters. (10x)

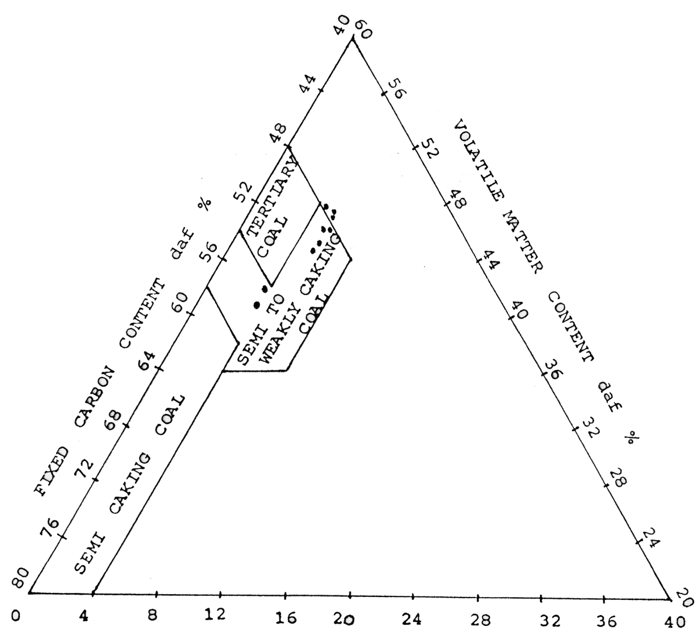


Fig. 11 : Proximate analysis of the coal samples presented in Triaxial Diagram
(Modified after Ahmed, 1971)

liptodetrinite of liptinite group. Leaf cutine and type of miospore observed in the coal suggests that the angiospermous vegetation were laid in near shore area under warm and humid climate with high rainfall. Under such environmental condition, the humification process was advanced and resulted in the dominance of vitrinite in major parts of the coal.

This type of vitrinite rich coals are likely to have formed in transitional (mostly lagoonal) environment[28]. The presence of collinite in thecoal indicates reducing condition of deposition with complete breakdown of organic matter. Pure vitrinite can only be formed under anaerobic conditions in reducing environment. Low percentage of liptinite with high volatile matter content is an indication of low maturity of the coal. Again presence of fusinite and semifusinite in some samples indicates that the coal were underwent some alteration and fluctuating ground water level. Replacement of vitrinite by pyrite indicates that the mineral inclusions are of syngenetic origin. Presence of more pyrite and framboidal pyrite in vitrinite indicates a marine influenced brackish water environment of deposition[29].

From ASTM classification of the coal, it is seen that the coals belong to the high volatile bituminous to sub-bituminous coals. From triangular plotation it has been observed that the coals are of semicaking to weakly caking and non caking coals. The ISI classification also shows that the coals, belong to the high volatile 'B' stage. Though the coals show caking property, it cannot be used for metallurgical purpose due to the high sulphur content, but can be suggested for blending and for using thermal power production and hydrogenation.

Conclusions

Finally it can be concluded from the study of the coal of Borsora area that -

1. The coal were deposited in a marine influenced transitional environment in a reducing condition.
2. They are non-caking to very weakly caking coals.
3. The rank of coals are ranging from sub-bituminous to high volatile bituminous type.
4. Due to the presence of high sulphur, they cannot be used as metallurgical coke.
5. On Seyler's chart, coal is Per-lignitous and Bituminous type.
6. From the study of trace elements, it is found that coal was formed in reducing environment under marine influence.
7. Petrographically, vitrinite is the most dominant part of the coal.
8. The coals are suitable for hydrogenation and thermal power production.

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