GEOCHEMICAL CHARACTERISTICSOFTERTIARY COALS OF COLLIERIES OF MAKUM COALFIELD: IMPLICATION TO DEPOSITIONAL ENVIRONMENT

Kakoli Gogoi
School of Sciences, Indira Gandhi National Open University, New Delhi

Abstract: The Makum Coal Field, largest of all the coalfields of North Eastern Regionis important from the point of view of the Tertiary coal resources of India. There are five regionally persistent coal seams and are confined to the basal 200m section of the Tikak Parbat Formation. Within this area Namdang, Boragolai, Ledo, Tirap, Tikak and Tipong collieries are situated. The coal seams are thick (max. 60ft) and are bright and non-banding in nature. It is observed that moisture content is highest in Tikak colliery (2.63%) and the average moisture and ash content of the coals in Tipong, Ledo, Boragolai, Tirap, Tikak and Namdang collieries are very low which indicate for a better utilization of the coals. The volatile matter content of the coals is very high in all the collieries which give an indication of absence of any igneous intrusion in the area. Namdang colliery contain high ash (7.28%), mineral matter (8.01%) but low in Carbon (68.80%). It is observed that the organic sulphur content is highest in Namdang (5.96%) and lowest in Boragolai (3.52%). Sulphur content of the Makum coal varies from 2.47 to 4.06% and acts as a catalyst in hydrogenation to produce syncrude and 80-90% of the coal can be liquefied and indicates that the coals were deposited under marine or transitional environment. The relatively low carbon/hydrogen but high oxygen/carbon ratios of the coals in all the collieries also make it suitable for hydrogenation to produce synthetic petroleum. The high contents of the elements like Barium, Copper, Nickel, Chromium etc also indicates marine influence in the depositional basin as these elements tends to be more abundant in marine water. The presence of Vanadium and Copper with Manganese and Cobalt indicates that they were deposited under reducing environment.

Keywords: **Collieries, Proximate and Ultimate analysis, 60ft seam, Calorific Value, Makum Coalfield.**

Introduction:

Coal is currently a major energy source worldwide, especially among many developing countries, and will continue to be so for many years (Miller,2005).Coal is a unique rock type in the geological column; it has a wide range of chemical and physical properties, and has been studied over a long period of time (Thomas, 2002). Chemically coal consists of a complex mixture of organic compounds along with small amounts of inorganic mineral matter and moisture(Sharma et.al. 1983). The various controlling factors of formation has made its complex nature. It is resulted from a series of geochemical reactions for a very long period in the geological history over the accumulated plant remains along with the sediments in the geosynclinal basin. Chemical analysis of coal consists of proximate analysis and ultimate analysis (Sharma et.al. 1983) and probably these methods are the earliest methods of analyzing coal chemically.Chemically, the members of the series are predominantly composed of carbon, oxygen and hydrogen, together with lesser amounts of sulphur, nitrogen and ash-forming constituents (Singh, 1997).

The Makum Coalfield lies between latitudes 27°16' to 27°18' N and longitudes 95°43' to 95°55' E (DGM, 1982) towards the northeastern fringe of Tinsukia District and adjacent to Margherita town in Assam. The coalfield shows the best development of Tertiary coals in Upper Assam. Within this area Tipong (27º17'41.2″N : 95º51'29.2″E), Tirap (27º17'55.2″N : 95º46'33.2″E), Ledo (27º16'54″N : 95º45'27″E), Tikak (27º17'30.6″N : 95º43'47.2″E), Boragolai (27º16'33.7″N : 95º42'49.4″E) and Namdang (27º15'9.2″N : 95º41'41.9″E)collieries are situated.

Tectonically, the coalfield areas of Upper Assam and its adjoining region occurs in the Belt of Schuppen(Mathur and Evans, 1964). The Belt of Schuppen with eight complex thrust faults are arranged imbricately along the Naga Hills and moved North West relative to the foreland ridges (Mathur and Evans, 1964). The Oligocene coal deposits on the northern flank of the Naga-Patkai range occurs in a belt that is >300km long broadly trending ENE-WSW. They extend over the states of Nagaland, Assam and Arunachal Pradesh. The structuralset up of Makum coalfield is represented by a EW striking syncline about 30km long and 2 to 4 km wide located between two main thrust- Margherita thrust on the north and Halflong-Disang thrust towards south (Fig. 1). The tertiary deposits are highly folded and faulted (Mathur and Evans, 1964; Raju, 1968; Ranga Rao, 1983), consequently the coal become friable and powdery due to geo-tectonic movements related to Himalayan orogeny.

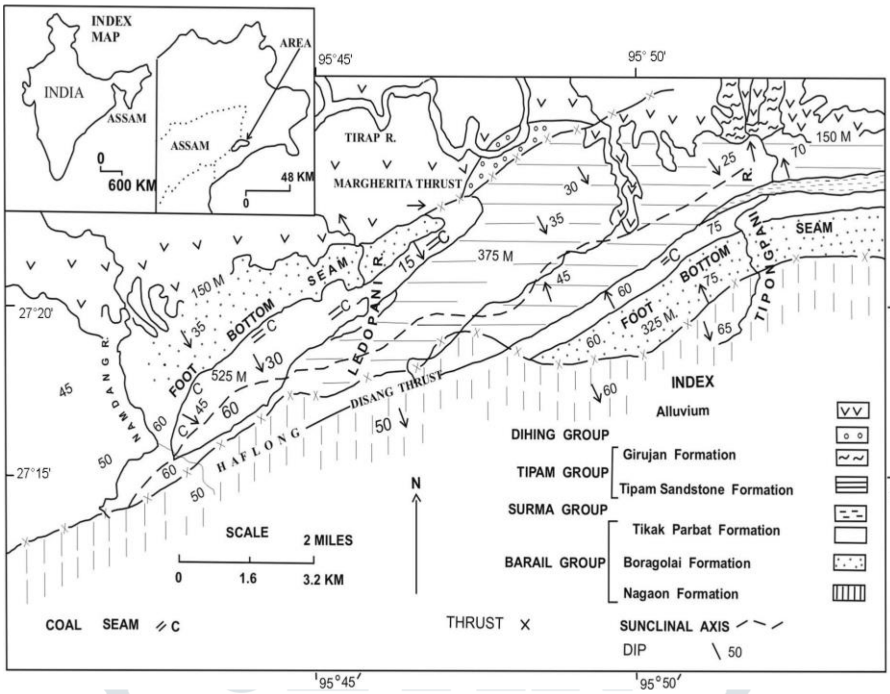

Fig.1 Geological map of the Makum Coalfield (after D.N.D.Goswami, 1987).

Megascopically coals are jet black in colour with vitreous lustre, devoid of any perceptible lithotype banding and are entirely made up of vitrain. Tiny pyrite specks are frequent in the coal. Pyrite concretions and encrustations are also common. From the Namdang colliery in the west to the Tipong colliery in the east, there are five regionally persistent coal seams.The seams are confined to the basal 200m section of the Tikak Parbat Formation (GSI,2009).The coal seams are thick (max. 60ft) and are bright and non-banding in nature. The coals are high volatile bituminous B/C, has excellent coking properties, and is of great importance as a blending coal to improve the coking properties of the lower-quality Gondwanan coals (Ahmed, 1996).The generalised sequence of the coal bearing deposits are as follows (Table 1):

Table 1: Generalised sequence of coal bearing deposits (GSI, 2009) of Makum Coalfield.

	Coal Seam	Thickness (in m)
5	8ft seam	2.4
	Parting	30 to 40
4	5ft seam	1.2 to 1.8
	Parting	3 to 18
3	20ft seam	5 to 7
	Parting	38 to 68
2	new seam	1.5 to 2.6
	Parting	5 to 20
1	60ft seam	15 to 33

60ft seam is separated into two, rarely three sections with the development of one or two partings of widely variable thicknesses. The partings mostly consist of clay, mudstone, carbonaceous shale or dark grey shale. Clay or carbonaceous shale occurs below (floor) the coal seams whereas; roof is usually represented by carbonaceous and dark grey shales occasionally with sandy shale. Both 60ft and 20ft seams are nearly of uniform thickness between Namdang and Ledo-Tirap collieries. In this paper an attempt has been made to study the chemical properties and concentration of trace elements inTipong,Ledo,Boragolai, Tirap, Tikak, and Namdangand collieries of the Makum Coalfield in detail.

Material and Methods:

Forty two channel and pillar samples were collected both from open cast and under ground mines namely Tipong, Tirap, Boragolai, Tikak, Ledo and Namdang.The collected channel samples are air dried to remove the free moisture. After drying, the samples are taken for coning and quartering and the portion selected are crushed and allowed to pass through 72 mesh B.S test sieves (211micron) and finally stored in airtight glass bottles for chemical analysis. The proximate analysisiscarried out by adoptingthe procedures as recommended in Indian Standard Methods of Test for Coal and Cokes [IS: 1350 (Part I)-1969].The calorific value is calculated with the help of the proximate analysis data using Goutal's formula. The ultimate analysisiscarried out by adoptingthe procedures as recommended in Indian Standard Methods of Test for Coal and Cokes [IS: 1350 (Part IV/Sec I)-1974]. The amount of mineral matter in coal is calculated by using the following formula:Mineral matter = 1.08 x ash + 0.55 x pyritic sulphur.

The trace element contents of some selected coal samples are measured by using the Perkins Elmer Atomic Absorption Spectrometer (model – 3110). For this purpose 2mg of each coal samples are burnt at 700ºC for an hour to obtain ash. The ash of the samples are digested in a mixture of 5ml HF, 4ml HNO_3 and 0.5ml $HClO_4$ in Teflon bomb for one hour at 140ºC. After that the mixture is mixed with H_3BO_4 solution (5 ml H_3BO_4 in 40 ml of water), filtered and the volume of the solution is made upto 100 ml. These solutions are used for elemental analysis.Regression analysis is a statistical tool that is used to investigate the relationships between trace elements and ash content of coal.

Result and Discussion:

The results of proximate and ultimate composition in air dried basis (in weight percent) from Tipong, Ledo, Boragolai, Tirap, Tikak, and Namdangand collieries of Makum Coalfield (Table 2). Concentrations of trace elements of these collieries of Makum Coalfield are presented in Table 3 and are plotted against ash contents of coals of Makum Coalfield in Figure 2.

Table 2: Average proximate and elemental composition in air dried basis (in weight percent) from different collieries of Makum Coalfield.

COLLIERY	M %	V M %	ASH %	FC %	CV (BTh.U/lb)	MM %	C %	H %	N %	O %	S org%
TIPONG	2.4	40.3	6.8	50.5	13271.80	7.47	70.03	4.34	1.32	11.75	2.90
LEDO	1.72	35.13	6.80	56.24	12396.67	7.48	71.27	4.43	1.30	10.24	3.58
BORAGOLAI	2.06	34.04	6.87	57.03	12535.31	7.26	72.23	4.37	1.28	10.50	2.47
TIRAP	1.88	39.23	6.64	52.25	12496.36	7.30	70.24	4.36	1.40	12.02	3.03
TIKAK	2.63	40.84	5.37	51.15	12571.49	5.82	71.38	4.39	1.16	10.99	3.86
NAMDANG	1.85	41.08	7.28	49.81	13009.36	8.01	68.80	4.29	1.20	12.13	4.06

[Moisture (M), Volatile matter (VM), Fixed Carbon (FC), Calorific Value (CV), Mineral Matter (MM), Carbon (C), Hydrogen (H), Nitrogen (N), Oxygen (O) and Organic Sulphur (S org)].

Table 3: Trace elements content of the Makum Coalfield in ppm of the total coal.

Sl. no	Ash (wt. %)	Trace elements (ppm)														
		V	Cr	Co	Ni	Cu	Zn	Ga	Sr	Zr	Ba	La	Pb	As	B	Mn
5	8.16	3.3	12.15	0.98	35.4	5.97	87.6	0.002	144.2	0.001	101.5	0.36	204.6	0.04	0.02	15.27
6	7.26	3.5	8.4	0.95	25.2	5.51	85.5	0.002	140.1	0.001	91.8	0.36	195	0.04	0.01	15.27
7	8.1	3.3	10.3	0.83	30.1	5.22	81.01	0.002	136	0.002	97.6	0.3	204.6	0.03	0.02	10.2
9	6.35	3.5	11.5	0.81	37.5	4.81	77.1	0.002	123.5	0.002	98.3	0.21	187.1	0.03	0.01	13.2
20	7.44	3.85	7.28	0.32	14.6	6.49	25.54	0.001	63.84	0.001	79.15	0.54	39.59	0.24	0.03	63.81
21	5.08	5.2	7	0.32	12.5	9.86	25	0.001	95	0.001	45.5	0.35	25	0.24	0.02	55
22	8.06	4.33	7.28	0.22	10	9.9	25.54	0.002	95.1	na	55.1	0.54	30	0.11	0.03	40
23	10.01	3.8	6.99	0.2	14.6	10	20	0.001	63.84	na	79.15	0.36	39.59	0.23	0.02	63.81
26	6.01	9.18	8.63	0.39	13.2	16.5	46.89	0.003	176.5	0.001	117.2	0.48	273.4	0.17	0.11	38.14
27	7.01	9	9	0.35	13.2	11.7	40	0.002	150	0.001	115.9	0.35	270.1	0.15	0.06	35
29	5.03	9	8.63	0.39	10	15.5	46.89	0.003	170	0.001	101	0.54	250	0.15	0.05	30.1
33	7.05	9.18	8.6	0.33	10	30.4	40	0.003	155	na	115.5	0.36	245.5	0.12	0.06	35.3
35	8.07	7	8.63	0.3	9.1	15.5	45	0.003	176	0.002	115	0.48	270	0.15	0.15	30.5
38	5.06	9.18	8.5	0.39	13.2	16.5	40	0.003	175	0.001	115	0.44	250.1	0.17	0.11	38
42	8.08	41.36	14.45	0.39	13.53	7.03	35.68	0.002	206.5	0.001	66.32	0.34	198.9	0.04	0.03	33.93
43	5.6	40	14	0.33	12.4	7.5	28.9	0.002	197.9	0.001	55.9	0.39	175.2	0.03	0.05	31.6
47	4.87	25.5	12.5	0.25	12.9	6.9	30.9	0.003	200.5	0.001	58.9	0.33	155.9	0.03	0.05	34.5
48	4.8	20	15.1	0.35	13	7.1	35.1	0.001	193	0.001	65.5	0.29	190	0.04	0.11	33.9
Average		11.68	9.94	0.45	16.69	10.69	45.37	0.002	147.9	0.001	87.46	0.39	178.0	0.11	0.05	34.31
Maximum		41.36	15.1	0.98	37.5	30.4	87.6	0.003	206.5	0.002	117.2	0.54	273.4	0.24	0.15	63.81
Minimum		3.3	6.99	0.2	9.1	4.81	20	0.001	63.84	0.001	45.5	0.35	25	0.03	0.01	10.2

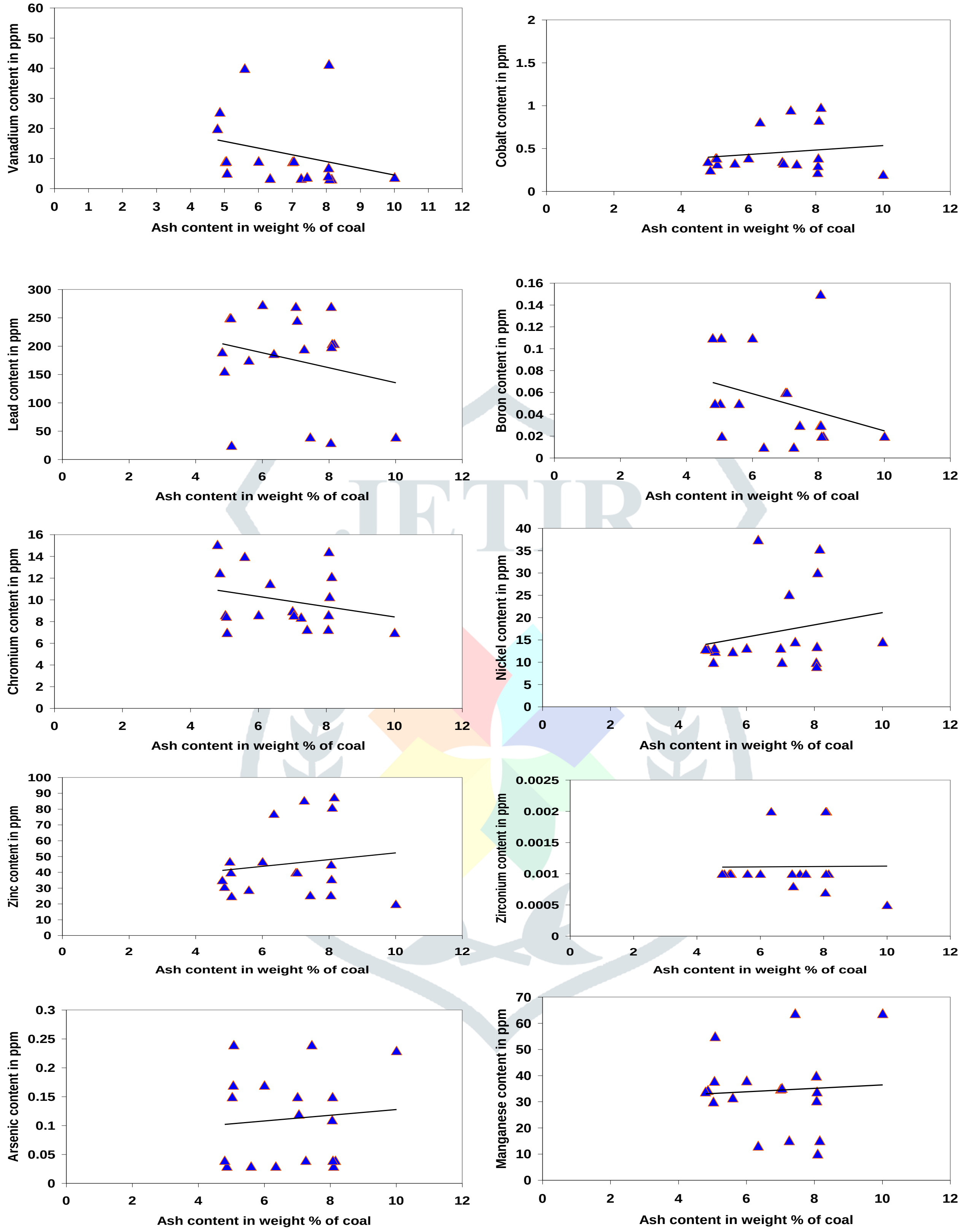

Fig.2: Trace elements content against ash contents of coals of Makum Coalfield.

Proximate analysis shows that in 60ft seam the average moisture contentin air dried basis is highest in Tikak (2.63%) and it is lowest in Ledo (1.72%); ash content is high in Namdang (7.28%) and it is low in Tikak (5.37%); volatile matter is lowest in Boragolai (32.04 %) and it is highest in Namdang (41.08 %); fixed carbon is high in Boragolai (57.03 %) and is low in Namdang (49.81 %).Elemental composition shows that in 60ft seamthe average carbon content is highest in Boragolai (72.23 %) and lowest in Namdang (68.80 %); hydrogen content is highest in Ledo (4.43 %) and lowest in Namdang (4.29%); nitrogen content is high in Tirap (1.40%) and low in both Namdang (1.20%) and Boragolai(1.28%); oxygen is highest in Namdang (12.13%) and lowest in Ledo (10.24%).The average organic sulphur in air dried basis is 2.90% in Tipong, 3.58% in Ledo, in Boragolai, 3.03% in Tirap, 3.86% in Tikak and in Namdang (Table4) .The average forms of sulphur content of the coals of different collieries of Makum Coalfield is presented as stacked bar diagram in air dried basis (Fig.4).Organic sulphur content is high in Namdang(4.06%) and low in Boragolai (2.47%).The calorific value of Makum Coalfield is calculated from the proximate analyses data using the Goutal's formula. The calorific value in air dried basis is 7373.22Cal/gm (13271.80BTh.U/lb) in Tipong, 6887.04Cal/gm (12396.67BTh.U/lb) in Ledo, 6964.06Cal/gm (12535.31BTh.U/lb) in Boragolai, 6942.42Cal/gm (12496.36Bth.U/lb) in Tirap, 6984.16Cal/gm (12571.49BTh.U/lb) and 7227.42 Cal/gm (13009.36BTh.U/lb) in Namdang (Table.3).

Concentration of the trace elements were measured in parts per million (ppm) of the total coal. The concentration ranges of the trace elements of the coals of Makum Coalfield are vanadium from 3.3 to 41.36 ppm, cobalt from 0.2 to 0.98 ppm, copper from 4.81 to 30.4 ppm, gallium from 0.001 to 0.003 ppm, barium from 45.5 to 117.2 ppm, lead from 25 to 273.4ppm, boron from 0.01 to 0.15ppm, chromium from 6.99 to 15.1 ppm, nickel from 9.1 to 37.5ppm, zinc from 20.0 to 87.6 ppm, strontium from 63.84 to 206.5ppm, zirconium from 0.001 to 0.002ppm, lanthanum from 0.35 to 0.54ppm, manganese from 10.2 to 63.81ppm, tin from 0.1 to 1.5ppm, germanium from 0.02 to 1.5ppm, selenium from 0.02 to 0.25ppm and antimony from 0.22 to 1.19ppm.

Conclusion:

The average moisture and ash content of the coals in Tipong, Ledo, Boragolai, Tirap, Tikak and Namdang collieries are very low which indicate for a better utilization of the coals. Low moisture content of the coal is advantageous for coking coal. But their low moisture content and relatively high calorific value7373.22Cal/gm (13271.80BTh.U/lb) in Tipong are indicative of high maturity. Moreover, this high calorific value and volatile matter with low ash content (5.37%-7.28%) suggest that the coal can be used in hydrogenation for production of a considerably wide range of petroleum products (Mukherjee and Samuel, 1987).But the volatile matter content of the coals is very high in all the collieries which give an indication of absence of any igneous intrusion in the area. Volatile matter always decreases with increase of thermal metamorphism, hence it is inferred that the coals are thermally less metamorphosed. The rank of the coal of the Makum Coalfield is low as it contains low fixed carbon in all the collieries. But the low moisture content is an indicative of high maturity. Low to medium ash content also indicates a short distance transportation of the plant debris and a high grade coal. It also suggests that the energy of the transportation medium i.e. running water was very low to carry inorganic materials along with vegetal debris.The relatively low carbon/hydrogen but high oxygen/carbon ratios of the coals in all the collieries also make it suitable for hydrogenation to produce synthetic petroleum.The ultimate analysis shows that the sulphur content of the Makum coal varies from 2.47 to 4.06% and acts as a catalyst in hydrogenation to produce syncrude and 80-90% of the coal can be liquefied (Mishra and Ghosh, 1996)and indicates that the coals were deposited under marine or transitional environment. Moreover high percentage of organic sulphur in total sulphur in all the collieries stands as an uncrossable barrier in desulphurization of the coal. Again, geological information (Baruah et.al., 1987; Handique et.al., 1992) shows that the Barail sediments were deposited in fluviatile condition that hosts the coal seams containing high amount of sulphur which indicates that there may be some marine influence during the deposition of the coal seams.The high contents of the elements like Barium, Copper, Nickel, Chromium etc also indicates marine influence in the depositional basin as these elements tends to be more abundant in marine water (Nichols, 1968).The presence of Vanadium and Copper with Manganese and Cobalt indicates that they were deposited under reducing environment (Vladimir Bouska 1981). Trace element studies indicate that the coals were deposited in a transitional to marine environment.

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