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Depositional Environments and Controls on Distribution of Aromatic Sulfur Compounds in the Oils of Tura-Sylhet in Khoraghat and Borholla Area of Assam and Assam Arakan Basin

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Summary

The Paleocene to Miocene reservoirs constitutes one of the most hydrocarbon producing horizons in the upper Assam basin of north east India. The oils from different formations have been characterized by geochemical technique and established genetic modeling of depositional environments, maturity and accumulation of hydrocarbon in the Khoraghat and Borholla area.

The genetic correlation study was assessed using compositional analysis, aromatic and saturated hydrocarbons distribution in oils. On the basis of aromatic and saturated biomarkers the oils have been identified into two groups. The oils from Bokabail, Barail and Kopili formations are comprise in group I and these oils are characterized by medium to high pristane to phytane ratio, low dibenzothiophene to phenanthrene ratio, low to medium oleanane index and low to medium C_{29} to C_{30} hopane ratios. These oils were derived from high clastic source facies deposited in oxic in fluvio-deltaic environments of terrestrial organic matter. The oils of Tura-Sylhet and Basement are in group II and these oils contain different geochemical properties than group I. The group II oils were derived from low clastic source deposited in shallow marine environments of predominately terrestrial organic matter of higher plants. The different maturity related parameters indicate that all the oils were derived from early oil window to peak oil generation stage (VRc-0.6 to 0.96%).These study suggests that Bokabil and Kopili oils were generated from the source rocks of Barial and Kopili formations where as Tura-Sylhet oils were generated from the source of Tura-sylhet formations from deeper part of the basin.

Introduction

Various geochemical parameters in oils have been proposed as indicators of depositional environments and lithology of the parent source rock. These may be divided into three broad categories: biomarkers, carbon isotopes and elemental composition. The biomarker applications include the presence or absence of C_{30} dimethyl steranes to discriminate between marine and nonmarine depositional environments (Moldowan et al., 1985; Peters et al., 1986) and the concentrations of various isoprenoids and sterane biomarkers to distinguish marine from lacustrine environments and to subdivide marine into evaporitic, deltaic and carbonate environments. The distribution of methyl dibenzothiophene (MDBT) isomers to distinguish oils derived from carbonate versus siliciclastic source rocks (Hughes, 1995).In this study, we propose to use two molecular indicators, the ratios of dibenzothiophene/phenanthrene (DBT/Phe) and pristane/phytane (Pr/Ph), which coupled together, provide a convenient and powerful way to infer crude oil source rock depositional environments and lithologies and to classify source rock paleo-depositional environments in terms of their most important microbiological and chemical processes (Hughes, 1995). The DBT/Phe ratio alone is an excellent indicator of source rock lithology with carbonates having ratios greater than one and shales having ratios less than one.

The study is mainly aimed at understanding the depositional environment, lithology of source rocks, maturity and oil-oil correlation of Tura-Sylhet oils with others of Khoraghat and Boraholla area.

Geological Settings and Stratigraphy

Dhansiri Valley, in which Khoraghat and Borholla and Champang fields are studied, is a part of the Assam-Arakan basin, situated in the southwestern part of Brahmaputra Valley adjoining Mikir hills towards northwest. The valley is bounded on the east by Naga thrust and on the west by Mikir hills. The entire area is covered by alluvium except for the linear outcrops of Neogene sediments along the fringe of Mikir hills towards West. Khoragahat structure is located about 20-30 km north east of Dimapur town and falls between 26^o 15' 15''N latitudes and 93^{o}45-94^{o}00'E longitudes. The granite basement is fractured and weathered and overlain non-conformably by the granite wash and basal sandstone (Tura Formation of Paleocene age). Sylhet Limestone Formation of Early-Middle Eocene age overlies the Basal Sandstone and is overlain conformably by Kopili Formation. Lower part of Kopili Formation is mainly shale with intercalated limestone whereas the upper part is mainly shale with intercalated sandstone and minor limestone streaks. Barail group of Oligocene age overlies Kopili Formation in the southern part of Khoraghat area whereas it is absent in the western part of the area. A regional unconformity separates the overlying Bokabil Formation from the Barail Formation. Upper part of Bokabil Formation is represented by a predominantly sandstone unit. Tipam group sandstone of Miocene-Pliocene age conformably overlies Bokabil Formation (Fig.1).

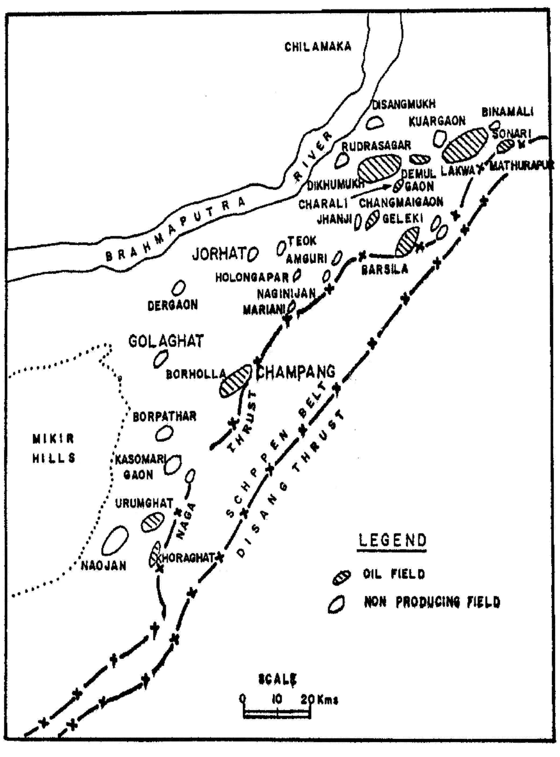

Figure 1: Location map showing the study area of A&AA basin

Samples and Experimental

Oil samples were collected from different formations and their geological information are given in table-1. Approximately 0.5 g of deasphaltened crude oil sample was separated in to chemical classes by column chromatography with 20 g of neutral alumina and 20g of silica gel (60-120 mesh). The sample was then successively eluted with 200 ml of petroleum-ether to obtain the aliphatic hydrocarbons and100 ml of benzene to get the aromatic fraction.

The saturated and aromatic hydrocarbons and its methyl derivatives were separated from the above aromatic fractions on GC-MSD coupled with HP 6890 series gas chromatograph, equipped with BP-1 fused silica capillary column (60 m X 0.25 mm X 0.25 mμ) using helium as carrier gas. The oven temperature was programmed from 80^o to 290^{o}C at a rate of 3^{o}C/min and the injector port was kept at 290^{0}C. Identification of isomers was done by co-injection with authentic standards and by comparison with published mass spectra and retention times.

Results and Discussion

Gross Parameters

The Bokabil oils of Khoraghat and Eocene oils of MEK-A, Khoraghat and Borholla area are characterized by moderate API gravity (27-40^o) and the Sylhet and Gondwana oils of ELA-B are comparatively of low API gravity (18 and 21^o). Group type composition of these oils indicate high saturate/aromatic ratio except for ELA-C oil and more than 40% saturate fraction abundance indicating aliphatic nature of these oils (Table –1).

Source Organics and Depositional Environments

Primary organic matter characterization (i.e. marine, algal, bacterial and bacterially, reworked terrigenous etc.), are important for oil composition. This may be estimated by using molecular marker ratios such as Pr/Ph, Pr/nC_{17}, Ph/nC_{18} extended hopane and ααα20R isomers of 27, 28, 29 sterane distributions. The oils contain high Pr/Ph ratio (3.3 to 5.3), predominance of n-alkanes in the range of C_{14} to C_{32} and high Pr/Ph ratio (>3) suggests that these oils have been derived from non-marine terrestrial organic matter under oxidizing condition (Powell and McKirdy, 1973). The C_{29} hopane to C_{30} hopane ratio (C29H/C30H) of oils appears to be sensitive to lithological changes. The ratio is greater than unity in carbonate source rocks and less and near to unity is assigned by clastic source rocks (Philp, 1985). The ratio (C29H/C30H) for Bokabil and Sylhet oils are different which suggests that the source organics and depositional environments of these oils are different and the oils may be derived from different source rocks.

Oleanane, a biomarker derived from higher plants (angiosperms) from Cretaceous or Younger age (Peters and Moldowan, 1993), is present in all the studied oils. The oleanane index of Bokabil oils is high ranging from 29-41% and the Eocene oils of Borholla and MEK-A have also high oleanane index, which indicates that these oils are derived from terrestrial organic matter with significant contribution from angiosperm plants of upper Cretaceous or Younger age.

The Bokabil oils in Khoraghat area have low content of organo-sulphur compounds as indicated by low ratio of DBT/Phe (0.06 to 0.12). However, the Sylhet oil of KH-H contains relatively higher proportion of organo-sulphur compounds (DBT/Phe 0.28). Significant difference in the values of DBT/Phe ratio indicates that Bokabil and Sylhet oils are derived from different depositional environments and source rocks. DBT/Phe ratio suggests that the oils from Kopili and BMS reservoirs in Charali area are similar in nature and are same as the oils of Bokabil in Khoraghat area.

Grouping of Oils

The DBT/Phe ratio in the studied oils is in the range from 0.06 to 0.36, which indicate that these oils have been derived from clastic/siliciclastic liothofacies. A plot of DBT/Phe and C29H/C30H (Fig. 2) indicates that the Bokabil oils are different from Sylhet/BSS oils. On the basis of aromatic biomarkers data and other geochemical parameters the oils were classified in to two main groups.

In Group-I oils DBT/Phe ratio are less than 0.20 and in Group-II oils these ratios are more than 0.20.
Group I- Bokabil oils of Khoraghat, Kopili and BMS oils of Geleki and Charali.

Group II- A Sylhet/BSS oils of KH-H, Borholla, MEK-A and ELAA

The Group-I oils are derived from the source rocks enriched in higher plants organic matter and also have significant clastic component and high content of pyrites during the deposition of sediments (Hughes et al., 1995) This source rock type is commonly deposited in deltaic settings that received abundant detrital input enriched in terrestrial organic matter. The Group-II oils are generated predominantly from algal and bacterial organic matter, but the source lithofacies generally contain relatively low content of clastic and pyrites (Fig. 3).

Maturity of Oils

The methyl phenantherane index (MPI_1) is the most widely used aromatic maturity parameter from which the calculated vitrinite reflectance (VRc) has been derived (Radke 1982). The calculated equivalent vitrinite reflectance (VRc %) values based on methyl phenanthrene index (MPI_1) indicate that it ranges between 0.81-0.91 for the Bokabil oils in Khoraghat area. The values of the VRc% ranges between 0.89-0.96 for the Sylhet oils in Khoraghat, Borholla and ELAA area.. The different aromatic maturity parameters indicate that the Sylhet and BSS oils including MEK-A, ELA are more mature than Bokabil oils of Khoraghat area. The Sylhet and Bokabil oils in Khoraghat area are of similar maturity.The maturity parameters indicate that these oils have been derived from early oil window to peak generation stages.

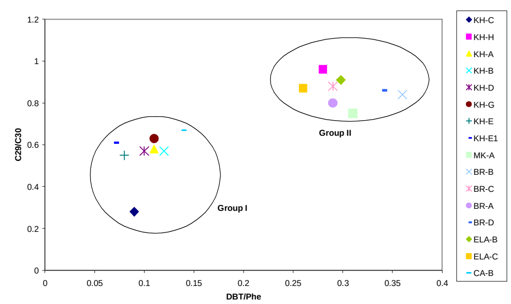

Fig. 2 CROSS PLOT BET. DBT/Phe VS C29/C30

Oil - Oil and Oil-Source Correlation

The oils occurring in Sylhet Formation of Khoraghat area are genetically different from Bokabil oils, but both the oils have similar maturity. The Khoraghat oils might have derived from the deeper part of the Schuppen belt from different kitchens and migrated i.e., Bokabil oils might have generated from Kopili or Barail formations, whereas Sylhet/BSS oils might have derived from Tura/Sylhet formations.

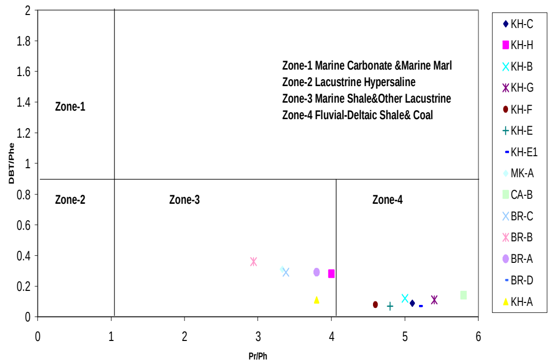

Figure 3: Cross plot of Dibenzothiophene/Phenanthrene (DBT/Phe) and pristine /Phytane (Pr/Ph) ratios indicationg oil source rock depositional environment and lithology.

Table 1 Bulk geochemical parameters of Assam & Assam Arakan basin oils

Well	Formation	Age	API^{o}	Sat %	Aro %	S/A	Pr/ Ph	Pr/ nC17	Ph/ nC18	DBT/ Phe	VRc %	O.I	C29/ 30H
KH-A	Bokabil	Miocene	30.9	48.1	47.5	1.01	3.08	1.37	0.33	0.11	0.85	30.2	1.58
KH-B	Bokabil	Miocene	30.2	47.8	46.4	1.03	5.88	1.72	0.27	0.12	0.81	30.6	0.56
KH-C	Bokabil	Miocene	34.0	67.1	29.1	2.30	5.10	1.4	0.29	0.09	0.82	32.6	0.55
KH-H	Sylhet	Eocene	35.6	69.6	29.9	2.32	4.50	0.98	0.20	0.28	0.84	8.00	0.71
KH-D	Bokabil	Eocene	29.6	52.0	40.6	1.28	4.50	1.30	0.28	0.10	0.84	29.1	0.57
KH-E	Bokabil	Eocene	34.6	62.9	29.1	2.15	4.80	1.60	0.34	0.07	0.82	38.6	0.65
KH-E1	Bokabil	Eocene	35.2	54.4	38.3	1.30	5.20	1.40	0.30	0.07	0.81	37.2	0.61
KH-F	Bokabil	Eocene	30.4	48.8	46.9	1.01	4.60	1.20	0.26	0.08	0.84	29.7	0.55
KH-G	Bokabil	Eocene	39.8	53.9	42.1	1.28	5.4	2.2	0.42	0.11	0.87	41.6	0.63
CA-B	BMS	Oligocene	26.8	50.0	40.0	1.25	5.75	4.05	0.67	0.14	0.60	31.0	0.67
BR-A	BSS	Oligocene	33.9	61.0	33.0	1.85	4.61	0.79	0.17	0.29	0.90	30.2	0.80
BR-B	BSS	Oligocene	30.4	65.4	23.2	2.81	2.94	0.80	0.26	0.36	0.89	28.2	0.82
BR-C	BSS	Paleocene	26.6	55.0	26.0	2.12	3.38	0.73	0.22	0.29	0.91	22.8	0.88
BR-D	BSS	Paleocene	33.8	59.8	20.3	2.95	5.25	0.66	0.13	0.34	0.91	22.7	0.86
MK-A	Sylhet	Eocene	31.9	57.5	35.0	1.64	33.3	0.77	0.22	0.31	0.87	36.0	0.75
ELA-B	Gondwan	Eocene	21.3	29.9	38.8	0.77	2.13	6.86	3.17	0.30	0.90	23.0	0.91
ELA-C	Sylhet	Eocene	18.0	36.8	43.6	0.84	5.25	2.76	0.71	0.26	0.91	29.0	0.89

API ^{o}-API Gravity: Sat-Saturate; Aro-Aromatic: NSO-Nitrogen, sulphur, oxygen; S/A-Saturate/Aromatic

Conclusions

The aliphatic biomarkers indicate that Bokabil oils in Khorahat and BMS /Kopili oils in Charali have been derived from terrestrial organic matter deposited in oxic condition. The Sylhet/BSS oils in Khoraghat, Borholla and East Lakhibari have been derived from terrestrial organic matter sediments deposited in relatively less oxic condition. The Bokabil oils in Khoraghat and BMS/ Kopili oils in Geleki and Charali contain low organo sulphur compounds and these oils have been derived from sediments containing low sulphur kerogen and high clastic input deposited in fluvio deltaic environments. The Sylhet/BSS oils in Borholla, Khoraghat and East Lakhibari have relatively more DBT/Phe ratio and these oils have been derived from the sediments having less clastic source rocks and deposited in shallow marine environment. The different maturity parameters indicate that Tura-Sylhet oils are more mature than other oils.

Oil to oil and oil to source correlation study indicate that Bokabil oils in Khoraghat area have been derived from the source of Barail or Kopili formations .The Bokabil oils in Khoraghat are more mature as compared to the potential source rocks in the area. So the Bokabil oils might have been derived from the source in the deeper part of basin. The Tura-Sylhet oils have been derived from the source of Tura-Sylhet formations.

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