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HYDROCARBON POTENTIAL OF CENOZOIC MUDSTONES, NORTHEASTERN BENGAL BASIN, BANGLADESH

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Abstract- *The Bengal Basin is situated in the northeastern part of the Peninsular Indian. It contains a huge volume of Cenozoic sediments (~22 km) consisting mainly of sandstones and mudstones, and is important for hydrocarbon generation potential. Twenty four mudstone samples were collected from Jaintia, Barail, Surma, Tipam and Dupitila groups in ascending order of late Eocene to early Pleistocene age in the Sylhet succession, NE Bengal Basin, Bangladesh. The source, depositional environment and hydrocarbon generation potential of organic matter in the Cenozoic Sylhet succession have been investigated using gas chromatography–mass spectrometry on aliphatic hydrocarbon extracted from mudstones. The n-alkane is characterized by systematic differences in Pr/Ph, Pr/n-*C_{17}*, Ph/n-*C_{18}*, oleanane/*C_{30}* hopane, Tm/Ts and sterane *$C_{29}/(C_{27}+C_{28}+C_{29})$* ratios throughout the succession. The Jaintia Group deposited entirely in seawater influenced oxic conditions, with dominated higher plants including angiosperms. The Barail and Surma groups consisted of mainly freshwater anoxic conditions, with high inputs of phytoplankton and minor land plants organic matter. The Tipam and Dupitila groups prevailed oxygen-poor freshwater conditions, with elevated planktonic organic matter as well as angiosperm. Relatively high TOC in the upper Jaintia and lower Barail groups may have generated/expelled condensates and oils in and around the investigated area.*

Keywords: Mudstone, Biomarker, Aliphatic hydrocarbon, Bengal Basin, Bangladesh

1. INTRODUCTION

This study investigates the hydrocarbon generation potential of northeastern Bengal Basin, Bangladesh during the Cenozoic. The Bengal Basin is situated in the northeastern part of Indian sub-continent, occupying all of Bangladesh, West Bengal, Assam, Tripura, and part of the Bay of Bengal (Fig. 1). The Basin had its origin during the collision of India with Eurasia and Myanmar, building the extensive Himalayan and Indo-Burman Ranges. The Bengal Basin contains the thickest (~22 km) Cenozoic sedimentary sequence in the world [1]. The northeastern Bengal basin, is a rapidly subsiding sub-basin of the Bengal Basin, placed just south of the crystalline Shillong Massif (Fig. 1), and contains hydrocarbon reserves, the only natural energy resource discovered so far in Bangladesh. The geologic history of this basin is complex. The sedimentary succession comprises sub-equal proportions of alternating sandstones and mudstones. Systematic organic geochemical data of the Cenozoic succession in this basin is still few. The aim is to document the biomarkers of mudstones, to determine their organic matter source, depositional environment and hydrocarbon potential.

2. SAMPLES AND METHODS

A total of 24 mudstone samples were collected from four petroleum exploration wells and surface outcrop from the Sylhet trough, northeastern Bengal Basin, Bangladesh.

About 35 g powdered mudstone samples were extracted by Soxhlet apparatus with a mixture of dichloromethane and methanol (9:1) for 72 hours. Aliphatic hydrocarbons from the extracts were separated using activated thin layer chromatography (Kiselgel 60 PF254, Merck). Gas chromatography–mass spectrometry (GC–MS) was conducted on 24 extracted aliphatic hydrocarbon fractions using a Shimadzu QP2010 with a fused silica column (DB-5MS; 30 m × 0.25 mm i.d.). The GC oven temperature was programmed from 50 °C to 300 °C at 8 °C/min. Helium was used as the carrier gas. The MS had an ionization potential of 70 eV, scan range 50-850 *m/z* at scan rate of 0.5 s.

3. RESULTS AND DISCUSSION

Aliphatic hydrocarbons are mainly predominated by *n*-Alkanes. Group wise average GC-MS of saturated fractions data from the Cenozoic mudstones are listed in Table 1 [8]. Total ion chromatogram (TIC) for aliphatic fractions of the representative Cenozoic mudstone is shown in Fig. 2. The *n*-alkanes patterns of mudstones range between *n*-C_{14} and *n*-C_{36} (Fig. 2). Long chain *n*-alkanes (C_{20}–C_{35}) are dominated in the Jaintia, Barail, Tipam and Dupitila groups and short chain ones (C_{12}–C_{18}) are abundant in the Surma Group. Among the short chain *n*-alkanes, *n*-C_{18} is abundant (Fig. 2), while in long chain *n*-Alkanes, *n*-C_{29} is relatively abundant. The high relative abundance of long chain *n*-Alkanes in the Jaintia, Barail, Tipam and Dupitila groups suggests that the organic matter were derived predominantly from land plant waxes [2, 3]. Short chain *n*-alkanes are dominant in the Surma Group mudstones, indicating an algal or planktonic source of the organic matter [4, 5]. The high maximum *n*-Alkanes of *n*-C_{18} to *n*-C_{24} with low CPI (carbon preference index; [6]) value inferring that the organic matter were originated from phytoplankton, zooplankton, benthic bacteria with no photosynthesis and land plants [7]. Presence of UCM (unresolved complex mixture) in saturated fractions is responsible to microbial effects to the organic matter [8]. UCM in the studied mudstones are low reflecting less degraded hydrocarbons present in the Cenozoic succession. Microbial reworked organic matter in sediments has relatively low CPI values at low maturation level [9]. However, CPI values in the succession range from 1.2 to 2.7 reflecting terrestrial derived organic matter with odd-over-even carbon atom number predominance at low to peak maturation stage. Odd-over-even predominance in *n*-Alkanes tends to decrease with rising thermal maturity of organic matter and low CPI values [6, 10]. The studied Cenozoic mudstones are characterized by low TOC contents range between 0.29 and 1.18% in Jaintia Group, 0.60 and 1.56% in Barail Group, 0.29 and 0.53% in Surma Group, 0.11and 0.51% in Tipam Group and 0.08 and 0.54% in Dupitila Group [8]. Relatively high TOC (~1.56%) in the Jaintia and Barail groups inferring that the lower part of the succession might have been generated/expelled a little amount of condensates and oils in and around the studied area [8].

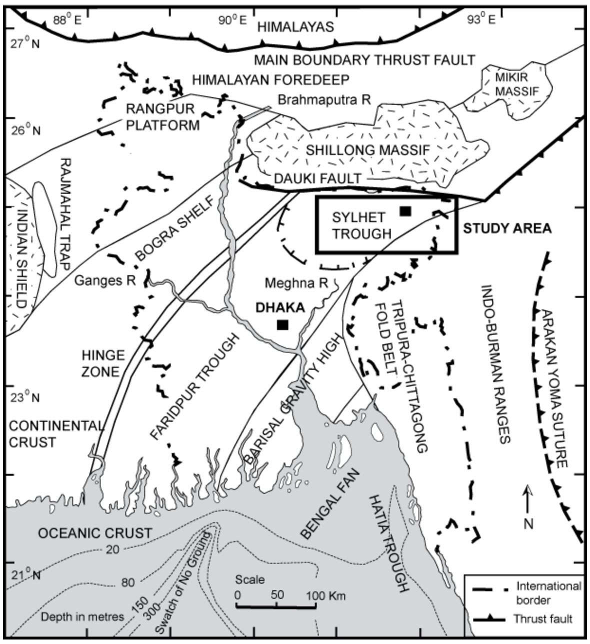

Fig. 1: Map showing location of the study area and major geographic features of the Bengal Basin and adjoining areas [11].

Table 1: Group wise average biomarker data for the Cenozoic mudstones, northeastern Bengal Basin, Bangladesh [8].

Group	Jaintia	Barail	Surma	Tipam	Dupitila
n	*3*	*4*	*11*	*4*	*2*
Pr/Ph	2.87	2.20	0.95	1.12	1.05
Pr/*n*-C_{17}	1.62	1.57	0.94	0.60	0.53
Ph/*n*-C_{18}	1.16	1.21	0.59	0.31	0.28
n-C_{29}/*n*-C_{19}	1.21	1.27	0.28	0.47	0.40
Sterane $C_{27\,(\%)}$	15.52	16.13	30.71	37.24	30.16
Sterane $C_{28\,(\%)}$	15.08	16.77	22.78	26.98	29.51
Sterane $C_{29\,(\%)}$	69.40	67.10	46.51	35.79	40.33
Sterane $C_{29}/(C_{27}+C_{28}+C_{29})$	0.70	0.68	0.46	0.36	0.40
Oleanane/C_{30} hopane	0.37	0.56	0.19	0.49	0.37
Tm/Ts	36.52	13.79	3.38	3.01	1.76

The mudstones contain relatively low pristane (Pr) and high phytane (Ph) values in the middle and upper part, where as high Pr and low Ph in the lower part of the Cenozoic succession. Pr/Ph ratio values range from 0.5 to 3.5 suggesting anoxic to oxic environmental conditions during deposition of organic matter [13, 14, 15]. High ratio values of Pr/Ph may also indicate a high input of terrestrial vascular plant material in the organic matter [10].

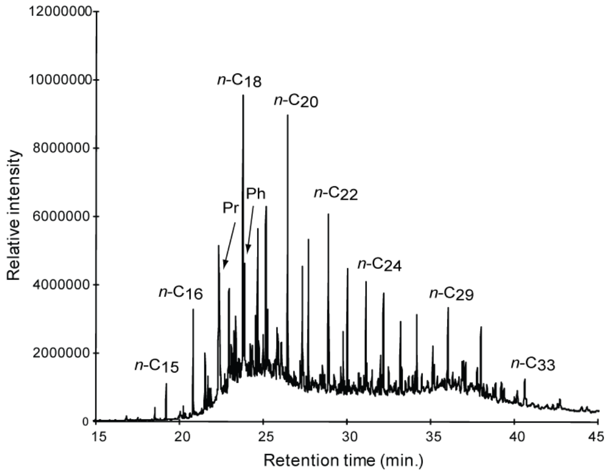

Fig. 2. (a) Total ion chromatograms (TICs) for aliphatic fractions of representative mudstones. Abbreviation: Pr, pristane; Ph, phytane.

Pr/*n*-C_{17} and Ph/*n*-C_{18} values range from 0.4 to 2.2 and 0.3 to 1.6, respectively. Both Pr/*n*-C_{17} and Ph/*n*-C_{18} values decrease with increasing maturity of organic matter [16]. Pr/*n*-C_{17} values in the mudstones suggest that middle and lower part of the succession contains some degraded hydrocarbons and also maturation effect.

Angiosperm-derived biomarker known as oleanane present in significant contents in the sample studied [17]. Oleanane/C_{30} hopane values in the Jaintia and Barail groups are relatively high (~0.95) indicating input of organic matter from angiosperm vegetation [8]. Low oleanane/C_{30} hopane values in the Surma Group mudstones suggest minor influx of angiosperm vegetation subsequently deposited in marine-influenced, oxygen-poor freshwater conditions, with some transitions between anoxic and oxic environments [8].

Organic matter in the Tipam and Dupitila groups were deposited in oxygen-poor, freshwater conditions with planktonic organic matter and low angiosperm vegetation.

The ratio value of 17α(H)-22,29,30-trisnorhopane (Tm) and 18α(H)-22,29,30-trisnorneohopane (Ts) is also used to assess oxic and anoxic environmental conditions during deposition of organic matter [15, 18]. High Tm/Ts ratios in the Jaintia and Barail groups suggest oxic environmental conditions whereas low Tm/Ts ratios in the Surma, Tipam and Dupitila groups reflect suboxic to anoxic conditions [8].

The distribution and relative abundances of steranes C_{27}, C_{28}, and C_{29} are widely used to evaluate type and different environmental conditions during deposition of organic matter [19]. The dominance of C_{27} steranes mainly derive from algae/phytoplankton [20], C_{28} steranes originate from diatom [21] and C_{29} steranes are typically associated with terrestrial higher plants [19]. The steranes distribution and sterane $C_{29}/(C_{27}+C_{28}+C_{29})$ ratios in the Cenozoic succession (Fig. 3 and Table 1), however, indicates that the organic matter in the Jaintia and Barail groups were considered to be land plants, whereas that in the Surma Group originated from dominantly aquatic organisms [8]. Organic matter in the Tipam and Dupitila groups were derived from both aquatic and land plants sources.

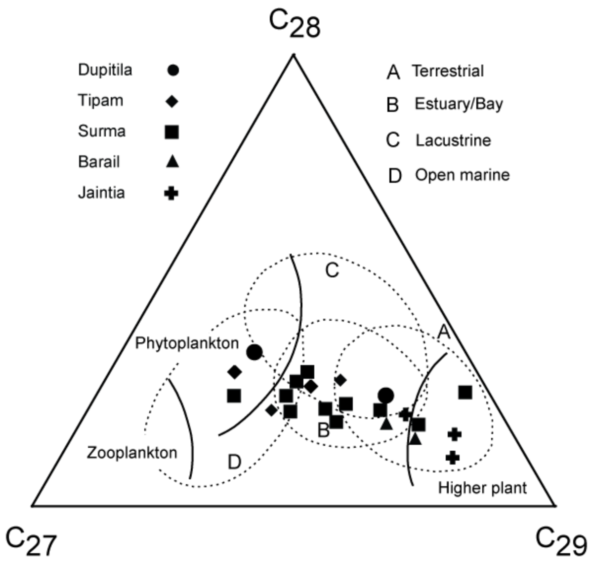

Fig. 3: Ternary diagram of C_{27}–C_{28}–C_{29} steranes indicating organic matter source and depositional environment [8, 19].

5. CONCLUSIONS

The Bengal Basin is situated in the northeastern part of the Peninsular India, and contains a large volume of Cenozoic sediments consisting mostly of sandstones and mudstones. The source, depositional environment and hydrocarbon generation potential of organic matter in the Cenozoic Sylhet succession have been investigated using GC–MS on aliphatic hydrocarbon extracted from 24 mudstone samples. The *n*-alkane is characterized by systematic differences in Pr/Ph, Pr/n-C_{17}, Ph/n-C_{18}, oleanane/C_{30} hopane, Tm/Ts and sterane $C_{29}/(C_{27}+C_{28}+C_{29})$ ratios throughout the succession. The Jaintia Group deposited entirely in seawater influenced oxic conditions, with dominated higher plants including angiosperms. The Barail and Surma groups consisted of mainly freshwater anoxic conditions, with high inputs of phytoplankton and minor land plants organic matter. The Tipam and Dupitila groups prevailed oxygen-poor freshwater conditions, with elevated planktonic organic matter as well as angiosperm. Relatively high TOC in the upper Jaintia and lower Barail groups may have generated/expelled condensates and oils in and around the investigated area.

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