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Geochemical characterization of source rock from the North Bank Area, Upper Assam Basin

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Abstract

The study area is confined to a part of Upper Assam Basin, north of River Brahmaputra (North Bank). It constitutes an alluvial plain flanked by the Arunachal foothills in the north and separated from the proved oilfields of Upper Assam basin by River Brahmaputra in the south. Seven exploratory wells have been drilled through this part of the basin in order to probe the hydrocarbon prospects of the area. The exploratory efforts did not indicate significant hydrocarbon prospects in the North Bank. Since the presence of source rock is an important component of the petroleum system, a detailed systematic study of source rock potential was carried out by analysing known source rock intervals in these seven wells. In the present study, Rock-Eval pyrolysis combined with specific geochemical analyses like GC and TLC-FID has been used to characterise the source rocks, their distribution and thermal maturity of the organic matter. The source rocks in the area show mainly Type III, land-plant derived organic matter along with some Type II organic matter. The source rocks are predominantly gas prone in nature, although mixed and oil-prone source rocks are occasionally present. Although source rock intervals have been identified in the Langpar, Sylhet Limestone and Kopili formations, the Barail Group and the Tipam Sandstone Formation, the bulk of the source rock occurs within the Kopili Formation. Geochemical analyses of the cores indicate oil signatures at certain depths, although no commercial oil was discovered. The hydrocarbon generation potential of these source rocks are constrained by low maturity at the presently drilled depths.

Keywords: Upper Assam basin, source rock potential, Rock-Eval pyrolysis, geochemical analyses

Introduction

The world's remaining oil and gas resources are becoming more and more challenging to find and develop. In addition to assessing the reservoir, trap and seal of their prospects, E&P companies must evaluate the petroleum-generating potential of the source rock. Source rocks form where environmental conditions support biologic activities that produce large quantities of organic matter, where depositional conditions concentrate this matter and where post depositional conditions permit its preservation (Jacobson, 1991). The study of source rocks is an important step towards accurate assessment of the hydrocarbon source potential of sedimentary rocks. The determination of the most favourable petroleum exploration targets depends on the geochemical knowledge of source rocks and on the knowledge of generation, migration and accumulation processes combined with the geophysical and geological features of the sedimentary basin under evaluation. Most petroleum hydrocarbons are generated from kerogen, which generally occurs finely disseminated in fine grained sedimentary rocks (Hunt, 1972). The inherent potential of a kerogen to generate crude oil or gas depends on its type, which in turn depends on the chemical nature of the materials forming the kerogen. Many techniques have been developed to evaluate levels of thermal maturation and kerogen type. Although other analytical methods such as vitrinite reflectance give added information on thermal maturity, Rock-Eval pyrolysis is probably the most widespread analytical technique used for the estimation of the organic matter content in sediments and provides the basic quantitative data for further geochemical analyses. It enables the rapid screening of sediment samples, without the tedious preliminary kerogen isolation, and the reliable estimation of the organic content. In the present study the source rocks have been characterized primarily by utilizing this technique.

Geological Setting

The study area is confined to a part of Upper Assam Basin, north of River Brahmaputra (North Bank, Fig. 1). It constitutes an alluvial plain flanked by the Arunachal foothills in the north and separated from the proved oilfields of Upper Assam basin by River Brahmaputra in the south. The area is logistically difficult in the North Bank of River Brahmaputra as it is criss-crossed by numerous rivulets, high grasslands, forests and thick boulder beds. A Tertiary sequence stratigraphically equivalent to that of the South Bank (Fig.1) (Raju, 1995) has been encountered in the North Bank. Seven exploratory wells, one each in Bihpuria, Nijlaluk, Madhupur, Dhakuakhana and SimenChapori area and two in Murkongselek area (Murkongselek#1 & 2) were drilled through this part of the basin in order to probe the hydrocarbon prospects of the area. The exploratory efforts did not indicate significant hydrocarbon prospects in the North Bank. However, minor shows of hydrocarbons have been encountered during the drilling and initial testing phases in some of the wells.

Experimental Details

Drill-cutting samples recovered from the various litho-stratigraphic horizons encountered in the wells were acquired for source rock analyses in the R & D geochemical laboratories of Oil India Limited. Hand-picked shale samples were subjected to Rock-Eval pyrolysis using Rock-Eval 6 (Make: Vinci Technologies, France) following the procedure of Espitalie *et al*. (1977, 1985a, 1985b, 1986). These samples were cleaned to remove mud and other contaminants, air dried and crushed. The parameters determined during the analyses are TOC (wt.%) content, S1 (mg HC/gm Rock, amount of free hydrocarbons in the sample), S2 (mg HC/gm Rock, hydrocarbon generated during pyrolytic degradation of organic matter during the temperature range of 300-550°C), S3 (mg CO_2/gm Rock, amounts of CO_2 produced during pyrolysis and indicates amount of oxygen in organic matters), T_{max} (temperature in °C, at which the maximum release of hydrocarbons from decomposition of organic matter occurs during pyrolysis).The secondary parameters calculated from the pyrolysis data are hydrogen index (HI= S2*100/TOC) and oxygen index (OI=S3*100/TOC).

The collected samples were also extracted using modified soxhlet extraction. A definite amount of each sample (~2.0 gm) was first grounded properly to fine powder. In a previously dried cellulose thimble the sample was extracted in boiling dichloromethane (DCM) for one hour followed by rinsing in DCM for another two hours. The extractable organic matter thus obtained was prepared with 1% solution in DCM and is analysed by GC-FID and TLC-FID. However, in the present study, these analyses were restricted to only those samples where TOC was >1% and S2 ≥ 2.0mg/g.

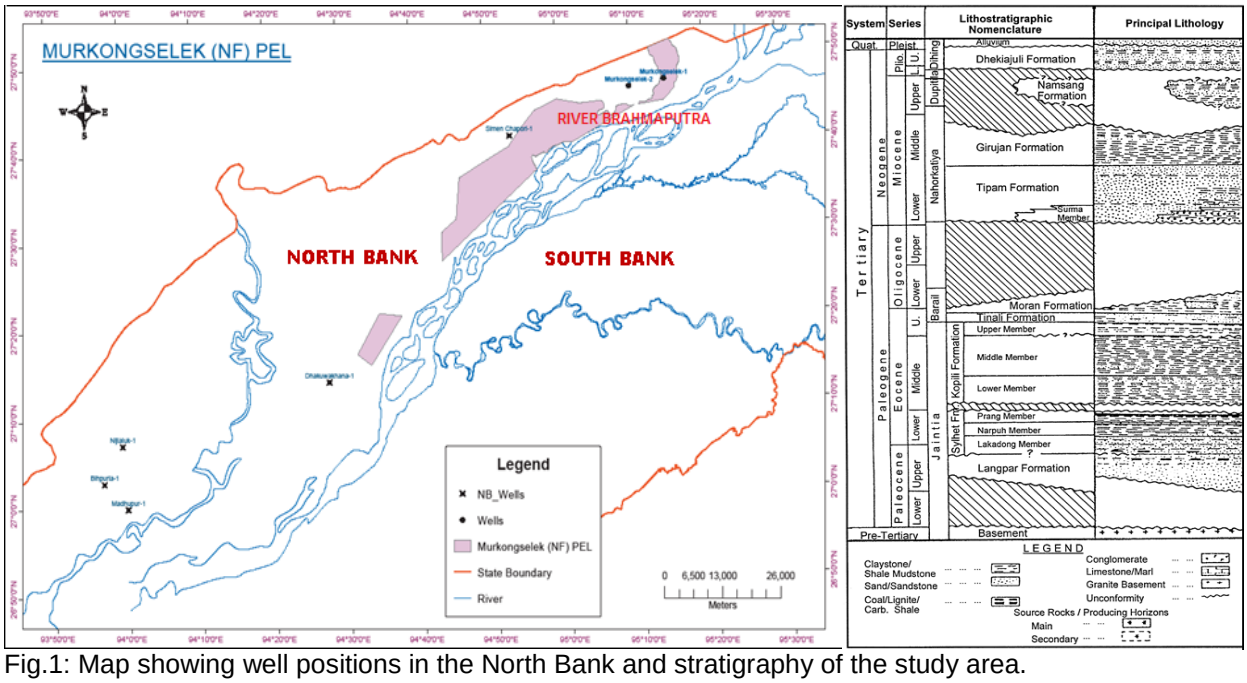

Fig.1: Map showing well positions in the North Bank and stratigraphy of the study area.

Results and Discussion:

The TOC and S2 values of the samples from the seven wells are summarised in Figures 2 & 3 and in Table 1. In the Madhupur area, most of the samples recovered from the Kopili Formation show significant TOC and S2 values with one sample each from the Namsang and Dhekiajuli formations also showing good potential. These, however, are reworked samples. Two coal samples each from the Dhekiajuli and Namsang formations show very high TOC values. These samples are also reworked. In the Bihpuria area, only few samples show significant TOC and S2 values. Most of these samples are from the Kopili Formation. Very few samples were available for analysis from the Nijlaluk area. However, a single sample recovered from the Kopili Formation in this well showed good TOC content and pyrolysis S2 yield. In the Dhakuakhana area, a number of coal samples were encountered from the Tipam to Namsang formations. These samples usually show very high TOC contents. The bulk of the samples showing good TOC contents and pyrolysis S2 yields occur within the Kopili Formation. In the SimenChapori area, most of the samples recovered from the Kopili Formation show very high TOC contents and pyrolysis S2 yields. A few samples from other formations show fair hydrocarbon generation potential. In the well Murkongselek #2, very few samples showed potential TOC and S2 values. These samples were mainly from the Barail Group, Langpar Formation and the Lakadong Member of the Sylhet Limestone Formation. In Murkongselek #1, the bulk of the source rocks occur within the Kopili Formation. The source rock samples show good TOC contents. Very few samples from the other formations show significant TOC contents and potential S2 yields. Source rock quality within the Kopili Formation appears to improve at Madhupur and in areas towards the northeast of it. Areas towards the north and northwest of Madhupur appear to have mainly poor source rocks within all the formations. From the source rock analyses of samples recovered from the seven wells it is observed that the bulk of the source rocks having fair to good potential yields occurs within the Kopili Formation. Owing to this, samples recovered from the Kopili Formation only have been selected for further analyses.

Organic matter type:

A plot of HI versus OI of the samples in a modified van Krevelen diagram is shown in Figure 4. Here, only those samples which have fair to good source rock potential have been considered (i.e. samples with TOC >1% and S2 > 2mg HC/gm Rock). This is to minimize the influences of “matrix effect” which can substantially lower HI values as compared with that of isolated kerogen for samples with low TOC values (<1%) (Espitalie *et al*., 1984).The plot shows that the composition of organic matter (OM) in the samples are mostly of mixed Types II and III kerogen which are oil/gas prone with a very few samples showing Type IV characteristics. The plot of HI versus T_{max} (Fig.5) also shows that the samples dominantly contain mixed Types II and III kerogens.

Thermal maturity:

Here, only those samples which have fair to good source rock potential have been considered, i.e. samples with TOC >1% and S2 > 2mg HC/gm Rock. The T_{max} of whole rocks having low TOC can be increased compared to that of kerogen by way of retention by minerals of the heavy fractions, the first to be released (Espitalie et al., 1984).

In the Madhupur area, most of the samples showing source rock potential have T_{max}<435°C. These are immature. One sample with source rock potential falls in the mature zone whereas one sample which also shows potential source rock have T_{max} >460°C and falls in the post-mature zone. In the Bihpuria, Nijlaluk and SimenChapori areas, all the samples showing fair to good source rock potential. However, they have T_{max}<435°C and are immature. In the Dhakuakhana area, only one sample falls in the mature zone. Although the bulk of the samples have fair to good source rock potential they are immature. In Murkongselek #2, only one sample having fair source rock potential recovered from the Barail Group falls in the mature zone. A few samples recovered from the Kopili Formation in Murkongselek #1 having fair to good source rock potential falls in the mature zone and all the other samples are immature. The mature samples could be reworked as the samples at lower depths are immature.

Hydrocarbon generation potential:

The source rocks encountered by drilling in the North Bank contain predominantly Type III; land plant derived organic matter, along with some Type II organic matter. In general, most of the samples fall in the immature zone, i.e. these are potential source rocks which have been altered by diagenesis but have yet to be exposed to sufficient heat for generating conventional liquid petroleum.

Compositional analyses:

All the samples which showed source rock potential i.e. samples with TOC >1% and S2 > 2 mg HC/gm Rock were further analysed with the help of TLC-FID and GC-FID. GC-FID analyses indicate irregular distribution of n-alkanes, with either very small peaks or no peaks at all (Fig. 6). TLC-FID analyses show variable composition of Saturates (S), Aromatics (A), Resins (R) and Asphaltenes (A) with the presence of very high amounts of R+A (>50%) (Fig. 7) indicating that the rocks are immature, thus suggesting absence of any kind of producible hydrocarbons.

Conclusions:

The formations encountered by the seven wells drilled within the North Bank contain predominantly gas prone source rocks, although mixed and oil prone source rocks are occasionally present. The source rocks contain mainly Type III land plant derived organic matter along with some Type II organic matter. The post Kopili formations have mainly poor source rock potential. Unlike the organically rich source rocks of the Barail Group south of the Brahmaputra River, the Barail source rocks here appear to have mainly poor hydrocarbon generative potential. Overall analyses of the samples recovered from all the formations and analysed in the laboratory indicate that the bulk of the source rocks occur within the Kopili Formation. Source rock quality within the Kopili Formation appears to improve at Madhupur and in areas towards the northeast of it. This formation contains the best source rock quality in Murkongselek #1. Fair to good gas prone source rocks occur in the Madhupur, Dhakuakhana and Simen Chapori areas. However, most of the samples fall in the immature zone (T_{max}<435°C) i.e. these are potential source rocks which has been altered by diagenesis but have yet to be exposed to sufficient heat for generating conventional liquid petroleum or gas. Hence, no commercial oil or gas is expected to be generated from the source rocks analysed so far.

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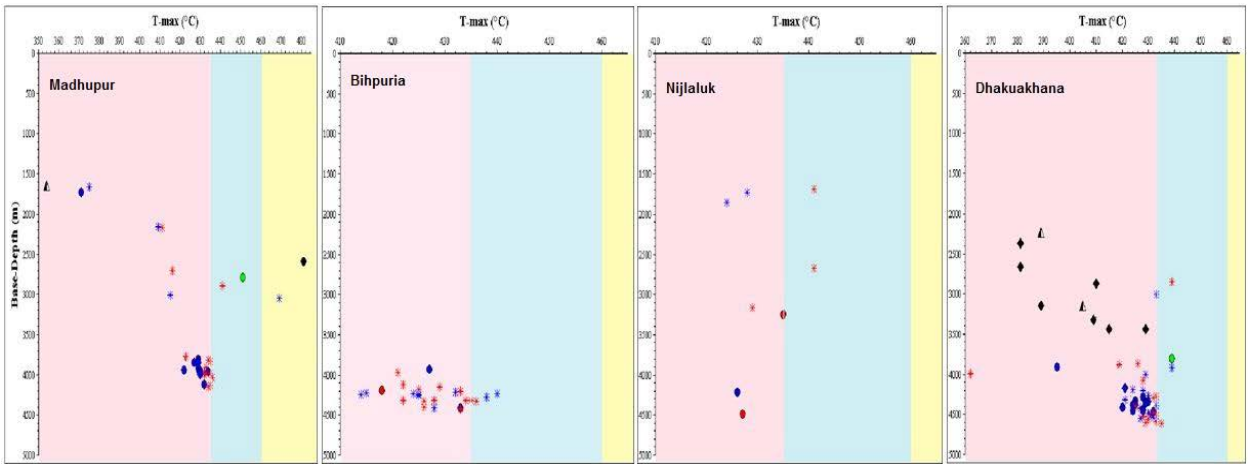

Fig. 2: Plot showing TOC and S2 distributions of samples recovered from wells in the Madhupur, Bihpuria, Nijlaluk and Dhakuakhana areas with respect to depth and T_{max}.

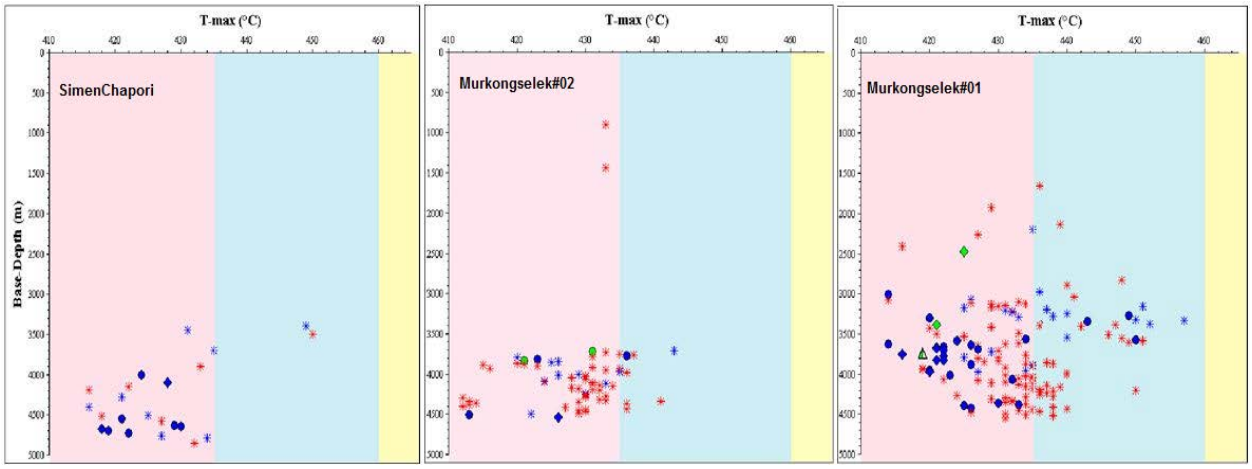

Fig. 3: Plot showing TOC and S2 distributions of samples recovered from wells in the SimenChapori and Murkongselek areas with respect to depth and Tmax.

Colour code for Figures 2 & 3.

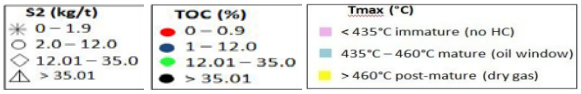

Table 1: Rock Eval pyrolysis data (range) of samples from Kopili Formation.

Well Name	S2	TOC	T_{max}	HI	OI
Murkongselek#2	0.0 – 1.78	0.2 – 1.26	389 – 436	0.0 – 422	15 - 192
Murkongselek#1	0.0 – 43.48	0.10 – 15.51	416 – 450	0.0 - 527	25 - 550
SimenChapori	0.97 – 14.25	0.74 – 10.67	398 – 430	65 – 164	42 – 237
Dhakuakhana	0.82 – 11.11	0.69 – 5.33	420 – 433	54 – 379	-
Nijlaluk	10.21	2.52	426	405	44
Bihpuria	0.22 – 4.07	0.64 – 4.38	414 – 440	16 – 635	12 - 769
Madhupur	0.35 – 24.81	0.55 – 5.55	422 – 436	61 – 447	13 - 210

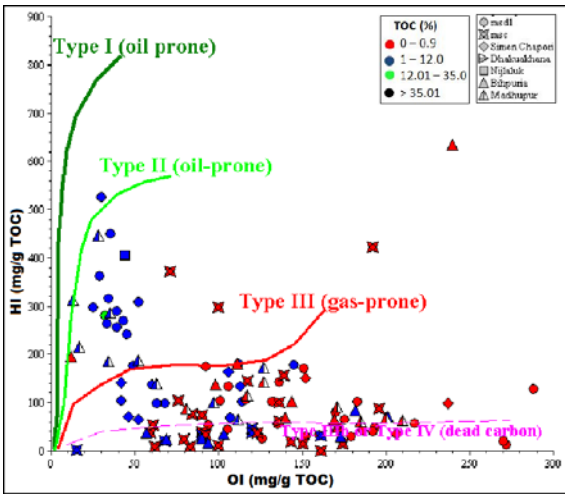

Fig. 4: Pseudo van Krevelen plot.

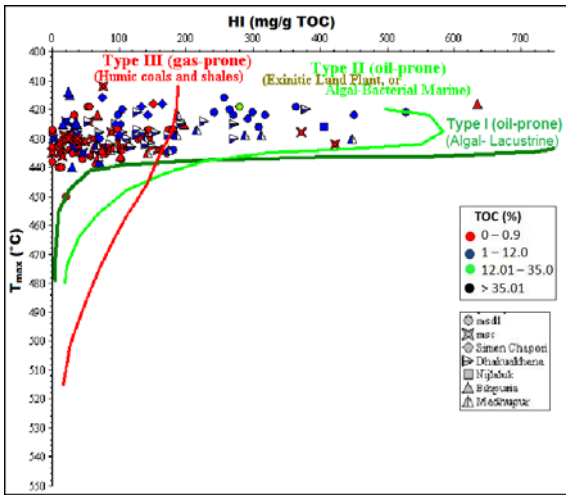

Fig. 5: HI vs Tmax plot.

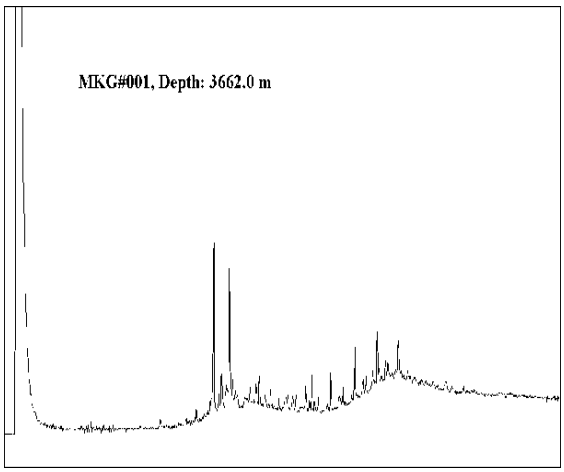

Fig. 6: Representative GC fingerprint of samples recovered from the Kopili Formation in Murkongselek#1.

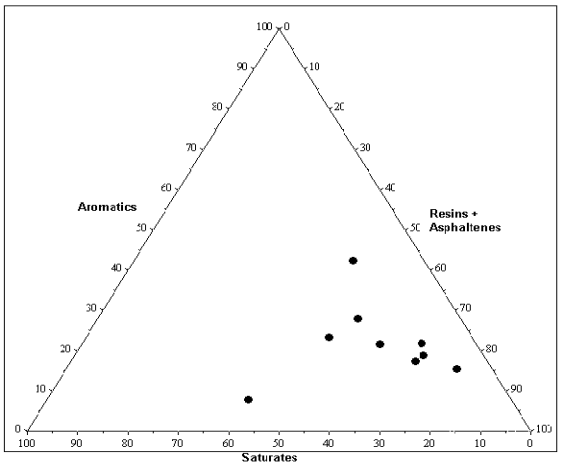

Fig. 6: Representative GC fingerprint of samples recovered from Kopili Formation in Murkongselek#1.