

Petroleum System of Bengal Basin in Bangladesh

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Summary

Prolific hydrocarbon accumulations in eastern part of Bangladesh indicates the presence of active petroleum systems in the Bengal basin. Petroleum system analysis attempts to establish paleo heat flow, determining thermal maturity, kerogene types and their distribution. Basin modeling also allow the prediction of hydrocarbon charge and expected yields. BPI of Bangladesh and JGI, JAPEx and Kyoto University of Japan, undertook a joint research program petroleum system analysis of the Bengal basin using available sand–shale% and organic carbon content, rock-eval pyrolysis and geological data to infer the paleo-heat flow, burial history, characteristics of the source rock, timing and quantity of hydrocarbon generation, expulsion, migration, accumulation properties and determine the Kitchen areas. Bakhrabad Gas Field being a well known gas field in the basin area, has been chosen for applying current methodology and then apply the same technique to an unknown Sariakandi-Madarganj area in the shelf-slope area. Detailed structural and seismo-stratigraphy of the Bengal basin have been established. Regional depth contour maps of different seismo-stratigraphic horizons of Madarganj-Sariakandi and Bakhrabad areas have been prepared to determine the sedimentary structures and spatial distribution of the stratigraphic units. In areas where there were no wells pseudo wells have been generated from those depth contour maps for the purpose of determining the kitchen areas.

The analysis revealed presence of type I, II, and III kerogens and three different active petroleum systems in the Bengal basin. though Type III is most common, Type II is less common and Type I is rare. Petroleum systems analysis of Basin area (Greater Bakhrabad) and Shelf area (Madarganj-Sariakandi) areas revealed hydrocarbon generation, expulsion and migration properties that are very encouraging in respect of prospect generation, prospect evaluation and hydrocarbon potential of the Bengal basin and may lead to new discoveries in future.

Introduction

In Bangladesh, gas field was first discovered in 1956 and production started in 1962. Since then exploration activity was continuing resulting in the discovery of 22 gas fields and 1 oil field. During 1910-2002 total 69 wells with 22 gas field discoveries with estimated proven reserves for 22 gas fields was confirmed at 15.5 Tcf. A map of oil and gas fields in Bangladesh is shown in Figure 1.

In 2002, BPI of Bangladesh and JGI, JAPEx and Kyoto University of Japan, undertook a joint research programme for the Petroleum system analysis of the Bengal basin. Bakhrabad (BK-1 Well), Meghna (Marichakandi BK-9 Well) and Narshingdi (Belabo BK-10 Well) Gas Fields being well known gas fields, have been chosen for applying current methodology based on geophysical prospect evaluation and basin modeling and apply this to the Shelf

area covering Bogra (Bogra-X1 Well), Kuchma (Kuchma-1X Well) and Slope area covering Sariakandi-Madarganj (northwest of Hazipur-1 Well) areas where there are indications of hydrocarbon (both oil and gas shows) in the wells but no commercial discoveries have been made yet. Detailed structural and seismo-stratigraphy of the Bengal basin have been established in BPI. Basin modeling and petroleum system analysis were carried out at Japan Geoscience Institute (JGI) to establish paleo heat flow, thermal maturity etc., to determine the kerogene types and their distribution. Sand–shale % and organic carbon content in well data have been used to calculate the burial history, maturation, generation and expulsion of hydrocarbon and then to determine their migration, accumulation properties and determine the kitchen areas of the basin. In areas where there were no wells or for the purpose of determining the kitchen areas pseudo wells have been generated from the depth contour maps.

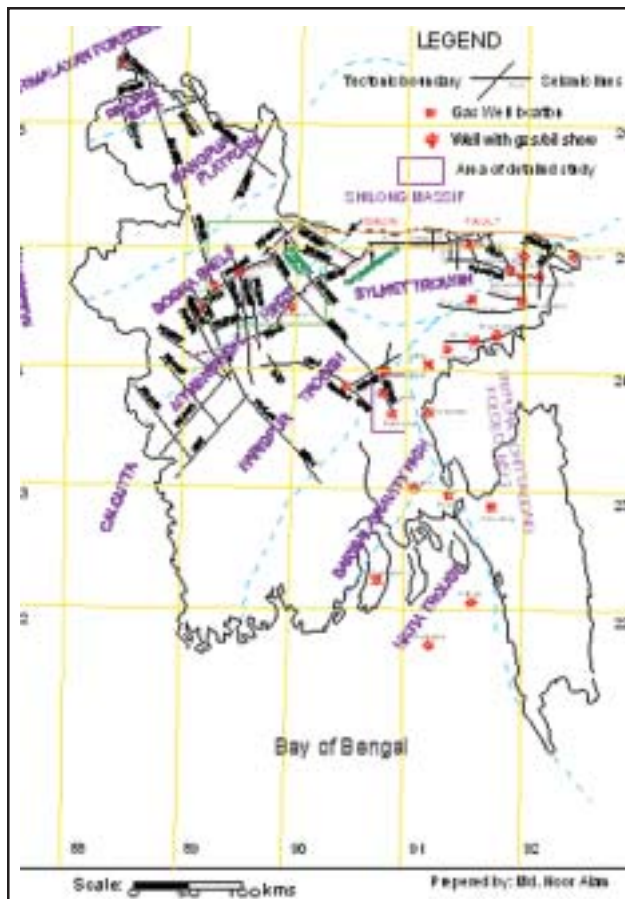


Fig.1. Map of Bangladesh showing tectonic divisions, location of seismic lines, gas fields, drill holes and the areas of detailed study.

Thick Gondwana coal have been discovered in the Kuchma-X1, Singra-1, Joypurhat wells i.e., in Shelf area of Bangladesh. An analysis of Kuchma-X1, Singra-1 wells have been made, to check whether the Gondwana coals of Bangladesh have produced any hydrocarbon or not.

2. Petroleum Geology and Tectonic settings of the Bengal basin

2.1 Tectonic settings

The major tectonic features of the Bengal basin are shown in figure 1 as: 1) Sub-Himalayan Fore-deep, 2) Rangpur Platform, 3) Bogra Shelf, 4) Calcutta-Mymensingh Hinge zone, 5) Bengal Fore-deep (which constitutes Sylhet Trough, Faridpur Trough, Barisal-Gravity High and Hatia trough) and 6) Tripura-Chittagong Folded belt (GSB, 1990). The two areas under consideration in this paper as Sariakandi-Madarganj falls in the Bogra Shelf and Calcutta-

Mymensingh Hinge zone and the Bakhrabad Gas Fields areas falls along the transition zone of the Sylhet Trough and Faridpur Trough with the Barisal-Gravity High areas.

Desired location of Figure-1:

2.2 Petroleum Geology of the Bengal Basin

Stratigraphy of the Bengal basin have been revealed by drill holes in the shelf, slope, and basin areas. Oligocene and Eocene carbonaceous marine shales are considered to be the potential source rocks of the Bengal basin. Early to Middle Miocene sandstones and siltstones of Surma and Tipam groups are the potential reservoir rocks in Bengal basin. Reservoir rocks in the Surma basin are chiefly Tertiary age sandstones of the Bokabil and Bhuban Formations (Miocene). Porosity ranges generally from 10 to 20 percent. Reservoir sands range from thick channel-fill and littoral or marine bar deposits to sandstones thinly interlaminated with shale and siltstone. Structural and combination traps of Miocene age occur along stratigraphic boundaries, in sandstone-filled channel deposits and in sandstone beds sealed laterally by shale-filled channels and these comprise major traps in the eastern part of the basin.

Mio-Pliocene shale sequence acts as an effective cap rocks for the gas reservoirs of the Bengal basin. Intra-formational shales and claystones of the Surma group are common seal for the gas fields of Bangladesh. The Kopili shale may act as a regional seal over the shelf-slope areas. So far the anticlines are the common type of traps for the accumulations of both oil and gas in Bangladesh.

3. Basin Modeling

In the current study two software viz., BSS-XLS and IVTSST, both developed at JGI of Japan have been used to invert the geochemical, geological data to infer the characteristics of the source rock, timing and quantity of hydrocarbon generation and expulsion (Nakayama, K, 1981, 1987). BSS Excel Version (BSS-XLS) is an one dimensional basin analysis tool to simulate the entire geologic processes of compaction, heat transfer, source rock maturation, and hydrocarbon generation and expulsion during a basin's development. It is designed to evaluate capability of source rocks to generate and expel hydrocarbons. In this analysis the thermal history resulted from BSS-XLS of each well which may give preciseness on the calculation of maturity, therefore the resultant kerogen parameters can be more reliable. HI observations at various maturation levels are necessary to distinguish

between groups of kerogens. Therefore, if HI is plotted against a suitable maturity indicator for all the data obtained from a single area, kerogens will fall into distinct groups. Kinetic parameters of each group of kerogens (Geochemical Facies) can then be determined.

3.1 BSS and IVTSST analysis for the determination of kerogene type, geohistory, thermal maturity, burial history, oil and gas generation and expulsion of Kuchma (Kuchma-1 well) area:

Desired location of Figure 2a & 2b

This simulation study does not mean to reconstruct the exactly same process as geologic process in the past. It simplifies the process. BSS modeling of Kuchma -1 well reveals Kerogen Type I : High yielding , 300 mg/g TOC between Ro=0.35 to 0.6 (Figure-2). Gas oil cracking starts from Ro = 0.6. Ro= 0.35 to 0.6 reaches between 700m to 2000m (figure 3(a)). Gas expulsion took place 10 my ago and oil expulsion took place 20 my ago. Since 20 my Bokabil

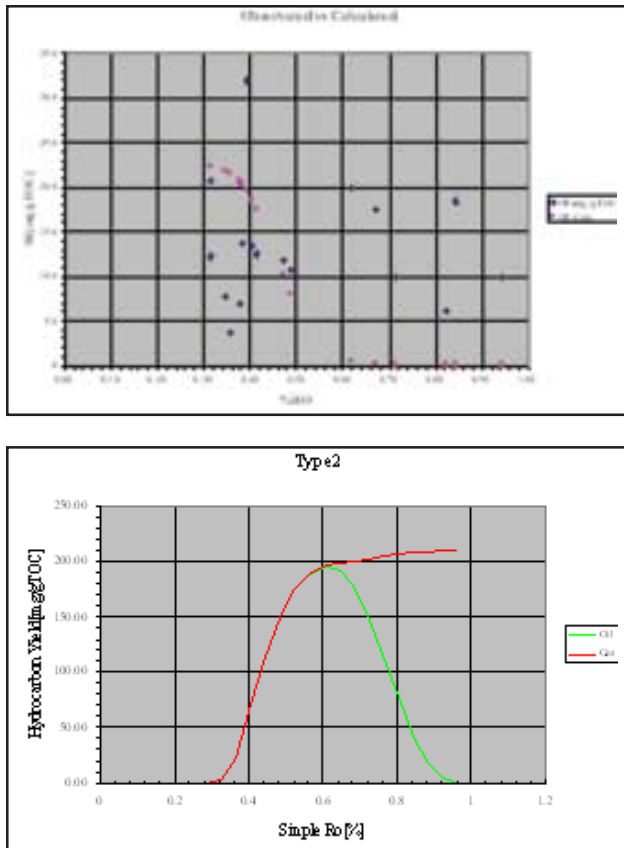


Fig.2 : (a,b). Hydrogen Index (HI) vs vitrinite reflectance (R_o) graph of the Kuchma-1 Well of Bogra area showing the distribution of three different types of Kerogen (Type-I, Type-II and Type-III).

has undergone a burial greater than 700m and Ro \geq 0.35, they must be gas producing. It has also been observed that supply of TOC was higher during Miocene (Bokabil) and Paleocene (Cherra) i.e., between 10 to 50 my.

Desired location of Figures: 2c&2d

Figure 2(c) shows that HC generation mainly takes place between Ro = 0.4 and Ro = 0.9 and gas oil separation takes place from Ro \geq 0.6. From figure 7 Depth of burial for Ro = 0.4 corresponds to 0.8 km and Ro = 0.6 corresponds

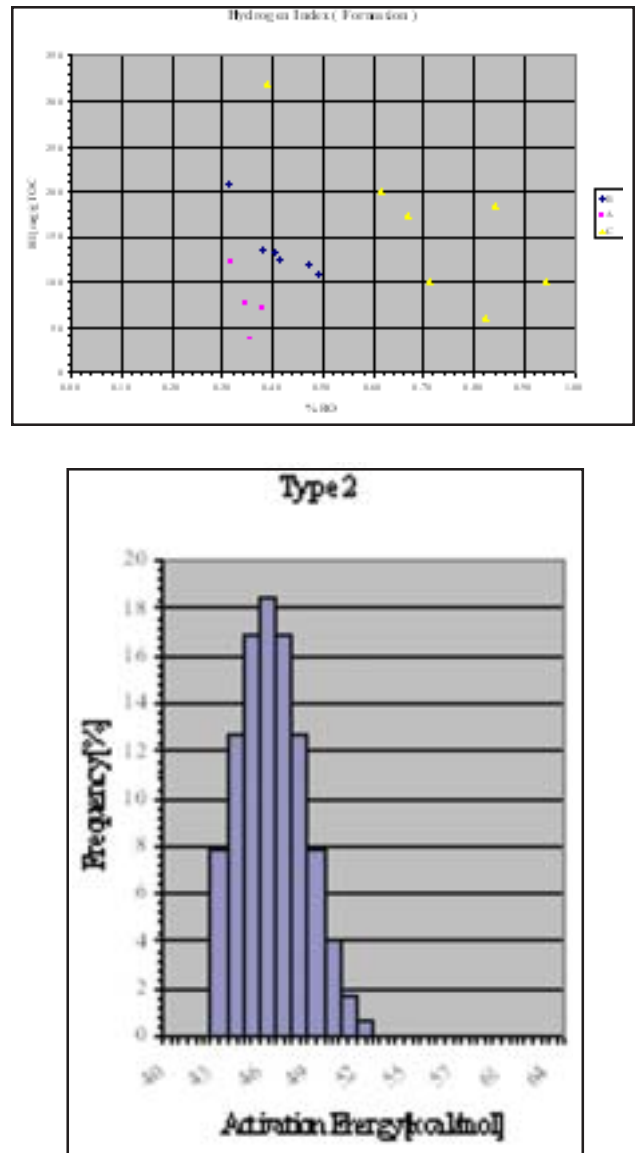


Fig. 2(c).Hydrocarbon Yield vs Vitrinite Reflectance (Ro) curve for the Kuchma-1 well showing HC Yield (mg/gTOC) for the Type II Kerogen.



to 2 km. Therefore formations having higher % of TOC and are below 2 km should be gas producing. Factors which affect the geochemical character of kerogen include both depositional environment and early diagenetic processes.

Desired location of Figure- 3a

Figure 3(a) shows the geohistory and Ro development in the Kuchma-1 area only. The Kuchma-1 well penetrated a depth of 2875 meter only and encountered Alluvium, Dupi Tila, Bokabil, M. Bhuban, Kopili Shale, Sylhet Limestone, Cherra, Trapwash, Rajmahal Trap and Gondwana Formations only. In the above figure it may be noticed that the Gondwana, Cherra, Upper and Middle Bhuban formation have entered maturity level greater than $R_o = 0.7$ only and the upper part and all the gas bearing part reached the maturity level = 0.5 only. The gas shows occurs at U.Bokabil, U. Bhuban, Kopili and oil shows in Cherra formations.

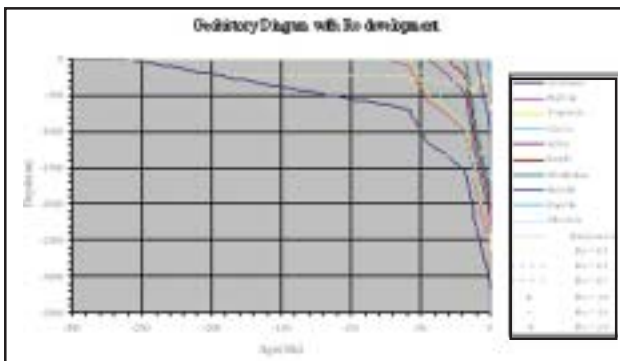


Fig. 3(a) Geohistory and Ro development of the Kuchma-1 well from 1D basin model using measured Kinetic Parameters.

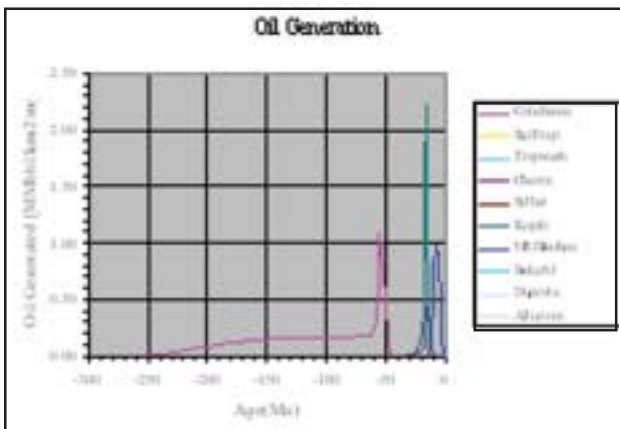


Fig.3(b). Oil generation curve for the Kuchma-1 well showing three distinct generation phases.

Figure 3(b) shows the oil generation vs. age graph. It may be noticed that some amount of oil has been generated from the Gondwana coal during the last 240 and 45 million years period. The peak generation was very brief between 45 and 60 million years ago. The Cherra, Kopili, Sylhet Limestone, U and M Bhuban have contributed during the last 25 million years.

Desired location of Figures- 3b and 3c

Figure 3(c) shows that the Kuchma-1 well area peak oil expulsion from Gondwana took place during the last 40-60 million years ago, the peak expulsion from the Kopili took place between 12 and 18 million years ago but the expulsion from Bhuban is happening now. The timing of oil expulsion from the Bhuban took place during and after the structural i.e., trap formation and therefore there the oil have chances of entrapment in the neighbourhood structural or in the stratigraphic traps.

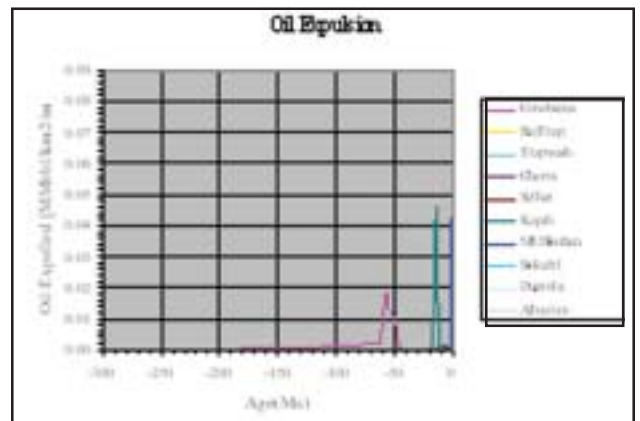


Fig.3(c). Oil expulsion curve for the kuchma-1 well showing three distinct expulsions.

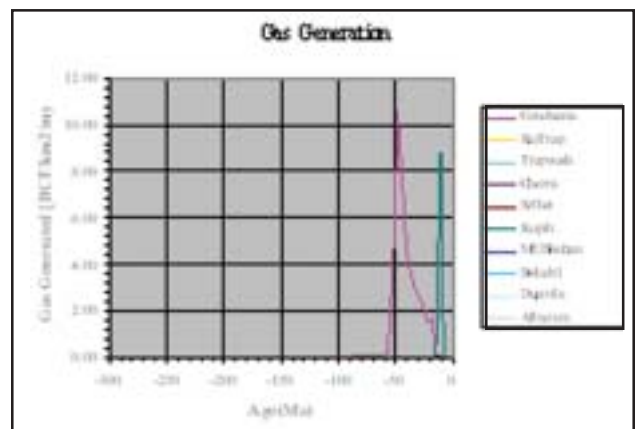


Fig.3(d). Gas generation curve for the Kuchma-1 well showing two distinct generation phases.

Desired location of Figures: 3d-3e

Figure 3(d) shows the gas generation vs. age graph for the Kuchma-1 well. It may be noticed in the graph that significant amount of gas have been generated from sources in the Gondwana and Kopili formations during 15-60 and 7-15 million years ago respectively. The graph shows that the both are still expelling some gas.

4. Petroleum system analysis in the Shelf (Kuchma) area

4.1.1. Shelf area: Petroleum systems in Kuchma -1 well:

The Shelf area i.e., around Kuchma-1 well, potential source rocks of the rift system include] the Gondwana coal and the shelf system are shales and carbonaceous shales of Paleocene-Miocene age. Kerogen type was mainly mixed with varying proportion of Type I, II and III but mostly Type II and III. Potential source rocks include the shales and carbonaceous shales of from Miocene to Paleocene and Permo-Carboniferous age. So it has three petroleum systems.

1. Oligocene-Miocene-Pliocene i.e., Barail- M. U. Bhuban-Bokabil petroleum system
2. Paleocene-Eocene i.e., Cherra-Sylhet Limestone-Kopili Shale petroleum system
3. Permo-Carboniferous i.e., Gondwana petroleum system

Petroleum systems in Bogra-X1 Well:

1. Oligocene-Miocene-Pliocene i.e., Barail- M. U. Bhuban-Bokabil petroleum system

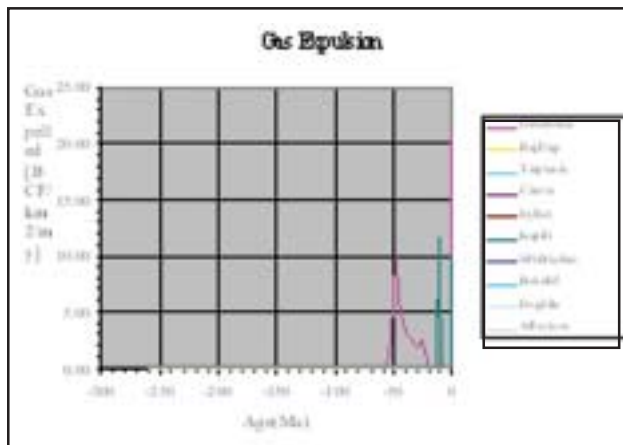


Fig.3(e). Gas expulsion curve for the Kuchma-1 well showing three distinct generation phases.

2. Paleocene-Eocene i.e., Cherra-Sylhet Limestone-Kopili Shale petroleum system

Similar studies have been carried out for the Madarganj-Sariakandi area (Hazipur-1 well) and Greater Bakhrabad (Bakhrabad-Mareichakandi-Belabo areas) gas fields area (BK-1, BK-9, and BK-10) and the results have shown the presence of petroleum systems as follows.

4.1.2. Slope Area: Petroleum systems in Hazipur-1 well:

1. Oligocene-Miocene i. e., Barail-Surma petroleum system
(Well penetrated only the upper part of Tertiary sequence of the Slope area where sediment thickness estimated around >7 km only therefore only one petroleum system could be determined)

4.1.3. Basin Area (Greater Bakhrabad : Bakhrabad-Mareichakandi-Belabo) gas fields area:

1. Miocene i. e., Bhuban-Bokabil (Surma Group) petroleum system

Petroleum systems in BK-9 Marichakandi Well

1. Miocene i. e., Bhuban-Bokabil (Surma Group) petroleum system

Petroleum systems in BK-10 Belabo Well:

1. Miocene i. e., Bhuban-Bokabil (Surma Group) petroleum system
(N.B.: It may be noted that the well depths of the BK wells are terminated within the Upper to Middle Miocene formations only.)

4.2 Determination of the kitchen area.

Desired location of Figure 4a & 4b

4.2.1. Shelf – Slope (Madarganj-Sariakandi) area:

Pseudo wells are synthetic wells prepared on the basis of seismic horizon depth maps at suitable locations in which lithological, temperature, pressure, porosity, vitrinite reflectance, rock-eval etc., data are generated by extrapolation from nearby wells.

It is apparent from the analysis of 3 pseudo wells in Madarganj-Sariakandi area that the kitchen area for oil

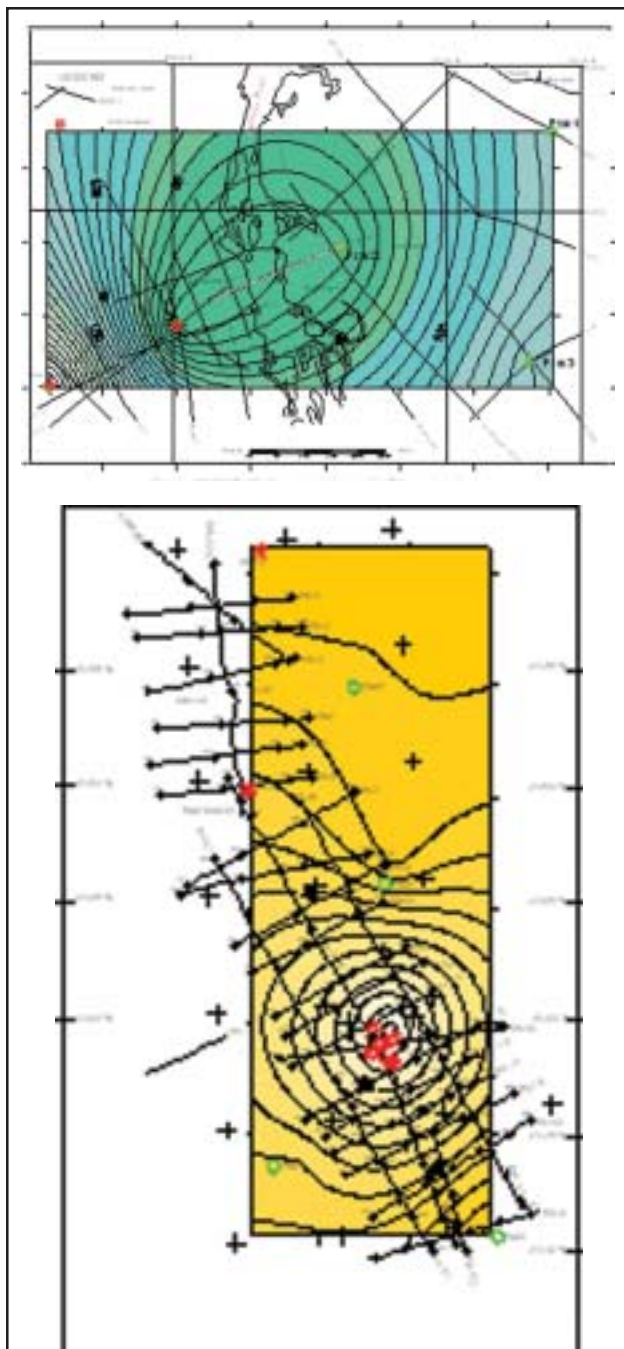


Fig.4 (a). Figure shows the total gas generation contour map of Madarganj-Sariakandi area. **4(b)**. Total gas generation contour map of greater Bakhrabad area.

is in the south-east of Bogra-1 well. (Figure-4a). Therefore deeper traps if any in the area might be charged with oil. Deep drill holes (>4500m) over the slope-basin area are required to this possibility. The gas generation contour maps shows that the kitchen for gas is towards the south-west

corner. This is a strong indication that Gondwana coal of the Bogra shelf area has contributed in the gas generation along with other source rocks.

4.2.2. Basin (Greater Bakhrabad) area:

In the greater Bakhrabad area i.e., Bakhrabad, Marichakandi and Belebo area, four pseudo wells Psw1, Psw2 and Psw3 were prepared (Figure-4b). Location of Pseudo wells. Analysis of BK-1, BK-9, BK-10 and four pseudo wells wells, shows that the potential source rocks belongs to the shales and carbonaceous shales of Brown, Red etc., horizons of Miocene age.

4.3 Petroleum system in Bengal Basin

It is now obvious from this analysis that three different petroleum systems are active in the Bogra Shelf area. They are 1) Gondwana (Permian-Carboniferous) petroleum system, 2) Cherra-Sylhet-Kopili (Paleocene-Eocene) petroleum system and 3) Barail-Surma (Oligocene-Miocene) petroleum System. It has been observed that the petroleum system of Bakhrabad is different from that of Madarganj-Sariakandi area. In Madarganj-Sariakandi the main source rocks belong to Gondwana, Kopili and Bhuban formations but in the case of Bakhrabad gas fields area, the Bokabil and Bhuban acted as the source rocks for hydrocarbon. The Bakhrabad gas fields area seems to belong to Surma basin petroleum system. BSS basin modeling of the Madarganj-Sariakandi area has also indicated that Gondwana over the shelf area (Kuchma-1 well) is both gas and oil prone and is still generating hydrocarbons. In the Bogra Shelf area the first phase of deposition took place during Permian-Carboniferous when Gondwana sediments were deposited in the rifted grabens. Presence of Permian-Carboniferous shales may provide excellent seals for interbedded sandstone reservoirs. Cretaceous Deccan Trap volcanics, Eocene marine limestones and shales may also contribute to reservoir sealing. Therefore Gondwana over the Bogra shelf could itself be a Petroleum system.

The Cherra-Sylhet-Kopili (Paleocene-Eocene) formations are distributed all over the Bogra shelf-slope and Surma and Faridpur trough area. BSS basin modeling of the Madarganj-Sariakandi area has indicated that Cherra-Sylhet-Kopili over the shelf area (Kuchma-1 and Bogra-1 wells) have produced both gas and oil and is still generating hydrocarbons. The Paleocene Cherra/Tura Sandstones, the Eocene fractured limestones and overlying younger sandstones may serve as the reservoir rocks. The Kopili Shale, tight limestones and Oligo-Miocene shales could be

the most effective seal for the system. The Paleocene-Eocene Cherra and Kopili Shales, with good hydrocarbon source potential can be the best candidates for charging not only for gases but also oil into this petroleum system. The expulsion of oil and gas from both the Cherra and Kopili Shales are continuing and may charge hydrocarbon into traps within lower and upper slope areas.

Oilgocene-Miocene i. e., Barail-Surma petroleum system possesses very thick sediments over the slope, basin and the folded belt areas. It has proven source rocks in the gas prone folded belt region and should have potential source rocks in the basin area. Depth of burial, maturation in the basin area should be sufficient for the generation of hydrocarbon. In the current study only Upper Surma-Tipam groups could be studied in the Bakhrabad area. Which comprises only part of the youngest petroleum system i.e., Oligocene-Miocene system. However, formations older than E. to M. Miocene and older formations appeared to be oil prone and seems very prospective for oil.

5. Conclusions

- 1) In the Bogra Shelf area three different petroleum systems are active. They are 1) Gondwana (Permian-Carboniferous) petroleum system, 2) Cherra-Sylhet Limestone-Kopili (Paleocene-Eocene) petroleum system and 3) Barail-Surma (Oilgocene-Miocene) petroleum System. However in the basin area only a part of the Oilgocene-Miocene system i.e., Bhuban-Bokabil formations (around Bakhrabad area) could be studied because of shallow wells.
- 2) Different formations of Bengal basin contains Kerogen of Type I, II and III in various proportions, though Type II is most common, Type III is less common and Type I is rare. They are capable of producing and have produced both oil and gas. The Lower Bhuban formation of Miocene Surma group in Bakhrabad area seems to be oil prone.
- 3) Basin modeling of the Madarganj-Sariakandi (Bogra) area has indicated that Gondwana over the shelf area (Kuchma-1 well) is both gas and oil prone and is still generating hydrocarbons. Since the coal bearing Gondwana basins are spread all over the Bogra Shelf area, this entire shelf area could be treated as Gondwana petroleum system. Huge Gondwana coal deposits of the Bogra Shelf area could be a source of hydrocarbon in the northwestern part of Bangladesh and future hydrocarbon exploration activities should be accelerated in the Bogra shelf and Slope areas.
- 4) In the Bogra (Madarganj-Sariakandi) area the possible kitchen for oil is in the south-east of Bogra-1 well. Therefore deeper traps if any in the area might be charged with oil. Deep drill holes (>4500m) over the slope-basin area are required to such possibility. The gas generation and expulsion contour maps shows that the kitchen for gas is towards the south-west corner. This is a strong indication that Gondwana coal of the Bogra shelf area has contributed in the gas generation along with other source rocks.
- 5) The petroleum systems of Bakhrabad is different from that of Madarganj-Saraiakandi area. In Madarganj-Saraiakandi the main source rocks belong to Gondwana, Kopili and Bhuban formations but in the case of Bakhrabad gas fields area, the Bokabil and Bhuban acted as the source rocks for hydrocarbon. Madarganj-Saraiakandi and Bakhrabad areas belong to different play areas. The Bakhrabad gas fields area seems to belong to Surma basin petroleum system.

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