PaperID **AU407**

Author **Amanjot Kaur , ONGC LTD , India**

Co-Authors **Sushil Kumar, Binita Mandal, Sushmita S Sengupta**

Petroleum Systems Analysis of Tripura-Cachar Fold Belt, Assam and Assam Arakan Basin, India

Abstract

Tripura –Cachar Fold Belt, part of Assam Arakan Basin, is one of the most challenging areas due to geological complexities and logistic difficulties. It hosts several hydrocarbon discoveries which prove a working petroleum system in the area and predominantly gaseous hydrocarbons indicate adequate source maturity. Till date source rocks and the kitchen remain an enigma. It is postulated that hydrocarbons have either generated /migrated through deep buried source rocks locally or that Surma Basin is the main kitchen for the hydrocarbons occurring both in Tripura - Cachar and across the border in Bangladesh.

Petroleum System(s) Modeling is carried out along E-W profile across Athramura-Batchia-Harargaj-Khubal anticlines in Tripura fold belt to understand the elements of petroleum system(s) and possible charging mechanism of traps in Tripura–Cachar. The effect of uncertain source data and stratigraphy on basin and petroleum system models is assessed through multiple simulation runs with varying model parameters. The model brings out Renji and Jenam formations (Oligocene) as the effective source rocks in the area and Jenam Renji-Bhuban Bokabil (.) as likely petroleum system in the area. Study indicates that traps can be charged locally given favourable source rock presence.

Introduction

Journey of hydrocarbon discovery and exploration in India began with Assam–Arakan Fold Belt, part of Assam and Assam Arakan Basin. The commercial discoveries are mainly restricted to Tripura-Cachar and Schuppen belt. Tripura-Cachar Fold Belt hosts a number of hydrocarbon discoveries and especially Tripura has been focus of exploration in light of recent success in Khubal. Still the full potential of the area is yet to be realized for the simple reason that petroleum system is least understood. In Tripura-Cachar most of the wells are drilled upto Mio-Pliocene sequence. The subsurface information about the source, reservoir and seals is constrained through drilled wells, which are terminated in the Upper and Middle Bhuban and a few wells in Lower Bhuban and Renji formations. Other than drilled wells, information from geological mapping and outcrop studies have given some inkling to Oligocene and older stratigraphy of the basin. This paper attempts to bring out the petroleum system(s) in Tripura-Cachar with its inherent uncertainties'.

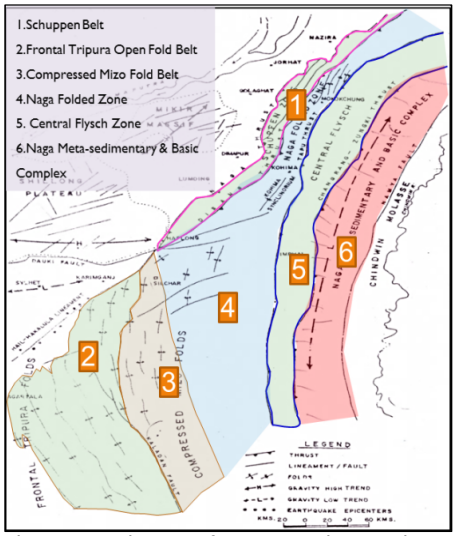

Fig.1: Tectonic Map of Assam-Arakan Basin (Adapted from B.M.Khar et.al.

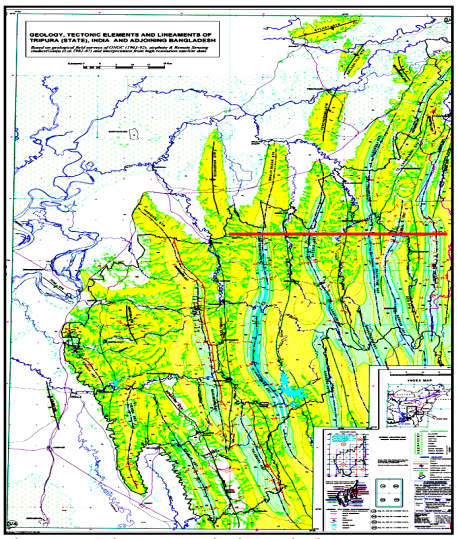

Fig.2: Study Area (Adapted from ONGC report)

Geology of the Area

The Assam–Arakan Fold Belt area is subdivided in six zones (Fig.1) based on their characteristic structural set up and physiographic occurrences. These are:

1. Schuppen Belt; 2. Frontal Tripura –Cachar Open Fold Belt; 3. Compressed Mizo Fold Belt; 4. Naga Folded Zone; 5. Central Flysch Zone; 6.Naga Meta-sedimentary and Basic Complex

The Tripura – Cachar Fold Belt consists of open, north-south trending en echelon, doubly plunging anticlines, separated by wide synclinal areas. Most of the anticlines have a topographic expression, may be fault bounded, are easily mapped and some are slightly arcuate to the west. The major anticlines and corresponding synclines in the area are long and arcuate, trending NNW-SSE to N-S to NNE-SSW from south to north with convexity towards west. Width of the syncline gradually diminishes from west to east where the folds become tight. The synclinal fold forms in the western and central part of the area are broad and wide. The fold belt is narrowed down to the south and gradually widens to the north (Fig.2).

Stratigraphy of the Area

The entire sedimentary column exposed in the area is constituted of sandstone, siltstone, shale, mudstone, sand rock and silt. Major stratigraphic units based mostly on lithologic characteristics are (1) Disang Formation of Eocene age is the oldest unit recorded in the region which is dominantly argillaceous. (2)These are followed by tidal to shallow marine Barail equivalent sediments of Oligocene age namely Liasong, Jenam and Renji respectively. (3) Surma Group (Miocene) consisting of a) arenaceous Lower Bhuban Formation (b) argillaceous Middle Bhuban Formation (c) arenaceous Upper Bhuban Formation and (d) argillaceous Bokabili Formation overlain by (4) Tipam Group (Pliocene). (5) The youngest Dupi Tila consisting of mottled clay, fine silt and laterite occupies the synclinal valleys to the west and overlies the Tipams over a pronounced unconformity (Fig.3).

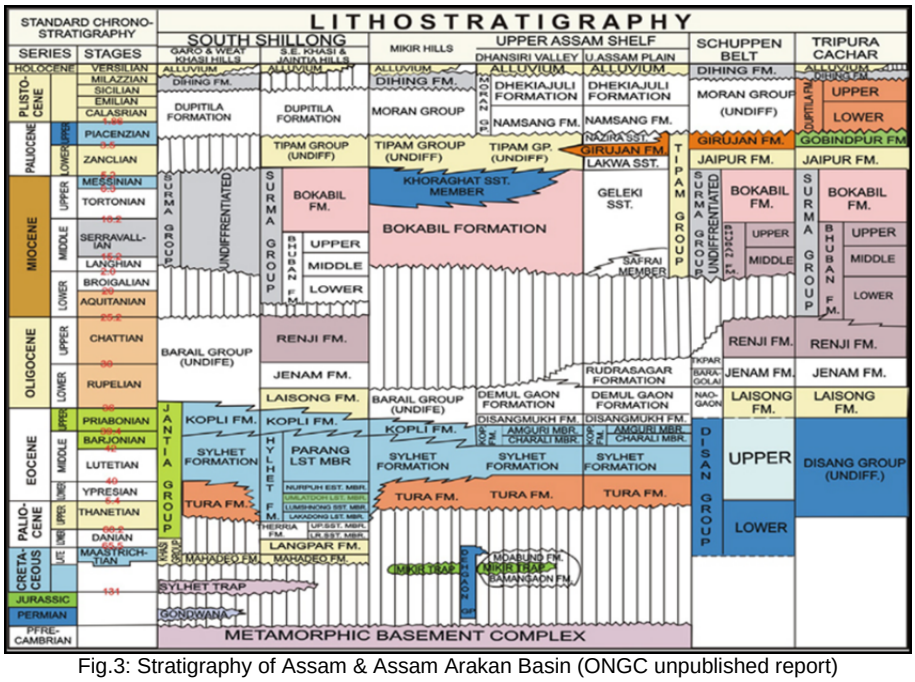

Fig.3: Stratigraphy of Assam & Assam Arakan Basin (ONGC unpublished report)

Petroleum System Modeling

Gaseous hydrocarbons pre-dominate the discovered hydrocarbons. A little oil has been discovered in few wells in Badarpur, Hilara and Masimpur fields of Cachar area. The presence of gaseous hydrocarbons in the region indicates that thermal maturity is sufficient to generate natural gas. There is no correlation of hydrocarbons in reservoirs with their specific source rocks, and hence the petroleum system in the areas are conjectural. Oligocene is widely assumed to be as most likely source rock. In neighboring Bangladesh, Curiale et al. 2002, opined that the Jenam–Bhuban Bokabil petroleum system alone is responsible for the generation of discovered gas in place, mostly in the Surma basin of the Chittagong-Tripura fold belt. Therefore it is postulated that the kitchen exists either in Surma Basin or there are local source pods buried deep contributing to the hydrocarbon generation. Thus, there is a need to understand the working petroleum systems and mitigate the

exploration risk in the basin. To test the hypothesis of generation of hydrocarbon from local source pods and effect of different modeled source rocks, a restored section through Atharamura-Batchia-Harargaj-Khubal anticlines was modeled through 2D TeckLink tool of PetroMod.
For a petroleum system to exist, elements like source, reservoir and seal in conjunction with the inherent processes are essential. Basin and petroleum system models encompass all the geological data to constrain the elements and inherent processes and provides scenarios. The impact of uncertain data has been studied by multiple simulation runs with varying model parameters.

Elements of Petroleum System

Source Rocks: In this area source rocks have not been identified with certainty, but is generally considered to be terrestrial with probably a minor contribution of Type II organic matter. The stratigraphic positions of the source beds are uncertain, and the hydrocarbons may have generated from relatively low concentrations of organic matter distributed throughout a large volume of sediments. Potential source rocks are deeply buried beneath the levels currently imaged on seismic reflection data and drilled well data.

Source rock sequence have been identified in 15 wells in Tripura-Cachar. The source sequence of these wells range from Renji Formation to Upper Bhuban source rocks. Mostly Upper and Middle Bhuban formations are organic lean and immature. Lower Bhuban is also immature in drilled section, having TOC ranges 1-2% and HI ranges 100-180 mg HC/g TOC but it can generate gas on achieving sufficient maturity. Late Oligocene (Renji) source sequence has an average TOC ranging from 1.38-4.42% and HI 122-246 mg HC/g TOC and is immature in drilled section. In Tripura_Cachar Fold belt stratigraphy older than Miocene are not exposed and therefore souce rock data for deeper stratigraphy is collated from the outcrop in Silchar –Shillong (Lubha river) and Silchar–Haflong (Barail range) traverses. Based on these studies Renji and Jenam formations were characterized as effective source rocks (Av TOC: 2-4.8%, Av HI 80-164).Source properties of Disang and Liasong Eocene formations are poor. In Silchar-Shillong traverses the carbonaceous shale of Renji and shallow Jenam formations are highly enriched in organic matter (TOC 9.75-30.8%, HI 123-368 mg HC/ g TOC) and Tmax values (448^{o}C) indicate main oil generation maturity (Natrajan, 2003).

Reservoir Rocks: The Surma Group consists of Bhuban and Bokabil formations of Miocene age. Lower and Upper Bhuban formations are predominantly sandstone. In general, their lithologies consist of deltaic, estuarine and shallow-marine sandstones, siltstones and shales that contain abundant plant derived organic matter, which produce gas and a minor amount of liquid hydrocarbons.

Seal: Shaly facies within Bokabil, Upper Bhuban, Middle Bhuban and Lower Bhuban with regional extent have acted as seals for upward migration and created favorable entrapment situations. Moreover, abnormal pressure regime in deeper the Bhubans' has also created a barrier for the upward migration of hydrocarbon.

For petroleum system model, depth to basement is a vital input. In the study area, the information about basement depth is not directly estimated as it has neither been imaged seismically nor drilled.The structural restoration in this area indicate that no structure existed in Tripura-Cachar prior to Pliocene. Speculative source rock sequences have been modeled in Disang, Jenam, Renji and Lower Bhuban to see their impact on generation and migration of hydrocarbons (Fig.4).

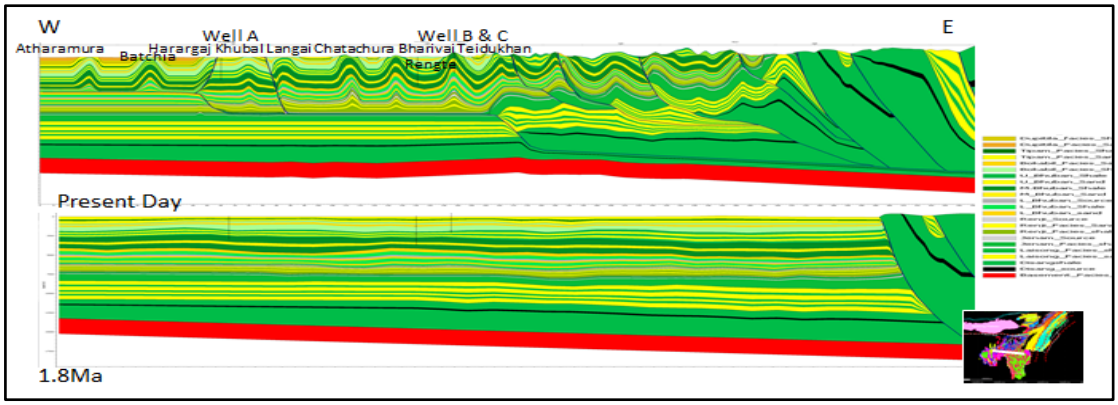

Fig. 4: Modeled profile showing sections at present day and 1.8 Ma

Generation and Migration

Model indicates that the oil window maturity present day is achieved at depth of 5000m. Observations from paleo time at 11 Ma indicate that Disang achieved dry gas to over mature window and is completely transformed. Present day it is over mature. At 1.8 Ma Jenam source rocks attain wet gas to oil window and transformations of ~90 % which continues through present day. Renji source rocks at 1.8Ma are in wet gas to late oil window maturity and are transformed ~ 75% of organic matter. This maturity and transformation ratio holds true for present day. It implies that Pliocene deformation and post Pliocene deposition in the area had little impact on source maturities (Fig.5 and Fig.6). Present day Lower Bhuban source rocks are also in oil window and have transformation ratios of close to 55%. In the west of the area they may be effective source rocks where they are likely to be at greater depths.

The gas analysis in the area favour a deep source by the carbon isotopic composition of methane which at ~39.0% (thermogenic gas) represents a gas past the oil generative window (Ro >1.2%).

The gas maturity corroborates maturity levels (Gas window maturity) of the two modeled Oligocene source rocks i.e. Renji and Jenam. It implies that Oligocene is the major source rock in the area but also Lower Bhuban source rocks are in the oil window maturity and can be effective source rocks west of the modeled area. Major structuration in the area is at less than 2Ma, it implies that most of the generated charge is lost for Disang source rocks and good amount charge for Jenam and Renji source rocks (Fig .7). Though there is a possibility of these source rocks to have charged sub-thrust prospects.

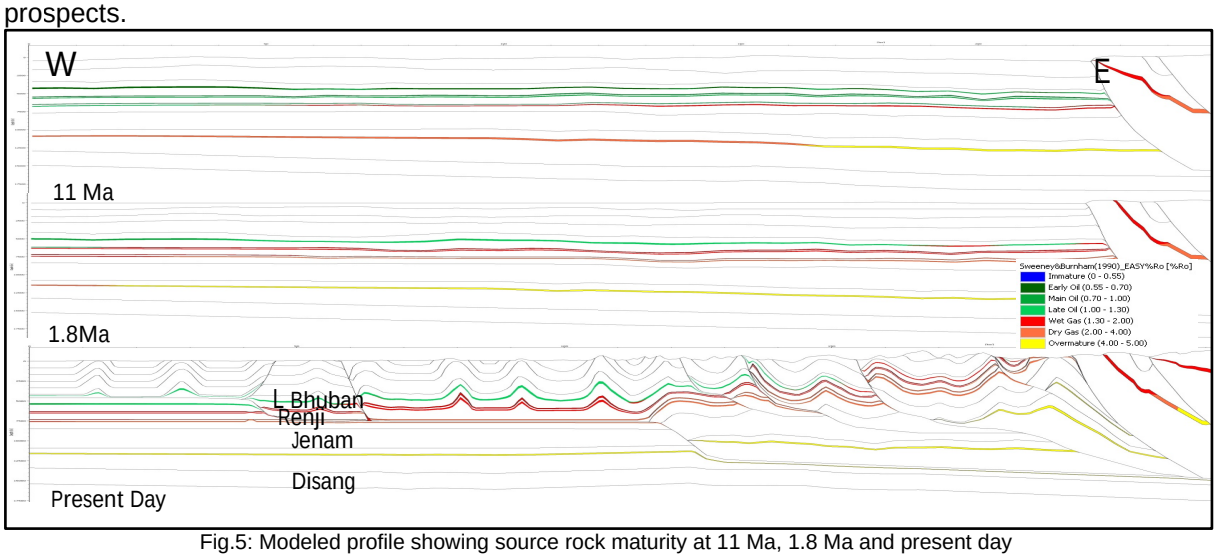

Fig.5: Modeled profile showing source rock maturity at 11 Ma, 1.8 Ma and present day

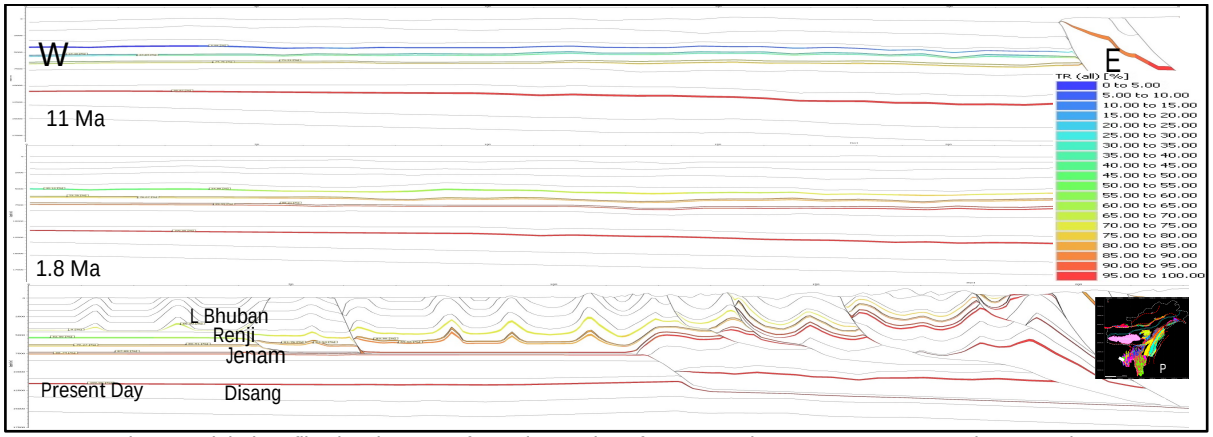

Fig.6: Modeled profile showing Transformation Ratios of source rocks at 11 Ma, 1.8 Ma and present day

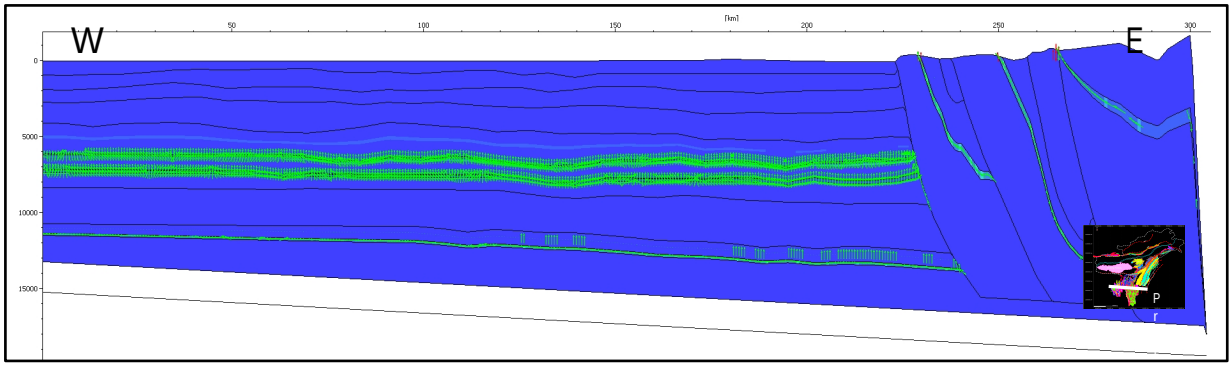

Fig.7: Modeled profile showing generation of hydrocarbons at 1.8 Ma

Migration pathways are complex and are generally vertical along faults and fractures and lateral through porous sandstones. (Fig. 8). Over pressured zones at depth have a control on migration and may impact seal integrity (Fig.9).Such zones in Lower Bhuban and Renji are believed to have significant future potential for gas resources. Future discoveries are expected within this over-pressured zone and in a great variety of stratigraphic and combination traps, many near known structures such as like Sundalbari.

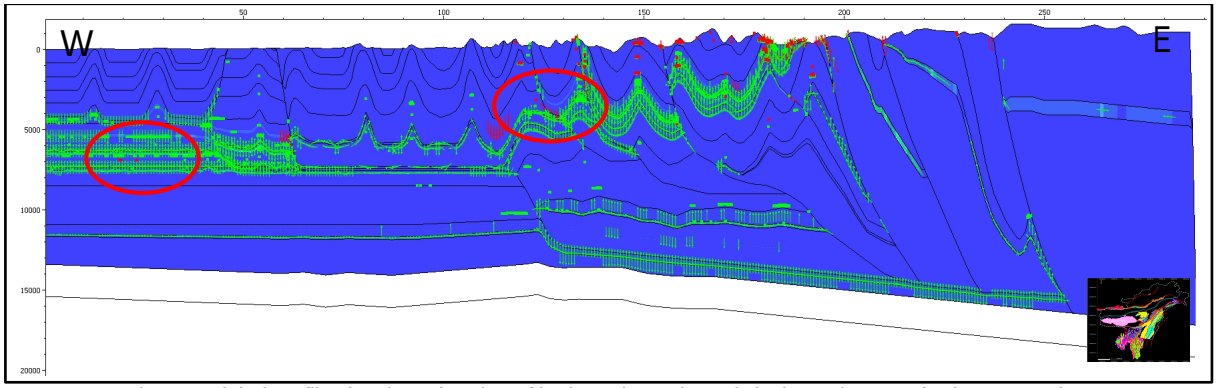

Fig.8: Modeled profile showing migration of hydrocarbons through faults and porous beds present day

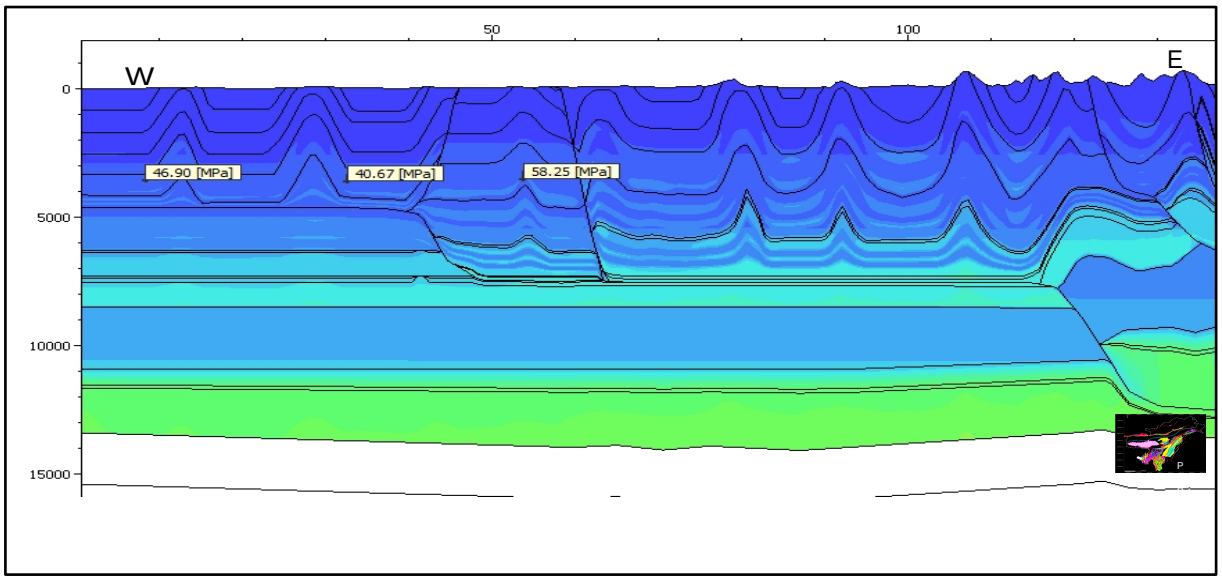

Fig.9: Modeled profile showing overpressures in Middle Bhuban

Entrapment: Potential source rocks from Oligocene to mid-Miocene age are within or have passed through the main gas-generating window prior to and during the development of the major anticlines. Charge analysis shows that most of the reservoirs are filled with hydrocarbons from Oligocene source rocks (Renji and Jenam Fig.10)).Primarily anticlinal folds serve as traps for hydrocarbons and these

structures have been forming since end of Miocene. Other trapping mechanisms such as stratigraphic traps and combination of structural and stratigraphic traps may also exist.
Based on the charge analysis Jenam Renji – Bhuban Bokabi(.) petroleum system is proposed in the area.

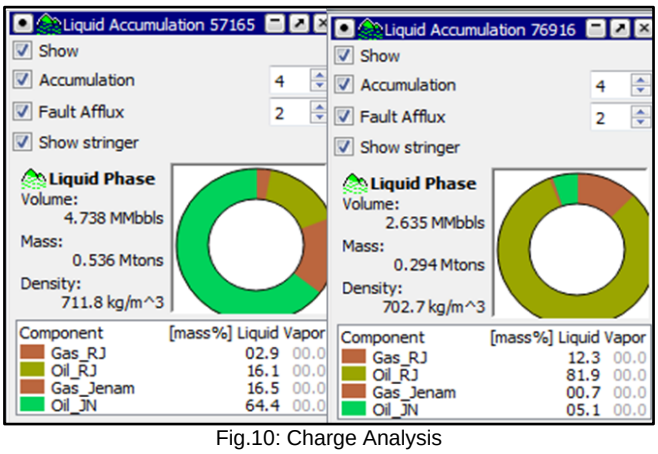

Fig.10: Charge Analysis

Conclusions

1) The source rocks at least buried to a depth of 5000m or below present day to be effective source rocks in the area.
2) Disang source rocks, which have poor source potential, are mature and transform completely prior to major trap formation in the area. However Disang in all likelihood may have charged sub-thrust prospects.
3) The effective source rocks in Tripura-Cachar Fold Belt are Oligocene source rocks i.e., Jenam and Renji which is also corroborated by carbon isotopic studies.
4) Model indicates that Lower Bhuban source rocks are potential source rocks and can be effective west of the study area.
5) Primarily anticlinal folds serve as primary traps for hydrocarbon accumulations.
6) Based on charge anlysis Jenam Renji– Bhuban Bokabil(.) petroleum system is proposed in the area.
7) Study brings out that the traps can be charged with the local generation given favourable source rock presence.
8) Lower Bhuban and Renji below over pressured zones are the future targets of exploration.

Acknowledgement

The authors express their sincere gratitude to Shri A.K.Dwivedi, Director (Exploration) for his kind permission to publish this paper. The authors are thankful to Dr. Harilal, ED-HOI KDMIPE, for his support in permitting the presentation and publication of this paper. Views expressed in the paper are of the authors and not necessarily of the organization they represent.

References

Deshpande, S.V., Goel, S.M., Bhandari, A., Baruah, R.M., Deshpande, J.S., Kumar, A., Rana, K.S.,Chitrao, A.M.,Giridhar,M., Chaudhuri,D.,Kale,A.S and Phor,L. 1993. Assam-Arakan Basin, Lithostrstigraphy of Indian Petroliferous Basins, Document-X, ONGC unpublished report

Dotiwala,F., Dotiwala,S., D.S.Mitra and Mullick,A.K. 2001. Digitized Geological Map of Tripura-Cachar-Mizoram. Unpublished ONGC Report

Evans, P. 1964.The Tectonic Famework of Assam. Jr. Geol. Soc. India. 5, 80-96

Khar, B.M and Ganju J.L, Tectonics of Tripura Folds-Probable Mechanics of Folding and Faulting. Petroleum Asia Journal, April 1984, pp.66-70

Magoon LB and WG Dow (eds.), 1994. The Petroleum system-From source to trap.
AAPG Memoir 60. Tulsa: American Association of petroleum Geologists, pp. 3-24

Curiale J. A., Covington G. H., Shamsuddin A. H. M., Morelos J. A. and Shamsuddin A. K. M.,2002. Origin of Petroleum in Bangladesh. AAPG Bulletin, v. 86, no. 4 pp. 625–652