BASIN MODELLING STUDIES OF THE NORTH AND SOUTH ASSAM SHELF REGION

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

INTEGRATED MASTER OF TECHNOLOGY

in

GEOLOGICAL TECHNOLOGY

By

SAUVIK DAS

DEPARTMENT OF EARTH SCIENCES
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE - 247 667 (INDIA)

JUNE, 2012

CERTIFICATE

I hereby solemnly declare the work presented i) this dissertation, entitled ***"Basin Modelling Studies of the North and South Assam Shelf Region"*** *in partial fulfilment of the requirements for the award of the degree of* ***'Integrated Master of Technology'*** *in* ***Geological Technology*** *submitted to the* ***Department of Earth Sciences, Indian Institute of Technology Roorkee,*** *is an authentic record of my own work carried out during the period August 2011 to June 2012, under the supervision of* ***Dr. Vir Narayan Singh,*** *Professor, Department of Earth Sciences, I.I.T. Roorkee and* ***Mr. Sumit Kumar Chakrabarti,*** *Chief Geologist, KDMIPE, ONGC Dehradun.*

The matter embodied in this dissertation has not been submitted by me for the award of any other degree of this or any other institute.

Date: 15/06/12
Place: Roorkee

Sauvik Das.
(SAUVIK DAS)

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Date: 15/06/12
Place: Roorkee

V. N. Singh

V. N. Singh
Professor
Department of Earth Sciences
Indian Institute of Technology Roorkee
Roorkee-247667 (Uttarakhand)

S.K. Chakrabarti
Chief Geologist
KDM Institute of Petroleum Exploration
Oil & Natural Gas Corporation Ltd.
Dehradun- 248195 (Uttarakhand)

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Sauvik Das

IIT Roorkee

ABSTRACT

The North and South Assam Shelf is one of the well-explored regions in India with lots of geological and geophysical data available chiefly because of the hydrocarbon exploration in the region. Different workers have done extensive petroleum systems modelling in these regions. For some further study purposes, a region has been chosen in the South Assam Shelf for the basin modelling purpose where there are only fewer modelling activities been conducted till date. Only fewer wells in the region have oil/gas signatures. So the study can give any new results regarding the hydrocarbons findings. However, the extensive basin modelling study conducted on one such section of 33 kilometres which also advances into the deeper regions of the Naga Thrust along with the geochemical data from the surrounding wells, shows that although there is enough of organic matter in the region, but there isn't any enough of the cooking conditions to generate and expel the petroleum from its pores. So from this study it is confirmed that the region selected in the South Assam Shelf, has little or almost no potential to generate the hydrocarbons. This study also concurs with the findings of the previous workers who have studied the surrounding areas of the same region in South Assam Shelf.

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CHAPTER 1: Introduction

1.1 Basin Modelling

Basin Modelling is the modelling of the geological processes in sedimentary basins over geological time spans; dynamic modelling is also ensured to bring in the effective changes in case of temporal changes of the subsurface conditions. A basin model is simulated through the geological time starting from the deposition of the oldest layer of the sediments until the entire layer of the sediments has been deposited till the present day. While conducting the basin modelling studies several geological processes are calculated and updated at each time step. Most important of these are the deposition, compaction, heat flow analysis, petroleum generation, expulsion, phase dissolution, migration and accumulation. The work undertaken will help to understand the genetic linkage to the accumulation of hydrocarbons.

Basin Modelling is highly important in determining the scale of the petroleum systems that are present in the area of the study and assessing the risk in exploring the hydrocarbons from the region associated with each of the elements of a pre-determined petroleum system e.g. organic matter richness, sufficient source volume, adequate source rock maturity, appropriate timing of generation relative to timing of the trap formation etc. One of the identified challenges includes uncertainties on heat flow, source rock properties and kinetics, which come under the geochemical domain of the investigation. Primary applications of the basin modelling are heat flow calibration, source rock maturation, charge estimation, generation, expulsion and migration of the hydrocarbons in the trap, timing of the oil and gas generation and finally petroleum system analysis. The thermal maturity components of the model are calibrated with various petrographic and geochemical thermal maturity parameters e.g. vitrinite reflectance, Rock Eval data, Tmax, etc. measured on rocks and biomarker maturity parameters measured in the oil. Possible choices for source rock kinetics data include either kinetic data from analogous source rocks or custom source rock kinetics data specific to the source interval in the model.

The process of basin modelling studies gives estimates to the various important queries like the volume of the petroleum expelled from the source rock, the petroleum losses due to migration, the quantity of the petroleum delivered to the trap. All these values are highly essential in determining the economic viability in production of the petroleum from the corresponding petroleum reserve.

1.2 Earlier studies in the Assam region

North East India had the first oil well in India when oil was struck at Makum near Margherita in Assam back in 1867. Then the Digboi oil field discovery in the Upper Assam started the new era in the oil exploration in India. After that more than a hundred oil and gas fields has been drilled in the region. The area has been thoroughly studied by several workers and other associated research bodies, with large volumes of the geoscientific data which has been derived especially due to the commencement of the petroleum exploration in the region. Since the inception of the Oil and Natural Gas Corporation in 1955 the studies has been focussed at optimizing the production from the region. Basin modelling studies has been one of the major attempts at understanding and optimizing the petroleum systems in the region.

Basin Modelling studies for the Assam Arakan basin was carried out by K.C. Balan et al. with the help of available 2D seismic and sparse well data. The IFP-ONGC collaborative project attempted at petroleum system modelling in the basin for the available geochemical data in Assam Arakan fold belt and adjoining Assam Shelf region. Prof. Bally et al. (1997) made a vivid review on some of the work done by the earlier workers in his report entitled 'Hydrocarbon potential of Assam Arakan basin' and also recommended some future guidelines for future exploration work and strategy. IFP, France had also attempted petroleum system modelling and analysis based on limited data. Since then a large volume of geological and geophysical data has been acquired in the Basin and the state of art technology such as Sclumberger Petromod 2D and 3D has been inducted in ONGC.

Petroleum system modelling studies require a region with ample G&G data and the region of the North and South Assam Shelf region thus has been selected for carrying out of further investigations. The region has several wells that have been drilled for the hydrocarbon exploration; some had oil and gas signatures while others have been dry. But all such drill data/samples have provided invaluable information of the region. Apart from that the seismic data has also furnished us important subsurface information regarding the various layers/horizons/formations and the faults in the region. All the necessary data will be utilised to reach at the final conclusion.

CHAPTER 2: Objective and workflow

2.1 Objective

One seismic section is chosen from South Assam Shelf for analysis along with the geochemical and lithological data from the three nearby wells for 'petroleum systems modelling' including oil/gas accumulation locations and potential to expel the hydrocarbons etc.

2.2 Workflow

- To be able to read the well completion reports, geochemical reports and other related reports of each of the wells in the working area and extract the necessary data.

- To interpret the various maps that has been prepared of the region e.g. TOC map, heat flow maps, temperature distribution map, present day temperature distribution maps, maturity distribution maps, gas/hydrocarbon generation potential maps, oil/gas quantity maps etc.

- To prepare well log correlations between the wells present along the seismic line(s) chosen or in close proximity of the line and correlated between the same formations of the different wells by correctly balancing the well log data and the data from the well correlation reports.

- To prepare the seismic depth section using the geological software Landmark® Openworks Seisworks/Superseisworks. It includes the properly marking of the horizons and the faults as well as agreeing with the correlated well logs from the previous step mentioned.

- To transfer the prepared image to the Petromod® to retrace the horizons and the faults and grid the data to determine any discontinuity, input the data for the faults and the facies, prepare the model the model for simulation by introducing the various boundary conditions like Paleo Water Depth (PWD), Sediment Water Interface

Temperature (SWIT), Heat Flow (HF) and simulate the model with few other specifications as per the user requirements.

- To correctly interpret the simulated results like source rock, reservoir rock, cap rock, the migration path, production from the source rock, production potential, and amount of hydrocarbons trapped within the reservoir rock, gas/oil ratio of the produced hydrocarbons, pressure, temperature etc.

CHAPTER 3: Discussion regarding the Area of Study

3.1 The Area of Study

The area of study chosen for my work is in the Assam Basin which is located in the north-eastern part of India (see Fig. 3.1). The Basin has thick sediment deposition ranging between five to seven kilometres. This is a Mesozoic Tertiary basin with the oldest known sediments to be deposited in the Early Cretaceous age. The oil and Natural Gas Corporation Limited since its inception has carried out systematic surface geological mapping and geophysical surveys of the areas since 1957, besides drilling several hundreds of wells for the hydrocarbon exploration and production. All these activities have helped to generate substantial geoscientific data.

One seismic section in this region has been chosen to conduct the Basin Modelling studies in the 2-Dimensional Petromod. From the Fig. 3.2, the *blue* box region towards the south is the approximate area from where the various geological and geophysical data are being utilised for the study. Three nearby well completion data along with various geochemical data of the region has also been gathered to conduct the analyses.

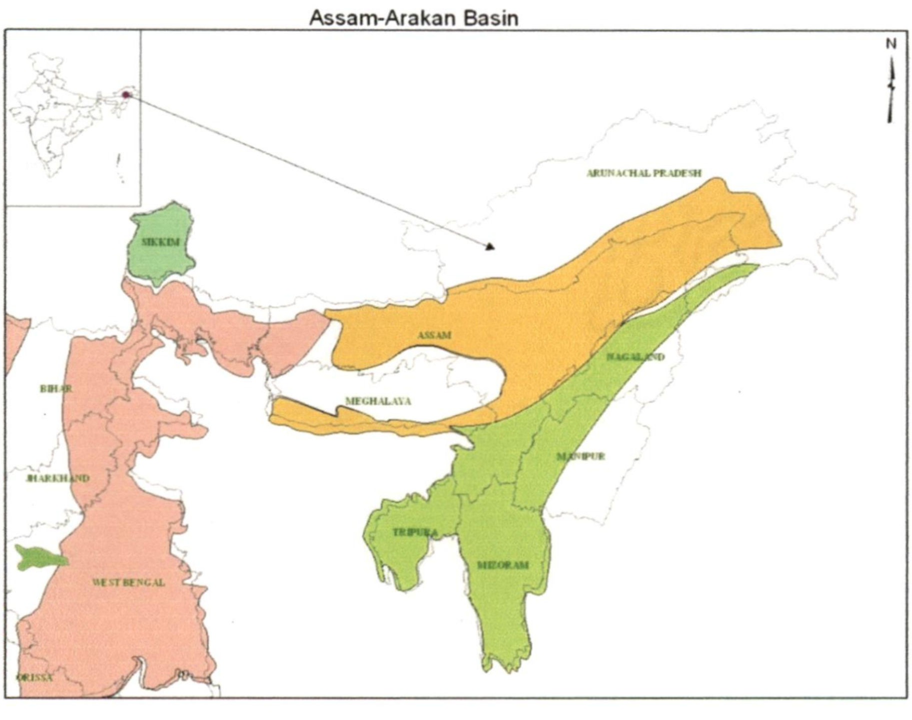
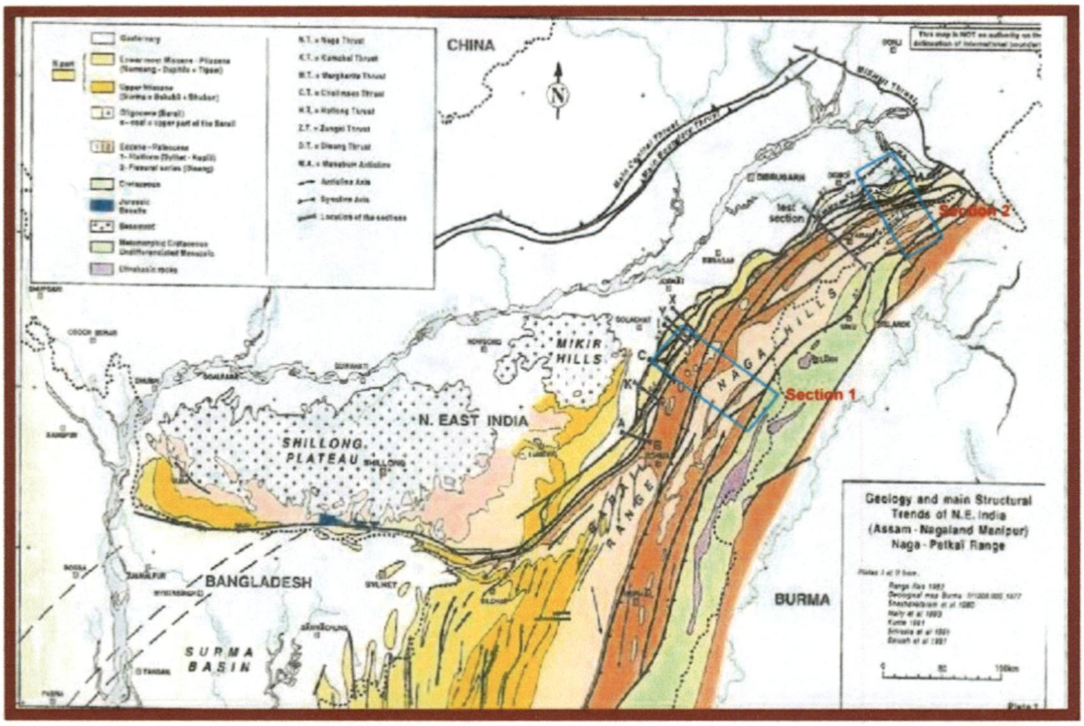


Fig. 3.1: Assam Arakan Basin (the area marked in *orange*)

Source: dghindia.org

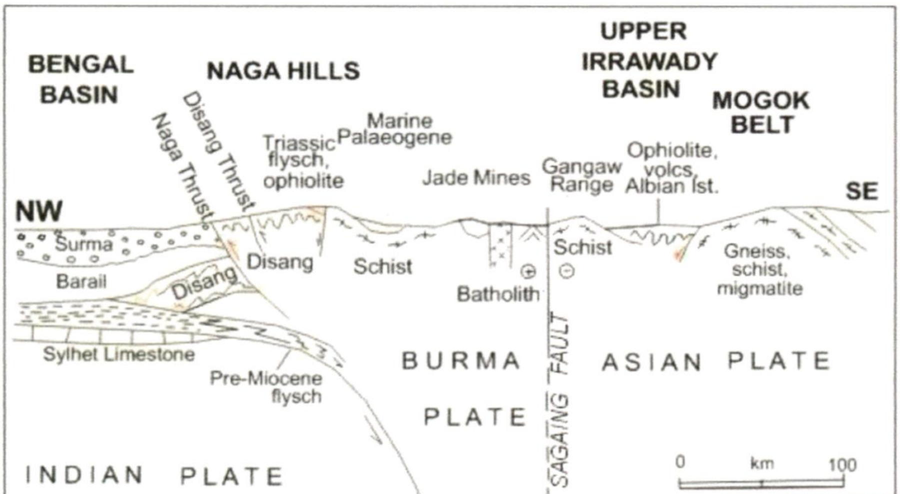


Source: KDMIPE, ONGC

Fig 3.2: Figure showing broadly the areas from which seismic lines and the wells that have been selected for 'petroleum systems modelling'

3.2 Geomorphology and basin architecture

The Brahmaputra River forms the major drainage system to the north of the Barail Range and the Naga Hills. This drainage network has resulted in the deposition of upto 2500 m of alluvium over the pre-existing older sediments. The Brahmaputra Valley gradually slopes towards southwest and west.



Source: KDMIPE, ONGC

Fig. 3.3: Schematic Geological Cross-section across the Brahmaputra Valley

The schematic geological cross-section (in Fig. 3.3) across the Brahmaputra Valley shows the presence of a broad arch at the basement level. The crest of this arch lies very close to the present course of the Brahmaputra River. This basement arch slopes both towards the Himalayan foothills on the northern end and towards Naga Hills towards the south. And the basement slopes towards the northeast, the deepest part being in front of the Mishmi Hills. This broad arch is divided into a number of smaller faults with general strike of NE-SW due to the subduction activity along the Naga Thrust region to the South west.

In this region the structural pattern in the sedimentary cover is largely controlled by the irregularities in the basement topography as has been indicated by the gravity data and by differential movements along the faults. A good matching exists between the observed gravity anomalies and structures in the sedimentary cover. The structures are typically gentle domes or elongated gentle anticlinal folds which are being dissected by numerous faults. These structures were later modified by the reactivation of the faults during the Late Oligocene and the Miocene time.

There has been an almost continuous sedimentation from the Cretaceous to the recent times through Tertiary period, accumulating enormous thickness of sediments. As per the basin fill map prepared on the basis of gravity magnetic, seismic and well data, the sediment thickness seems to decrease in value towards the Shillong Plateau and Mikir Hills as expected. In the area north of Brahmaputra the thickness of the paleo-sediments increases greatly around Lakhimpur which has a deposition of more than 6000 m of sediments.

CHAPTER 4: Methodology adopted

As a part of the executed work, well completion reports were used extensively which required adept handling of the various essential information are contained e.g. regarding the well drilling initiation, all the well activities undertaken, recording data regarding the lithology encountered as well as all the approximate formations that was found while drilling. Some of the reports are also accompanied by the printed well logs that were recorded at the same time. Chiefly the task demanded gathering of the lithology and the recorded formation tops from the well completion reports.

The 'petroleum systems modelling' requires various geochemical data like the Total Organic Carbon (TOC) values, Hydrogen Index (HI) and the thermal values like the heat flow data, sediment water interface temperature (SWIT) data etc. TOC, HI values are mostly available from the geochemical reports that are being prepared at the various geochemistry laboratories of the Petroleum Exploration Institutes. Since geochemical analyses are both costly as well as time consuming, only some of the drilled wells are being conducted for the geochemical studies. While working, the geochemical data were collected from the reports of the North Assam Shelf; whereas the geochemical data pertaining to the South Assam shelf were collected from the concerned laboratory personnel at KDMIPE.

TOC maps, organic matter maturity maps, gas/hydrocarbon generation potential maps, temperature distribution maps were extensively consulted for the purpose of the data collection. The contoured maps are very effective in estimating the geochemical and the heat values even in the areas where there is almost little and no data.

The correct data acquisition is of very large importance in modelling of the petroleum systems, since on the basis of the instruction sets, data and parameters provided from the user end, all the operations and simulations are going to be carried out in Petromod. In cases of the little or no data, we need to either collect the data from the nearby areas or make a rough estimate of the values.

The next part of the data acquisition and data analysis are being conducted on the seismic data followed by the transfer of the traced seismic section to Petromod and further feeding of geochemical data to derive at the results. It is further discussed in the Chapter 6.

CHAPTER 5: Description of the Encountered Formations

In this section brief descriptions of the formations that have been encountered in the latest seismic section and the nearby wells. The formations have been arranged from the bottom to the top as below:

A. METAMORPHIC BASEMENT COMPLEX

The sedimentary rocks in the Assam Basin are known to rest on the Pre-Cambrian crystalline rocks belonging to the Shillong Plateau. These rocks were later studied in detail by the Geological Survey of India and found to be outcropped in the two major areas of Shillong Plateau and the Mikir Hills. Later the drilling activities due to the hydrocarbon exploration in the area has confirmed their presence in several more areas like the sub-surface areas of the South Shillong Plateau, Dhansiri Valley, Upper Assam and parts of the Schuppen Belt.

These granites have been indicated by several names in a variety of literature both formally as well as informally e.g. Shillong Granite, Shillong Series, Mikir Granite etc. The basement encountered in the present study is informally referred to as the Metamorphic Basement Complex (M.B.C.). This is particularly to include all the crystalline rocks found at the base of the sedimentary sequence and formed before the oldest known sediments of the basin.

B. GONDWANA (UNDIFFERENTIATED)

Nomenclature: The exposure of the Gondwana sediments in the Assam Basin is very uncertain and there have been only fewer exposures. In the region that I have picked up for the study till now there have been only two wells where there is presence of the Gondwana.

But since there is very little significance of these sediments, all the Upper and Lower Gondwana along with the Traps sediments (thickness approximately 20-30 m) have been clubbed together to form the Pre-Tertiary sediments to indicate all the depositional events and products before the Tertiary Period.

Extent: As per the previous records there has been very few presence of the Gondwana which has been observed only around the South Assam Shelf and the adjacent South Shillong Plateau.

Description: The reports show the lithology of the gritty sandstones with few carbonaceous shales present in the exposure.

Thickness: There is no precise data about the thickness of the Gondwana as it varies largely. Some areas may show a thickness from few hundred metres; however adjacent areas within a few kilometres may have only a few metres of the tailing. Any typical Gondwana is also observed to be bounded by two sets of faults forming a grabben-like feature. To be more specific generally we encounter a half-grabben feature, where the sediment thickness quickly decreases to the minimum before the bounding fault arrives on the other end.

Fossil Content: Presence of the typical Lower Gondwana plant fossils viz. *Vertebrartia indica* and gymnospermous rhizomes etc.

Age: The age of the sediments as per the literature ranges between Carboniferous and the Lower Triassic.

Depositional Environment: It is deposited in the continental environment.

C. SYLHET TRAP FORMATION

Nomenclature: Medlicott (1869) recorded the presence of the basaltic volcanic rocks at the base of the sedimentary sequence in South Shillong Plateau. Later workers established the extent of the area and assigned the rank of the formation.

Extent: The extent of the Sylhet Trap Formation extends all along the Khasi trough from Jadukta River to Dauki with average outcrop width of 3-4 km.

Boundaries: It has an unconformable relationship with the underlying Metamorphic Basement Complex.

Description: Sylhet Trap consists of a number of the dark to bluish grey basaltic and andesitic flows with individual thickness of 6 to 8 m. Since the thickness of the trap is very small and almost undetectable in the seismic studies, it has been clubbed with the Upper and the Lower Gondwana lying below, if present to form the Pre-Tertiary sediments.

Thickness: In the subsurface areas, especially to mention in the region of the South Assam Shelf the well completion reports have shown the presence the Sylhet Trap with thickness not more than a few metres. Not much of a signature is available from the seismic data, however their presence can be read from the well completion reports.

Age: The sediments from this formation may have an age varying from Upper Jurassic to the Lower Cretaceous.

D. SYLHET FORMATION

Nomenclature: The sequence of the fossiliferous limestones alternating with the sandstones outcropping along the southern edge of Shillong Plateau were named Nummulitic series by Medlicott (1869), Evans (1932) used the name Sylhet Stage for limestone-sandstone sequence in the South Shillong Shelf. Wilson and Metre (1953) separated lowermost limestone and sandstone into Tura sandstone and remaining limestone and sandstone were grouped under Sylhet Limestone stage.

In Mikir Hills and in the subsurface of the Upper Assam and the Dhansiri Valley the Sylhet Formation is not differentiated into Members.

Extent: The outcrops of the Sylhet Formation are found all over along the Southern edge of the Shillong Plateau. When looked for northwards, some presence has also been there in the Kopili valley. It is also exposed along the Southern fringes and some rifted parts of the Mikir Hills. These keep on continuing along eastwards and north-eastwards along the sides of the Mikir Hills. Here the Sylhet Formation continues in the subsurface of the Dhansiri Valley and the Upper Assam as well as in the sub-thrust of the Schuppen belt.

Boundaries: It has a conformable relationship with the Tura Formation at the bottom and slowly grades upwards into the Kopili Formation which is to be discussed in the subsequent paragraphs.

Description: The lithologic description is a little bit complex as it has alternate layers of the limestones and sandstones. However, in certain areas it has also shown a lithology with the inclusion of the calcareous shales accompanied by the limestones; where the percentage shales decreases upwards.

Thickness: Thickness has been observed to be varying from a few hundred of metres to just within a metre. In the South Assam Shelf particularly, the formation thickness varies just around a hundred metres with high organic content. This has contributed it to be the major source rock of the hydrocarbons.

Stratigraphic Relation: In Garo Hills and its North it has shown the inter-tonguing relationship with the Tura Formation. In Mikir Hills the underlying Tura grades into the Sylhet with increasing content of the limestones. The Sylhet Formation has also been observed to grade into the overlying Tura Formation; however due to the absence or very thin presence of the Tura Formation in the South Assam Shelf, nothing of the sort of conclusion can be arrived at. But there may be some indications of such grading from the North Assam Shelf regions.

Age: The Sylhet Formation ages between Early and Middle Eocene.

Depositional Environment: In Shillong Plateau it represents deposition in shallow shelf area and the sedimentation is interrupted by either the changes in sea level or short pulses of increased clastic supply. In other parts it represents deposition in the shallow shelf deepening towards North-East and South of Mikir Hills.

E. KOPILI FORMATION

Nomenclature: Medlicott (1869) had grouped the Eocene rocks of the South Shillong Plateau in his Nummulitic Series. Evans for the first time pointed out a dominantly shaly sequence overlying the Sylhet Limestone stage and named it as the Kopili Alteration Stage or Kopili Stage. Later on it was given the status of the formation. Presently Kopili is defines to contain a shale dominated sequence occupying a position between Sylhet at the bottom and the Barail above it.

Extent: Kopilis are exposed as the narrow linear outcrops in the Garo, Khasi and Jaintai Hills, along the Southern edge of the Shillong Plateau due to steeper dips. Whereas in the Kopili Valley and along the fringes of Mikir Hills these rocks have wider outcrops due to the gentler dips in these regions. These rocks have extensive presence in the subsurface of the Dhansiri Valley and the Upper Assam and continue below the sub-thrust of the Schuppen Belt.

Boundaries: Kopili Formation is seen to overlie Sylhet Formation conformably with grading feature. Lithologically the contact is considered at the base of the shale dominated sequence which overlies the continuous limestones. On the other end, Kopili Formation is overlain by the Barail Formation with sometimes a sharp contact, otherwise a gradational contact. To identify lithologically, the boundary is at the top of the shale dominated sequence which is overlain by the massive sandstones or inter-bedded sandstone-shale sequence.

Description: A Barail is composed of a mix of sandstones (ferruginous) carbonaceous sandstones and grey shales which also accompanied by the fossiliferous mudstones. Generally the lithological composition varies with a combination of all the above dominated by some.

Thickness: Its thickness varies from a wide range of 500m in South Shillong Plateau to 135m in the Dhansiri Valley. In the North Assam Shelf it has thickness of around a hundred or two. In the region of the South Assam Shelf it shows a trend of thickness of not more than a hundred metre.

Stratigraphic Relation: The Kopili Formation shows a lateral gradation with the underlying Sylhet Formation both in the Shillong Plateau and in the subsurface. It has a gradational relationship with the overlying Barails.

Depositional Environment: The Kopilis represent the regressive deposits subsequent to the major transgressive event during the Sylhet Formation. As referred earlier that the lower part of the Kopili Formation represent lateral facies variation of the Sylhet Formation. There are suggestions of the sediments to be sourced from the lagoonal environment. Mostly we can find the presence of carbonaceous matter, thin coal streaks and few disseminated pyrite along with phosphatic noodles association to support the idea of lagoonal or highly saline depositional conditions. The rocks from the upper part are found to be from the oxidising environment with disseminated carbonaceous matter. As of finally, the basal part of Kopili is deposited in the Inner Shelf environment. This with overall regressive trend suggests the littoral to sub-littoral environment with certain deposits of the Inner Shelf regions too. Rao (1983) advocated that if any delta existed in Kopili, it had formed in the north-eastern part of the Upper Assam.

F. BARAIL FORMATION

Nomenclature: The term 'Barail Series' was applied to the strata, mostly of the Oligocene age, overlying the Disang or Jaintai or Kopili and underlying Surma or Tipam or Bokabil Series. In this exercise, the nomenclature has been in accordance with the one proposed by Evans (1932). The Barail Formation encountered in the Upper Assam and Dhansiri Valley are subdivided into Disangmukh, Demulgaon and Rudrasagar Formations in order of superposition.

Extent: These sediments are extensively encountered in the subsurface of the Upper Assam and the Dhansiri Valley. The Barail sediments outcrop extensively in the Eastern part of the Fold Belt, Schuppen Belt and in the Barail Range in North Cachar. Thin outcrops are also found along the South Shillong Plateau.

Boundaries: In the Assam shelf region they conformably overlie the Jaintai Group or the Kopili Formation. And in most part of the basin the Barail sediments is unconformably overlain by the Surma Group or the Tipam Group. However, in the present area of study we can't distinguish between the Tipam and the Girujan; hence together they overlie the Barail Formation as the undifferentiated Tipam. Except in the Tripura-Cachar Fold Belt the contact overlying the Surma sediments is apparently conformable.

Description: The Barail group predominantly consists of arenaceous sediments with finer clastics and coal in the upper part. The presence of the coaly facies helps to distinguish Barails from the overlying slightly coarser massive bedded Tipam and the underlying carbonate sediments of the Surma Group.

Age: From several wells it has been noticed, that the Barail Formation belongs to the Late Eocene and the Early Oligocene.

Depositional Environment: It is usually interpreted to have deposited in the deltaic environment. Some of the fossils also have certain indications of marine influence.

G. BOKABIL FORMATION

Nomenclature: Originally Evans proposed the Bokabil stage within the Surma Series. After that many workers have refined the idea. Later on while drilling a well for hydrocarbon exploration in Khoraghat-Uriamghat area, sandstones with minor shales were encountered. These unit within the formation were found in the subsurface of the Dhansiri Valley and the present Mikir Hills. This is presently recognized as the Khoraghat Sandstone member.

Extent: Bokabil Formation is traceable from the western extremity of the Garo Hills and along the Southern Margin of the Shillong Plateau in discontinuous outcrops. Further east, after the Barail outcrops in North Cachar Hills it is again present in the Mikir Hills. It is exposed in the Barail Range and Tripura-Cachar-Mizoram area and Schuppen Belt. In subsurface it is encountered in wells drilled in Dhansiri Valley, Cachar and Tripura.

Boundaries: In the designated area of the study it unconformably overlies the Barails or pre-Barail sediments. The upper contact with the Tipam Group is however conformable and also sometimes gradational.

Description: It is majorly consisting of the laminated shales, clays with interbedded silts and sands. In certain areas there can be minor presence of the siltstones and the sandstone.

It is further subdivided into three separate units as (i) Upper Bokabil or the Khoraghat Sanadstone (ii) Middle Bokabil (iii) Lower Bokabil. From the electrologs, the Middle Bokabil can be easily distinguishable as it varies from both the overlying Khoraghat sandstone and the underlying Lower Bokabil, due to the higher shale content. However, the Khoraghat sandstone is more prominent by the thickness as it consists of the Bokabil formation in comparison to the lower two units.

Thickness: The thickness of the formation can vary as widely as the 1100m in the Tripura region to almost 400m in the Schuppen belt. In the South Shelf region majorly we can find variation of thickness above 400m. Along the seismic section 1 the wells show a thickness of about 400 – 600m.

KHORAGHAT SANDSTONE MEMBER: The member is exposed in an arc like tract along the margin of the Mikir Hills. It gradationally overlies the shale dominated section which can be demarcated as the Middle Bokabil. It slowly grades upwards into the massive sandstones, of undifferentiated Tipam Group. However there is presence of the interbedded shales within the sandstones, however its thickness and the occurrence decrease on moving up. Basically it is a constant gradation from the Middle Bokabil shaly sequence. This unit also has distinct depositional structures like cross laminations, trough cross-bedding, ripple marks and upwards coarsening cycles.

Fossil Content: Abundant fossils especially planktonic assemblages are found in this region.

H. TIPAM GROUP (UNDIFFERENTIATED)

Nomenclature: Evans (1932) amended the previous definition to include the Tipam sandstone, Girujan Clay within it. Usually Tipam Series is bounded by two unconformities within its typical area. Later on the classification and nomenclature was modified by Bhandari (1973) to differentiate Tipam into three constituent formations namely Lakwa Sandstone, Girujan Clay and the Nazira Sandstone in the subsurface of the Assam Valley. However the Namsang beds of Evans (1959) are separated from the Girujan Clay stage by regional unconformity whereas the Namsang Formation of Pandey occurs below the regional unconformity at the top of Tipam Group. In my designated area of study only a few cases of the differentiating Namsang formation were encountered atop the Girujan and Tipam Formation.

Extent: In a major portion of the shelf area and bordering a part of the South Shilong Plateau, Tipam is exposed but is absent in Kopili Valley. In the Schuppen Belt, it is present only in the NW of the Disang thrust. It further extends southwards even into the Bangladesh. In the South Assam Shelf region it is found in huge thicknesses.

Boundaries: In the North Assam Shelf, Tipam Group is sandwiched between the Barail Group and the Moran group. In Dhansiri Valley, the undifferentiated Tipams have gradational relation with the underlying Surma Group and unconformable contact with the overlying Moran Group. In the south-western tracts of the Schuppen Belt the Tipam conformably lies over the Surmas or the Bokabils.

Description: The sediments of Tipam constitute the major arenaceous sequence in Assam. The sandstones of the Tipam Group are much coarser and having massive bedding in comparison to the underlying Barail Group. This sequence is also characterized by the presence of the thick clays of the Girujan Formation. However, in the certain areas, the Girujan Formation cannot be differentiated from the Tipam sandstone. They form a thick layer of the 'Undifferentiated Tipam'.

CHAPTER 6: Data Processing in Seisworks and Petromod

The first and foremost requirement is to prepare the seismic data in Seisworks and import the prepared seismic data to Petromod ready to be digitized. So to prepare the seismic data to be readily transferred to the Petromod, Landmark Seisworks/Superseisworks has been used for preparing the seismic data ready to be digitised. The software has been handy and flexible enough to enable even the weaker signals to be enhanced greatly to give a satisfactory interpretation of the horizons. Along with that the assigning of the different horizons tops with the variety of coloured lines help to clearly demarcate one formation from the other.

In the previous chapters the formations that are being encountered during the investigation have been listed and have been described briefly of their general nomenclature, extent of their presence, overlying and the underlying formation and their characteristic lithological signature in differentiating the section on electrologs or elsewhere. In addition to that a brief description of the some other significant features have also been discussed in relevance to the area of the study; the characteristics that have been observed in the geoscientific data from the area of the study. From the previous experiences of the workers in this region, there is a fair possibility of the Barail and Kopili to be the main source rock with good organic matter content and with necessary temperature/depth and the maturity conditions beneath the Naga Thrust region there is a fair possibility of the generation of the hydrocarbons. On the other hand the shaly Middle Bokabil has good characteristics of being the cap/seal rock to check the escape of the hydrocarbons post the production from the source rocks. As a result the possibility of the intermediate formation rocks between the mid-Bokabil and Barail-Kopili of being the reservoir rock is quite evident.

6. 1 Seismic Data Processing and Analysis

The section that has been selected for the purpose of investigation for the presence of 'petroleum systems' consists of two seismic lines conjoined in between. From the Fig. 6.1 the line that is indicated in yellow has been chosen for the seismic interpretation in Seisworks from the South Assam Shelf region. From the sectional view of the selected seismic lines (see

Fig. 6.2), there is a clear line of demarcation between the two sections chosen; with a part of being overlapped too in between. However if we can keenly observe, the whole section runs for around 33 kms and geologically the two regions have been differentiated by their faulting pattern and the geomorphology. For convenience, the stretch of 33 kms has been marked separately as Region A and B to demonstrate their distinctive pattern. The seismic line is headed in the NW-SE direction and is bounded by the Naga thrust in the SE direction.

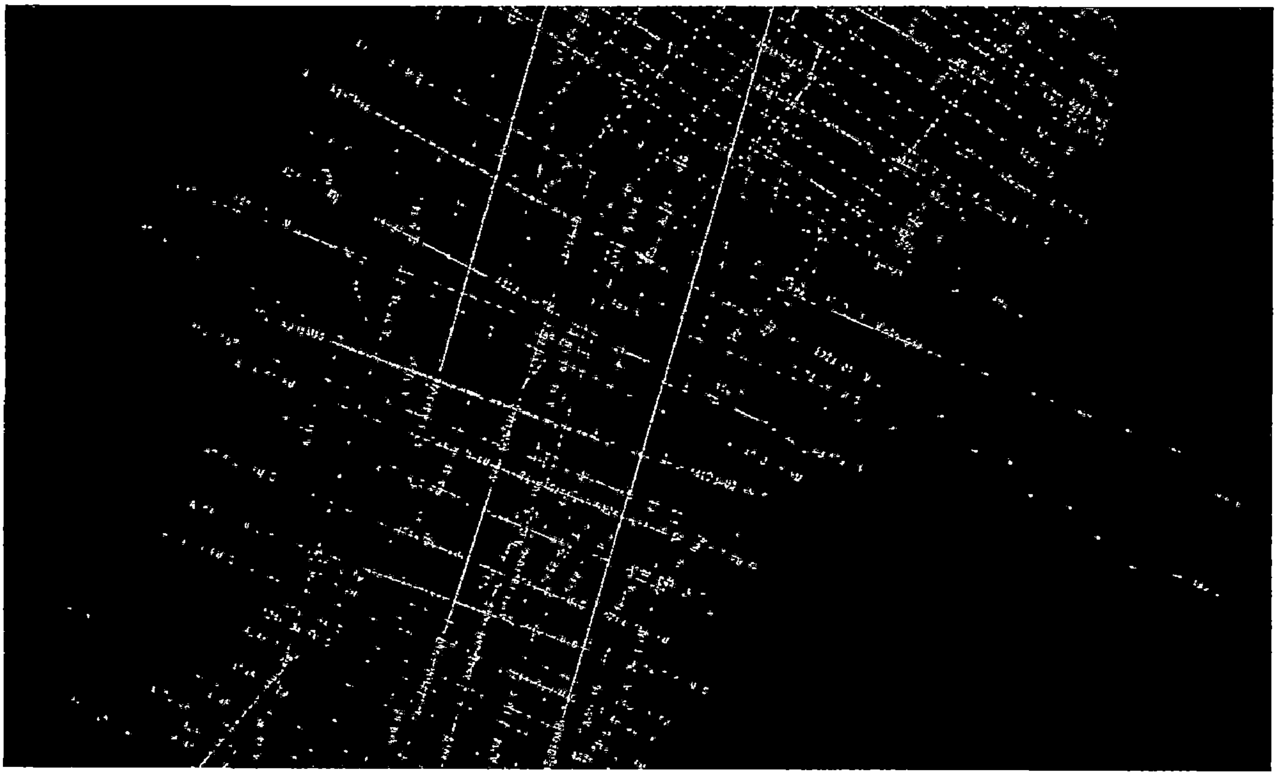
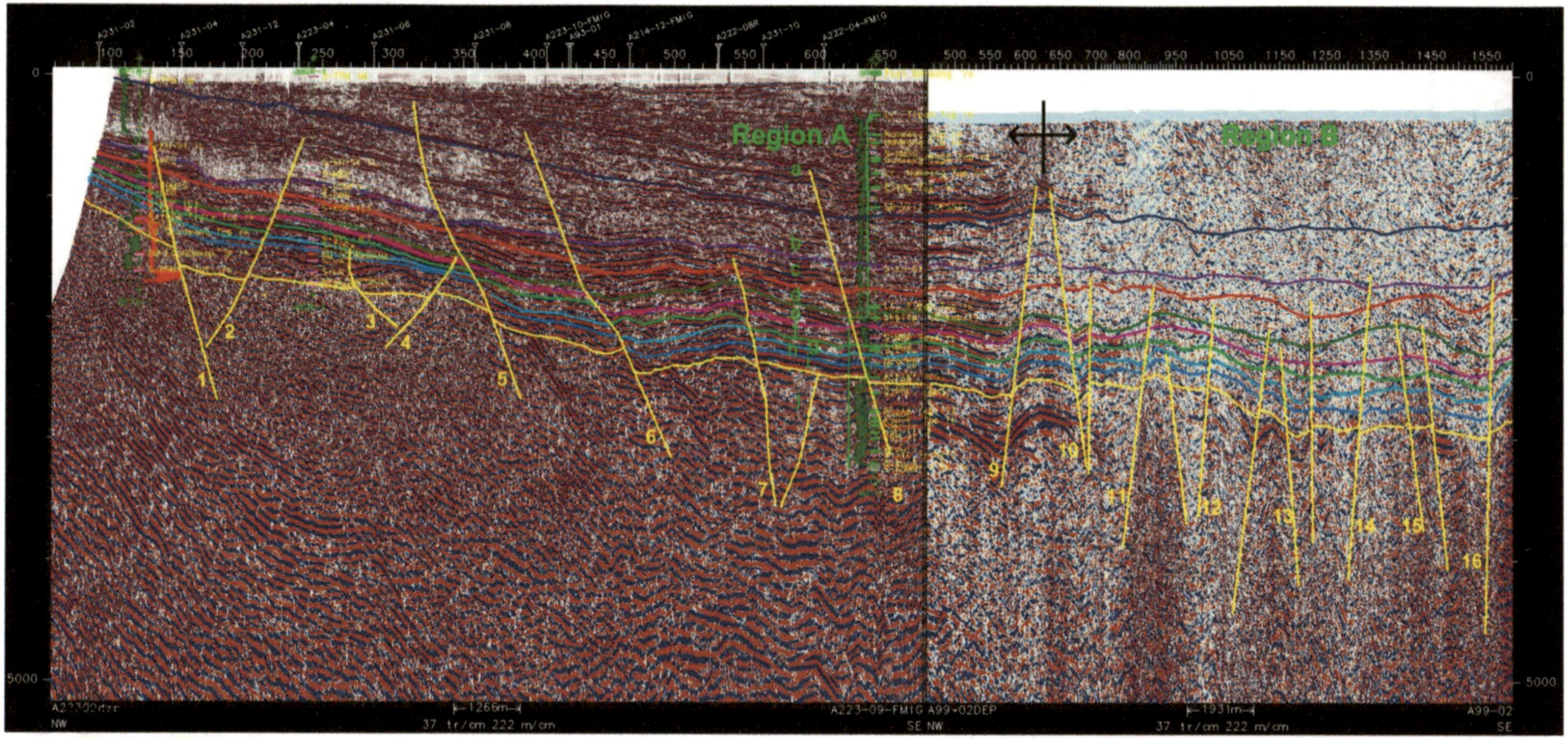


Fig 6.1: 2D Seismic Lines (in *yellow*) from the South Assam Shelf Region

Due to the subduction under the Naga thrust we observe a distortion of the horizon tops of the Region B. Also as we move towards the SE we gradually move towards the basin where there has been more filling of the sediments than in the NW direction. So this is the reason behind the gradual thickening of the sediments with more of folding and thrusting encountered below the Naga Thrust. The Region A however shows less of thickness as well as folding and warping in comparison to the Region B; the reason has already been stated earlier.



TOPS OF THE HORIZONS

a: Alluvium
b: Undifferentiated Tipam
c: Upper Bokabil / Khoraghat Sandstone
d: Middle Bokabil
e: Lower Bokabil
f: Barail
g: Kopili
h: Sylhet Top
i: Sylhet Base
j: Basement

1-16: Faults

Fig. 6.2: Horizons and faults as marked in the Openworks Seisworks after well-pick correlation in Stratworks of the shown wells

Also we observe a distinct pattern of faulting in each of the regions. Region A has a series of faults with near equal dips; though a slight increase of dipping is noticed towards SE. These types of faults are being classified as the 'domino faulting'. Generally 'domino faults' are accompanied by the half graben features like one such graben between Fault 1 and 5. This feature consists of the thinning of the faulted layer on one end. Such is also a typical feature associated with the Upper and Lower Gondwana. However in this case the Gondwana has been clubbed with the Sylhet Trap to form the Pre-Tertiary sediments. The feature is still clearly visible from the Fig. 6.2 showing the seismic section. In contrast to that the Region B has a series of graben features; some may also be the inter-graben faults. Since they increase the unnecessary complexities of the calculations, time and risk factors the inter-graben has been selectively removed from the model traced in Petromod (see Fig 6.3). All the graben features along with the formations are at a greater depth showing the subduction below the Naga Thrust.

As discussed in the earlier paragraph, the region of half-graben may be a zone of considerable interest as because of the surrounding faulting it has provided with a perfect zone to restrict the movement of the generated hydrocarbons from the lower layers. It may be a zone of interest from the point of view of accumulation of hydrocarbons. There is a second zone between the faults numbered 9 and 10. A regional anticline with appropriate lithological features is very instrumental in trapping the rising hydrocarbons. It has also been noticed that the Sylhet below the Naga Thrust has the optimum depth and thus the temperature to process the organic matter to generate the hydrocarbons. However on the leftwards we find the formation at a lower depth and thus not-so-optimum P-T conditions to generate hydrocarbons. So if there is an accumulation at a lower depth on the NW end away from the Naga Thrust, it has certainly migrated from the formations below the thrusted zone. There may be more zones of accumulations but it can only be determined on completing the whole of the simulation process in Petromod.

The Well Log data as featured of the three wells namely Wells 1A, 1B and 1C has significant correlation with the well completion report as well as the seismic section. Even though the wells are located at a distance between 2-3 kms, but still we found considerable matching of the well picks and formations from the seismic section.

The wells were initially correlated on Landmark Openworks-Stratworks and since the well 1B didn't contain any picks, a rough estimation has been applied from the rest two wells to determine the same. Some new picks were introduced too based on the well logs mainly GR and ILD logs e.g. the Middle Bokabil, the lower Bokabil etc.

While marking the final horizons on the Seisworks/Superseisworks the well logs along with the seismic data were jointly used in determining the horizon tops of the formations. In certain areas, the wells were drifted away by a km or two from the section considered, yet there was much of relevance in considering their logs while correlating with the seismic section.

6. 2 Work carried out in Petromod

Finally, the prepared seismic sections after several stages of refining were suitable to be transferred to the Petromod platform to be further digitised. The digitised screenshot from the Petromod is presented in the Fig. 6.3. The model prepared has been subjected to several more stages of refining and also retaining the major faults which has a role to play in the petroleum system, while removing the others especially the minor inter-graben faults which can unnecessarily restrict the flow of the fluids within the system.

Gridding of the already digitised horizons and faults are done to break the whole of the section in smaller squares and any two dimensional linear feature into smaller lines either horizontal or vertical. Hence the inclined fault-lines are broken down into a connected series of the horizontal and vertical lines (see Fig. 6.5). The gridding stage is also very essential from the viewpoint that it helps to find out any discontinuity either within the horizon-lines or the fault-lines. After gridding we get a continuous model like in Fig. 6.4. Unless and until gridded properly, the model cannot be made to function in the subsequent stages.

In the next step, the lithological facies data along with the fault properties are being fed in the Petromod. A screenshot of the dialog box has been provided in Fig. 6.6. It defines all the facies that has to be assigned to which layer from the section in addition to the last age of the deposition of the sediments from that particular facies. An erosion layer can also be added along with the depositional layers. So this segment of the workflow is particularly instrumental in assigning the facies with their time of deposition along with the erosional events too.

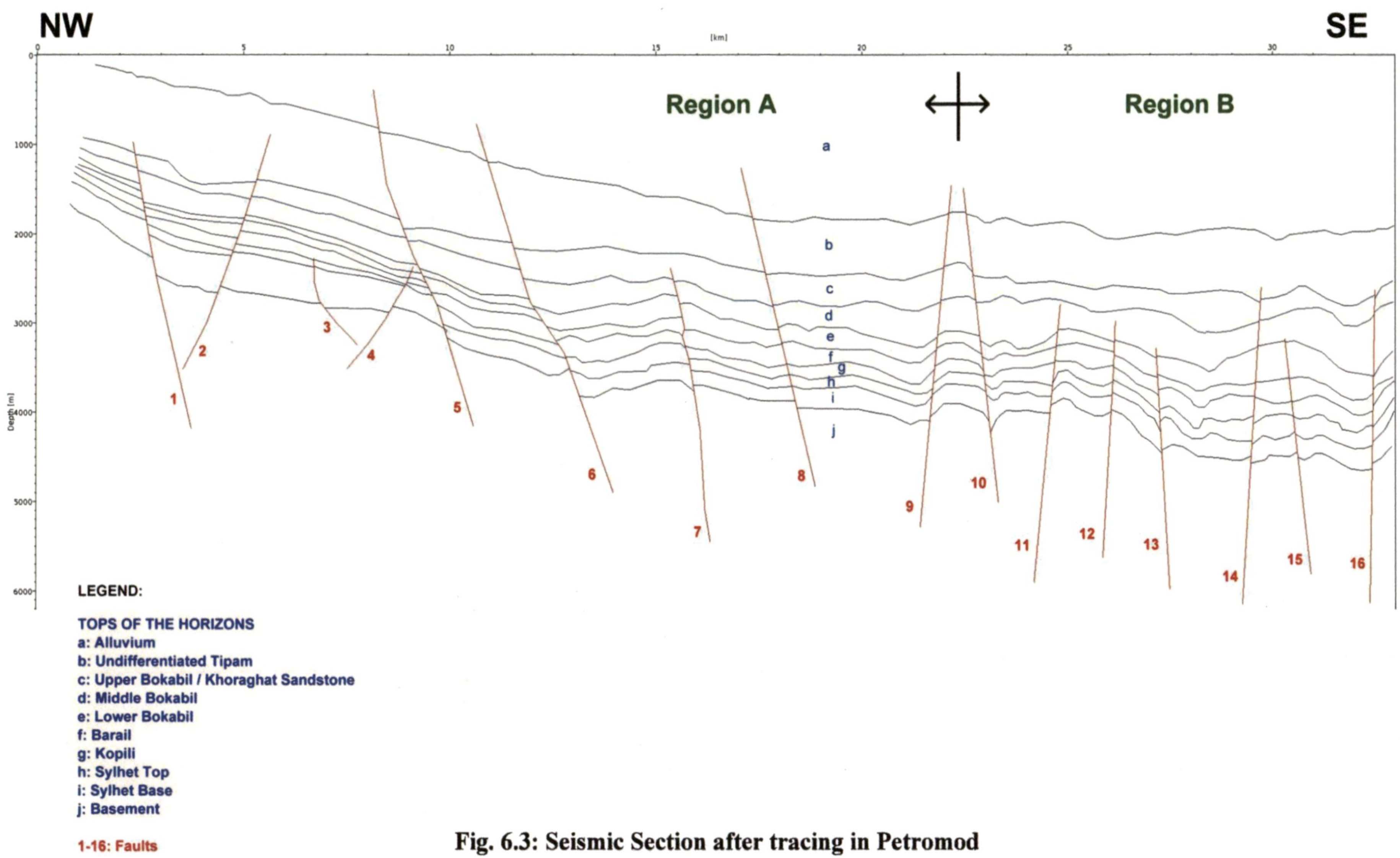


Fig. 6.3: Seismic Section after tracing in Petromod

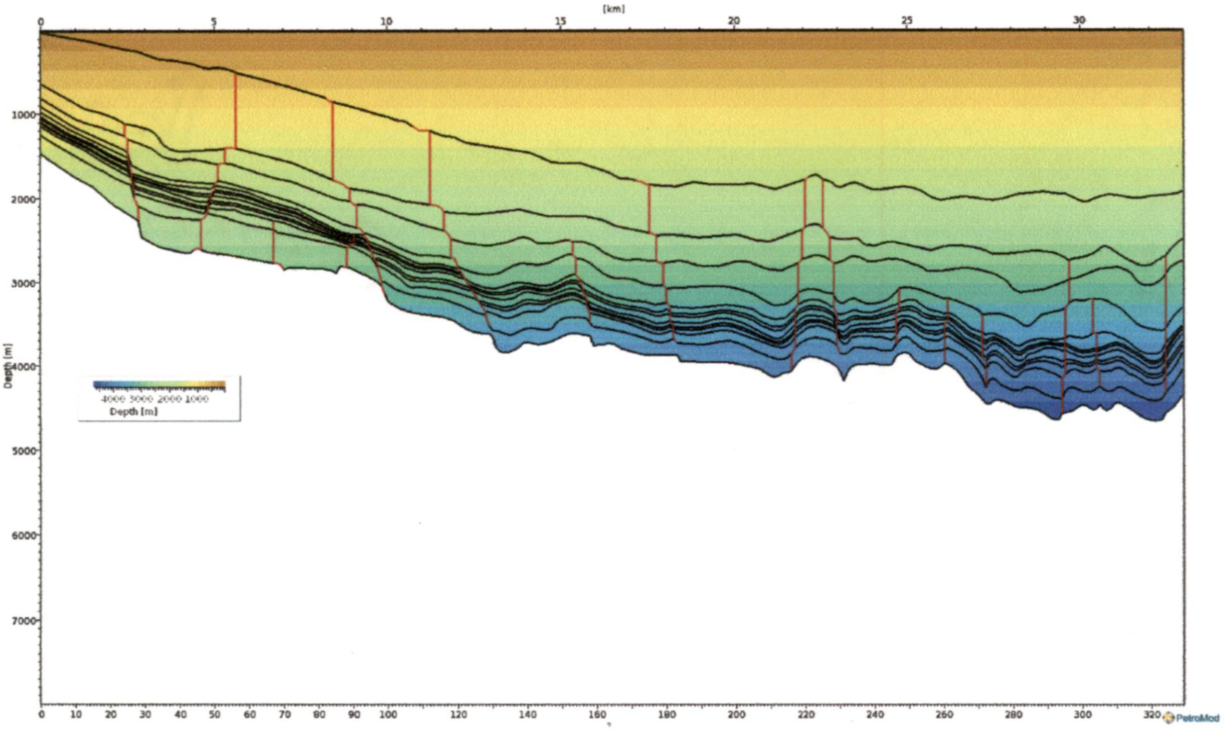


Fig. 6.4: The Section after gridding from the perspective of depth

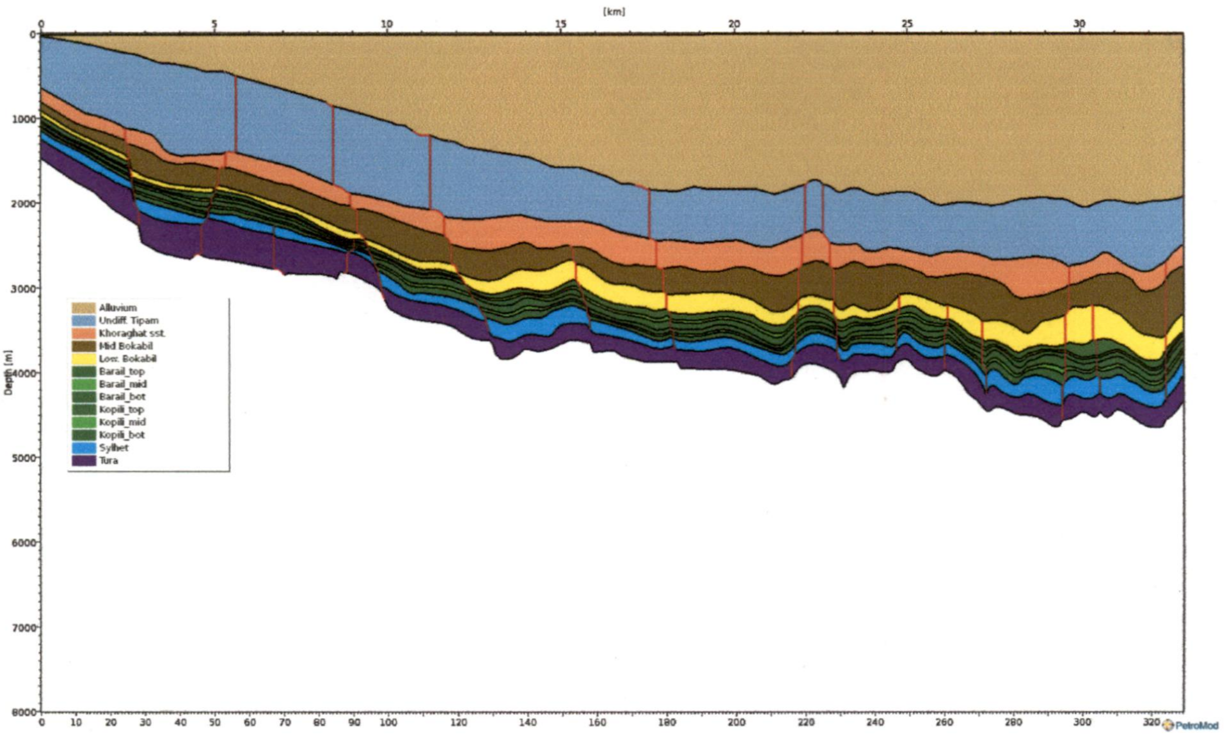


Fig. 6.5: The Section after gridding from the perspective of the litho-facies

Age Assignment

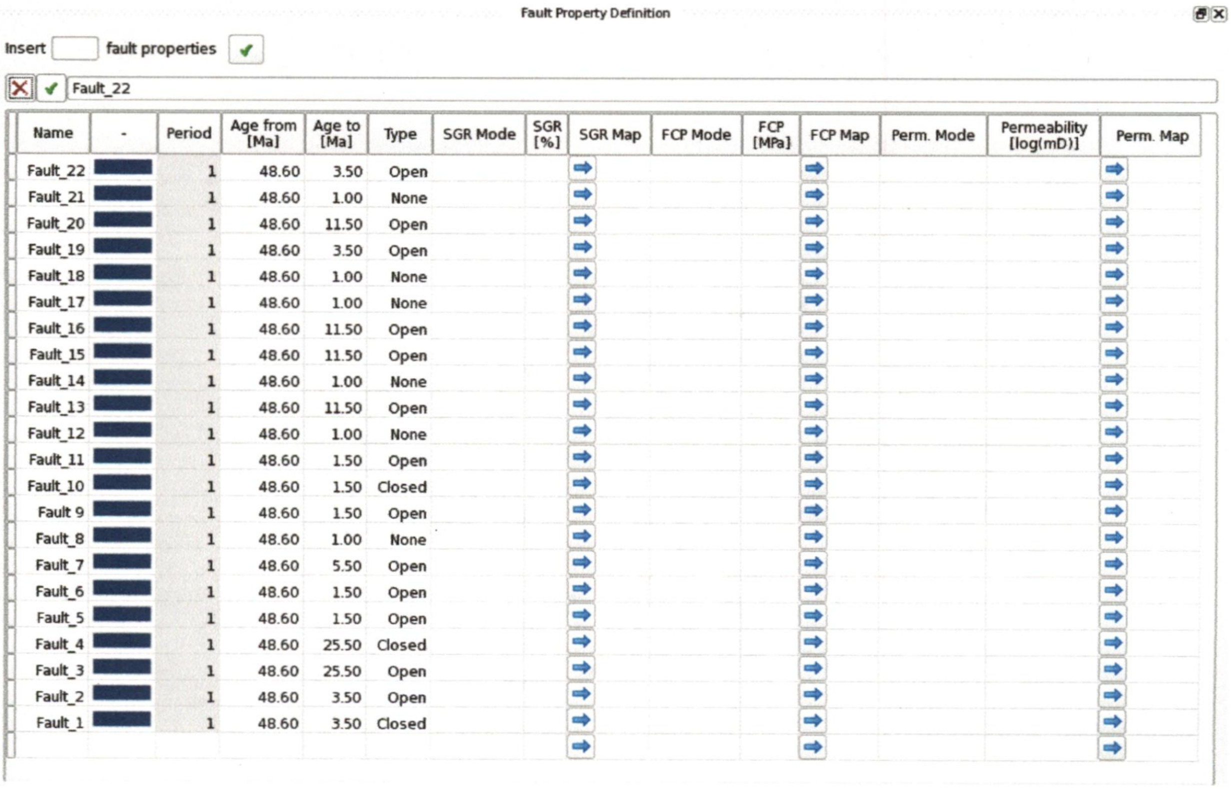
Insert [ ] layers at the top of the table | Clear Table | Layers

0.00

	Age [Ma]	Horizon	-	Pre-grid Horizon	Gridded Horizon	Erosion Map	Layer	-	Event Type	Facies Map	No. of Sublayers	Max. Time Step [Ma]
1	0.00	Alluvium		Alluvium	Alluvium_Map							
2							Alluvium		Deposition	Map_F_Alluvium	1	10.00
3	1.80	Undiff. Tipam		Undiff. Tipam	Undiff. Tipam_Map							
4							Undiff. Tipam		Deposition	Map_F_Undiff Tipam	1	10.00
5	3.60	Upp. Bokabil		Upp. Bokabil	Upp. Bokabil_Map							
6							Khoraghat sst		Deposition	Map_F_Khoraghat sst	1	10.00
7	6.00	Mid. Bokabil		Mid. Bokabil	Mid. Bokabil_Map							
8							Mid Bokabil		Deposition	Map_F_Mid Bokabil	1	10.00
9	12.00	Low. Bokabil		Low. Bokabil	Low. Bokabil_Map							
10							Low. Bokabil		Deposition	Map_F_Mid Bokabil	1	10.00
11	22.00	Barail Erosion										
12							Barail Erosion Layer		Erosion			10.00
13	26.00	Barail		Barail	Barail_Map							
14							Barail_top		Deposition	Map_F_Barail_top	1	10.00
15	29.20	Barail_mid		Barail_mid	Barail_mid_Map							
16							Barail_mid		Deposition	Map_F_Barail_mid	1	10.00
17	30.80	Barail_bot		Barail_bot	Barail_bot_Map							
18							Barail_bot		Deposition	Map_F_Barail_bot	1	10.00
19	34.00	Kopili		Kopili	Kopili_Map							
20							Kopili_top		Deposition	Map_F_Kopili_top	3	10.00
21	35.28	Kopili_mid		Kopili_mid	Kopili_mid_Map							
22							Kopili_mid		Deposition	Map_F_Kopili_mid	1	10.00
23	35.92	Kopili_bot		Kopili_bot	Kopili_bot_Map							
24							Kopili_bot		Deposition	Map_F_Kopili_bot	1	10.00
25	37.20	Sylhet Top		Sylhet Top	Sylhet Top_Map							
26							Sylhet		Deposition	Map_F_Sylhet	1	10.00
27	45.00	Sylhet Bottom		Sylhet Bottom	Sylhet Bottom_Map							
28							Tura		Deposition	Map_F_Tura	1	10.00
29	57.00	Basement		Basement	Basement_Map							

Uncompacted data view

Fig. 6.6: The dialog box showing the assigning of the litho-facies



Fault Property Definition

Insert [ ] fault properties

Fault_22

Name	-	Period	Age from [Ma]	Age to [Ma]	Type	SGR Mode	SGR [%]	SGR Map	FCP Mode	FCP [MPa]	FCP Map	Perm. Mode	Permeability [log(mD)]	Perm. Map
Fault_22		1	48.60	3.50	Open									
Fault_21		1	48.60	1.00	None									
Fault_20		1	48.60	11.50	Open									
Fault_19		1	48.60	3.50	Open									
Fault_18		1	48.60	1.00	None									
Fault_17		1	48.60	1.00	None									
Fault_16		1	48.60	11.50	Open									
Fault_15		1	48.60	11.50	Open									
Fault_14		1	48.60	1.00	None									
Fault_13		1	48.60	11.50	Open									
Fault_12		1	48.60	1.00	None									
Fault_11		1	48.60	1.50	Open									
Fault_10		1	48.60	1.50	Closed									
Fault 9		1	48.60	1.50	Open									
Fault_8		1	48.60	1.00	None									
Fault_7		1	48.60	5.50	Open									
Fault_6		1	48.60	1.50	Open									
Fault_5		1	48.60	1.50	Open									
Fault_4		1	48.60	25.50	Closed									
Fault_3		1	48.60	25.50	Open									
Fault_2		1	48.60	3.50	Open									
Fault_1		1	48.60	3.50	Closed									

Fig. 6.7: The dialog box showing the assigning of the faults and their corresponding properties

Fig. 6.7 shows the Fault properties dialog box. All the faults digitised have been assigned a fault number. Since the faults play a very important role, whether we keep it open or closed, has a significant effect on the movement of the fluids and thus the accumulation. Also the time of the faulting has also a role to play in a way; if the faulting is post-migration (if generated) there can be little or no effect on the fluid flow by the particular fault. However if the faulting has occurred pre-migration, it has a consequential role on the migration and hence accumulation.

In this petroleum system, Barail and Kopili are the main source rock layers. However, the shales are in the dispersed form within each of the layers. So avoid the complexities, each of the layers has been divided into a 20 percent thickness shale sandwiched in between two sandstone layers of equal thickness (see Fig. 6.8). In general the kerogen present in the source rocks of the Assam shelf are of Type II and the best kinetics that is applicable is that of the Behar et al (1997). The above determination of the kerogen type and the type of kinetics that is applicable is a resultant of several previous analyses and modelling that has been done in and around the areas of the North and South Assam Shelf which utilise the TOC (Total Organic Carbon), HI (Hydrogen Index) and Kinetics data. The kinetics is very instrumental in designing the chemical reactions to be encountered by the kerogen molecules to break down into the petroleum. The Fig. 6.9 shows the assignment of the lithology with their TOC, HI and kinetics value and also their behaviour/role within the petroleum system i.e. whether they will act as the 'source rock', 'reservoir rock', 'seal rock' or just an 'overburden rock' or an 'underburden rock' to each of the formation layers. In his petroleum system, the Barail and the Kopili are the major source rocks, the Middle Bokabil consisting of majorly shales, act as the 'seal rock' and the sandstones in between and around the areas act as the 'reservoir rock', bounded at the bottom by the granite basement.

The boundary conditions define the basic energetic conditions of the basin for different temperatures. There are three boundary conditions that are to be fixed. They are Paleo Water Depth (PWD) (see Fig. 6.10), Sediment Water Interface Temperature (SWIT) and Heat Flow (HF) (see Fig. 6.11). The Heat Flow map shows the variation of the heat flow with time with the geographical coordinates set for the North and South Shelf region. It takes into account all the plate movements and other factors too.

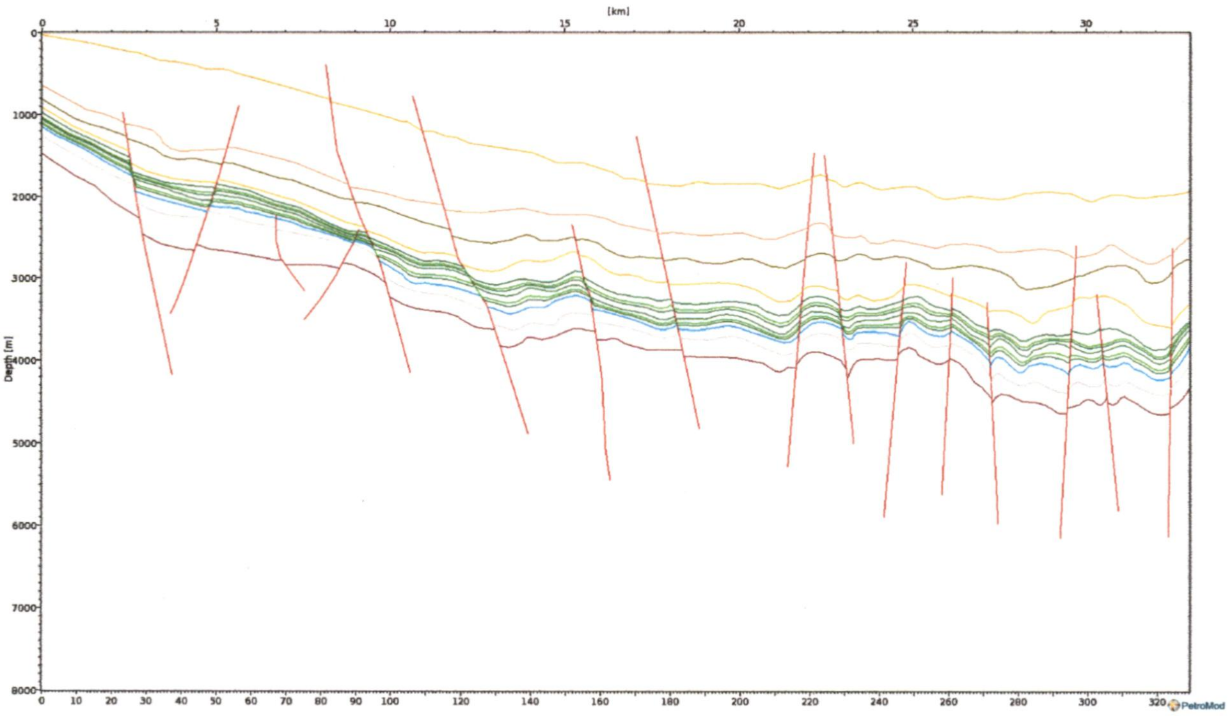


Fig. 6.8: Each of the formations of Kopili and Barail (in *green*) are being further divided into 3 sub-layers with the middle sub-layer consisting of the main source rock

Facies Definition

F_Alluvium

Name	Color	Lithology Value	TOC Mode	TOC Value [%]	TOC Map	Kinetics	HI Mode	HI Value [mgHC/gTOC]	HI Map	Petroleum System Elements
F_Alluvium		SILT&SAND	Value	0.00			Value	0.00		Overburden Rock
F_Undiff Tipam		Sandstone (clay rich)	Value	0.00			Value	0.00		Overburden Rock
F_Khoraghat sst		Sandstone (clay poor)	Value	0.00			Value	0.00		Overburden Rock
F_Mid Bokabil		Shale (typical)	Value	0.00			Value	0.00		Seal Rock
F_Low Bokabil		Sandstone (clay poor)	Value	0.00			Value	0.00		Reservoir Rock
F_Barail_top		Shale (organic lean, sandy)	Value	0.00			Value	0.00		none
F_Barail_mid		Shale (organic rich, 20% TOC)	Value	2.10		Behar_et_al(1997)_TI(GRS)	Value	125.00		Source Rock
F_Barail_bot		Shale (organic lean, sandy)	Value	0.00			Value	0.00		none
F_Kopili_top		Shale (organic lean, typical)	Value	0.00			Value	0.00		none
F_Kopili_mid		Shale (organic rich, 20% TOC)	Value	1.20		Behar_et_al(1997)_TI(GRS)	Value	177.00		Source Rock
F_Kopili_bot		Shale (typical)	Value	0.00			Value	0.00		none
F_Sylhet		Limestone (shaly)	Value	0.00			Value	0.00		Reservoir Rock
F_Tura		Sandstone (typical)	Value	0.00			Value	0.00		Reservoir Rock
F_Basement		BASEMENT	Value	0.00			Value	0.00		Underburden Rock

Fig. 6.9: The dialog box showing the assigning of the lithology type, TOC, HI values as well as defining the type of the 'petroleum system element' for each of the formations

BOUNDARY CONDITIONS:

Age from [Ma]	Reference	Layer	Mode	Depth [m]	Depth map
0.00	Water depth	➡	Value	5	➡
1.80	Water depth	➡	Value	5	➡
6.00	Water depth	➡	Value	5	➡
10.00	Water depth	➡	Value	5	➡
12.00	Water depth	➡	Value	5	➡
16.00	Water depth	➡	Value	5	➡
24.00	Water depth	➡	Value	3	➡
26.00	Water depth	➡	Value	5	➡
28.00	Water depth	➡	Value	10	➡
34.00	Water depth	➡	Value	15	➡
35.00	Water depth	➡	Value	5	➡
36.00	Water depth	➡	Value	35	➡
37.00	Water depth	➡	Value	15	➡
57.00	Water depth	➡	Value	5	➡
		➡			➡

Fig. 6.10: The assigning of the Paleo-Water Depths (PWD) as one of the boundary conditions

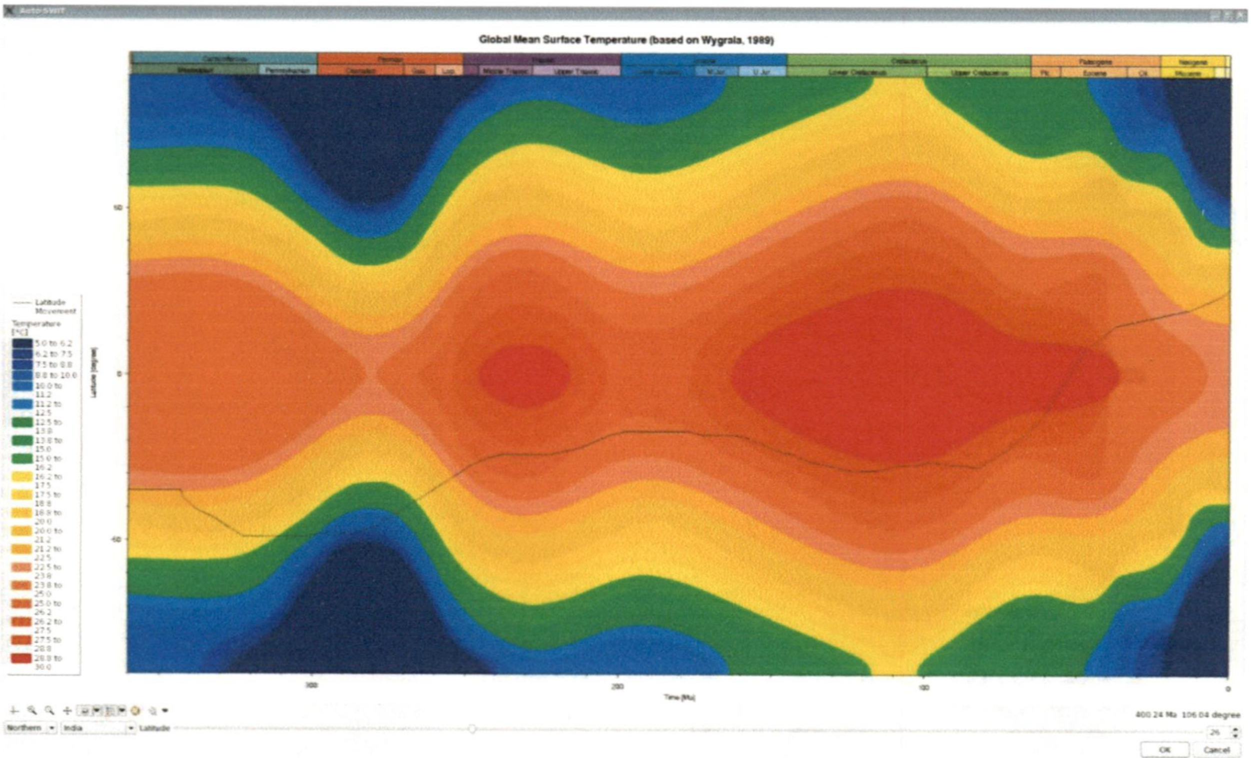


Fig. 6.11: The diagram of the heat flow map of the Northern India having latitude 26 degrees set for the geographical location of the North and South Assam Shelf.

CHAPTER 7: Discussion

7.1 Deposition of the layers

The sequence of the screenshots below shows how the deposition started and how progressively in phases the rate of deposition has increased and decreased. Starting from the 45 Million Years earlier, the deposition in the South Assam Shelf has commenced with the deposition of the bottommost sediment i.e. Sylhet (in *purple*) atop the basement. Followed by the Sylhet, the deposition of the Kopili started at around 37.2 Ma. Here in the petroleum system, Kopili (in combination of *light and dark green*) acts as one of the source rocks but it is in differentiated form. So to avoid unnecessary complications it has been differentiated into three different layers with the middle layers consisting of pure shale acting as the main source rock with good TOC value, sandwiched by two layers of sandstones. Similarly, above the Kopili lies another dispersed shale source rock in Barail (again in *light and dark green* to signify source rock) which started depositing at 34 Ma. Similarly to accommodate the dispersed shale factor, it has similarly been divided into three layers with the middle one consisting of the major organic matter in the shales. Above the Barails lie three distinct layers: Lower Bokabil (in *yellow*; rich in sandstone), Middle Bokabil (in *dark maroon*; rich in shales) and the Upper Bokabil (in *buff*; rich in sandstones). Here the Bokabils act as the major 'cap rock' to preserve the generated petroleum from evading the system. Below the 'cap rock' the reservoir rock mainly rich in sandstones with high porosity and permeability acts as the major rock to channel the fluids and also the rock to preserve the generated petroleum in its pores. The Bokabil commenced the deposition period at around 26 Ma. By the end of 12 Ma there is more of the deposition of the clay to start the commencement of the formation of the shale rich Middle Bokabil. Due to its high shale content, it acts as a prominent 'seal rock' or 'cap rock'. In terms of the deposition rate too there is a huge rate of deposition at this period because of the proximity to the Brahmaputra. Towards the basinal side of the section, it can be clearly derived that there has been a deposition of more than one kilometre of sediments within a span of just 6 Million Years at it maxima. The next layer deposited atop is the Khoraghat sandstone or the Upper Bokabil which steadily grades into the Tipam undifferentiated. Although majorly sandstone, there are sometimes smaller events of the deposition of the shales too giving it sometimes interbedded layers of the shales within the sandstones. The depositional activity is also vigorous during this period. However, at the commencing of the deposition of the Tipam undifferentiated at 3.6 Ma, there has been a faster rate of deposition of the sediments; within a stretch of just 1.8 Million years there has been deposition of more than a kilometre of sediments. On the top is the thickest layer of the alluvium which is of thickness of nearly two kilometres at the basinal side which began depositing at 1.8 Ma. These rapid events of deposition are both the resultant of the proximity to the Himalayas as well as the Naga Hills on the South Western end. The rates of the deposition can be very easily derived at from the Figure 7.2.

The Figs. 7.1.1 – 7.1.13 below show the commencement of deposition of each of the formations at the different ages.

Fig. 7.1.1: Starting of the deposition of Sylhet at 45 Ma

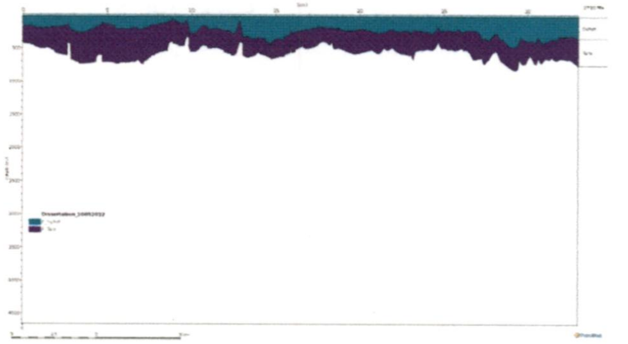


Fig. 7.1.2: Starting of the deposition of Kopili Bottom at 37.2 Ma

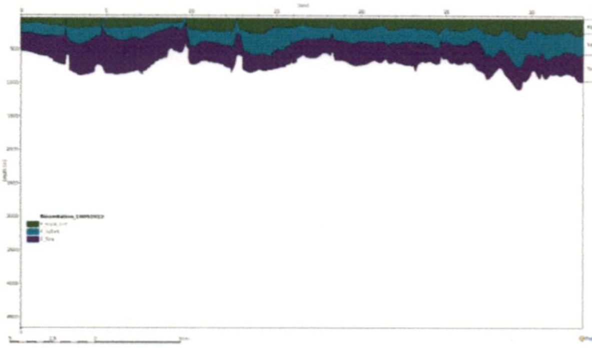


Fig. 7.1.3: Starting of the deposition of Kopili middle at 36 Ma

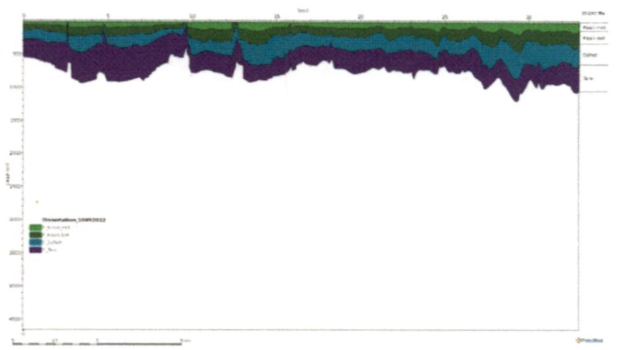


Fig. 7.1.4: Starting of the deposition of Kopili top at 35.28 Ma

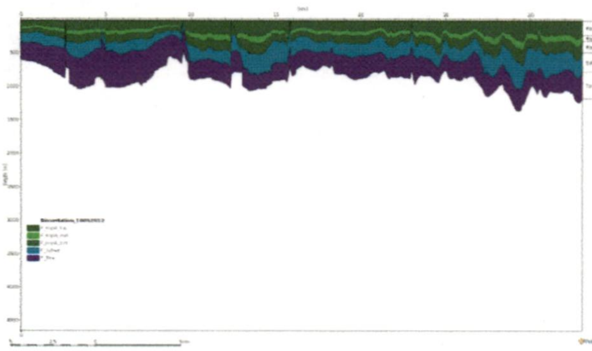


Fig. 7.1.5: Starting of the deposition of Barail bottom at 34 Ma

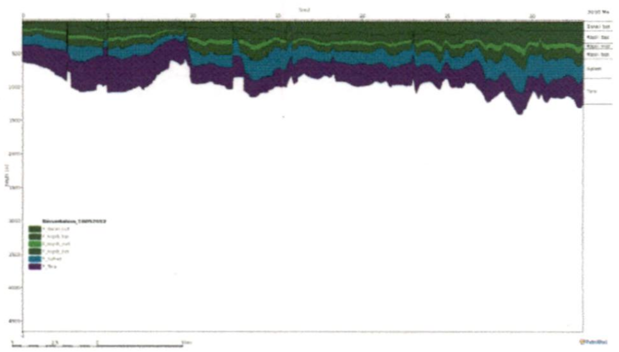


Fig. 7.1.6: Starting of the deposition of Barail middle at 30.8 Ma

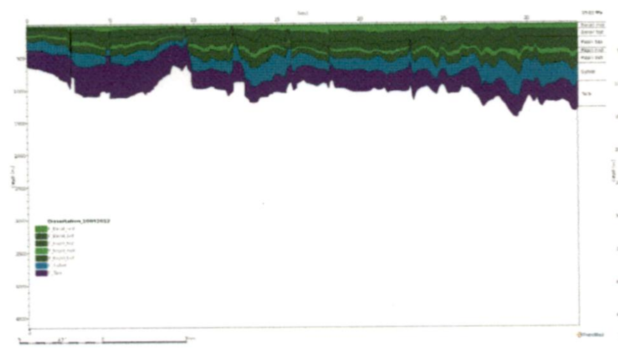


Fig. 7.1.7: Starting of the deposition of Barail top at 29.2 Ma

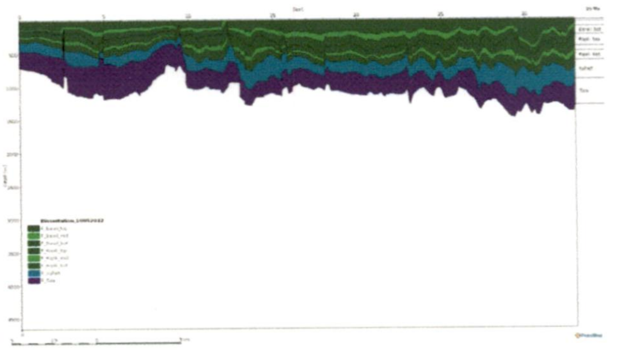


Fig. 7.1.8: Starting of the deposition of Lower Bokabil at 26 Ma

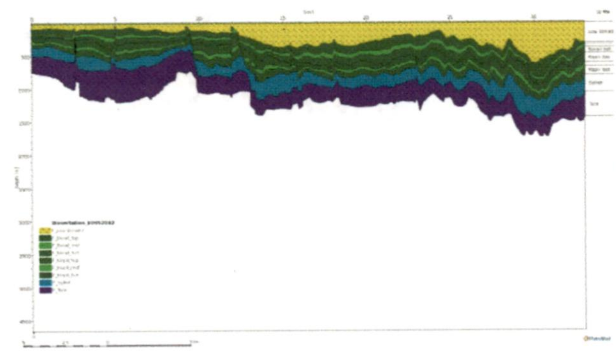


Fig. 7.1.9: Starting of the deposition of Middle Bokabil at 16 Ma

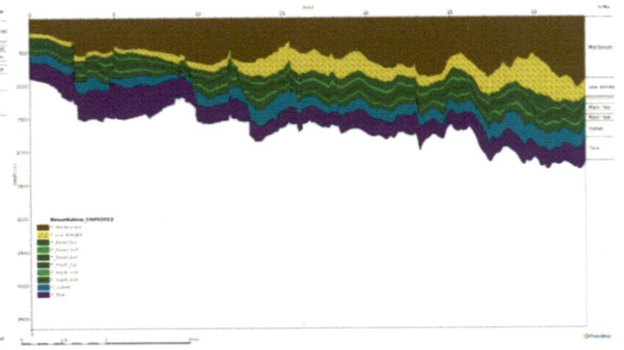


Fig. 7.1.10: Starting of the deposition of Khoraghat sst. at 6 Ma

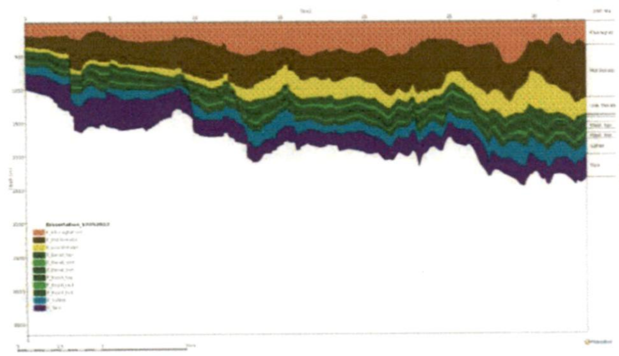


Fig. 7.1.11: Starting of the deposition of undiff. Tipam at 3.6 Ma

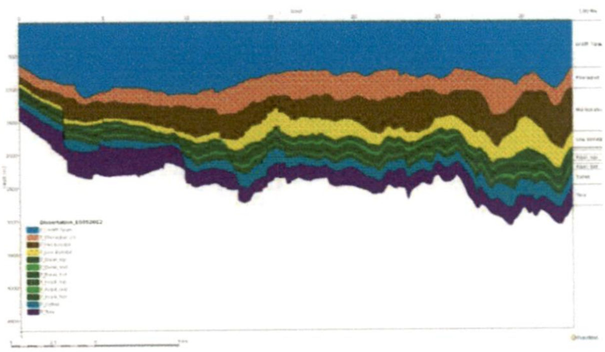


Fig. 7.1.12: Starting of the deposition of Alluvium (at top) at 1.8 Ma

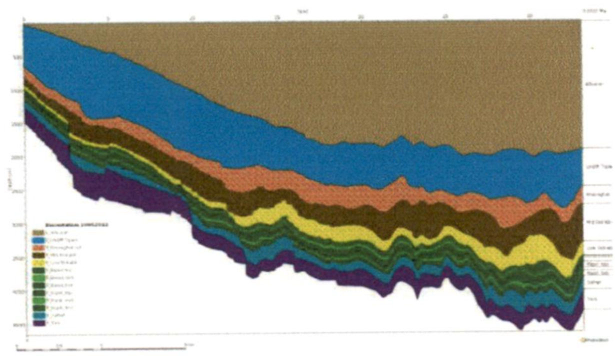


Fig. 7.1.13: The Present day

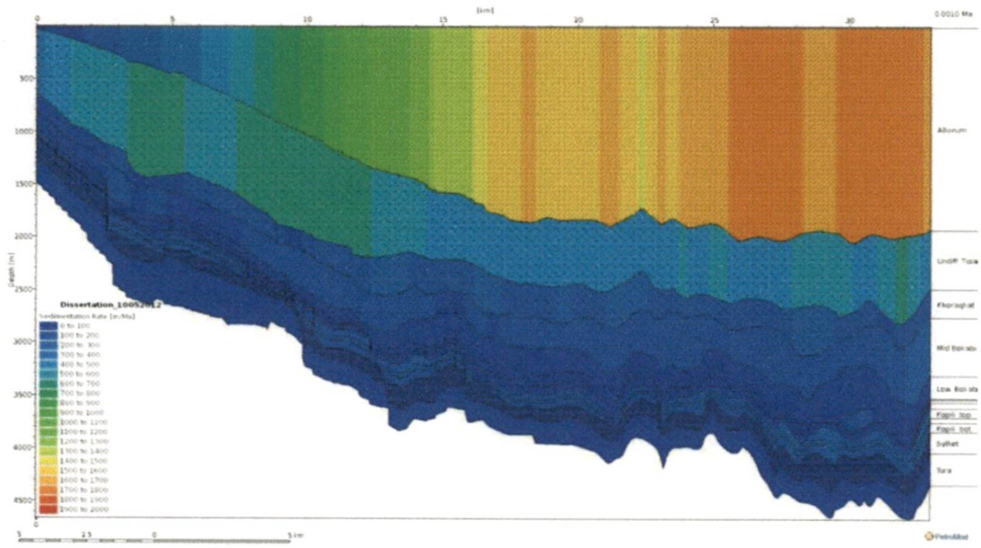


Fig. 7.2: The sedimentation rate (in m/Ma)

In the impending paragraphs, the results of the analysis of the data are documented under the following heads:

7.2.1 COMPACTION:

In the forthcoming paragraphs the resultant figures from the simulation and their interpreataion will be discussed. In Fig. 7.3 showing the porosity distribution of the section, the Kopili and the Barail show significant low porosity because of the high shale content. The middle Bobabil also also has a near characteristic of the pure shales. They act as the main 'seal rock' for the reservoir. However the surrounding rocks of the Lower Bokabil alongwith the Upper and Lower Barail and Kopili also has comparibly higher porosity which ensures the reservoir capability of the rocks.

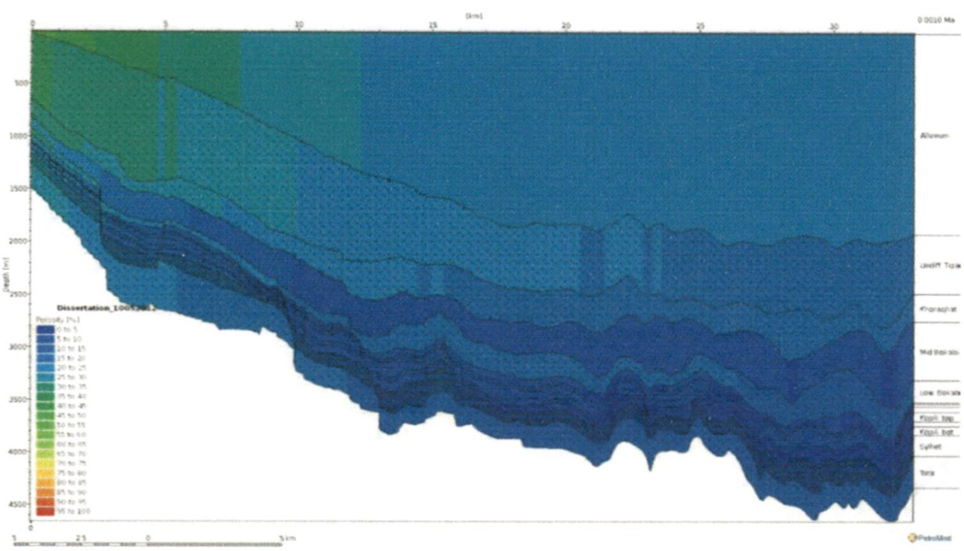


Fig. 7.3: The porosity distribution (in %)

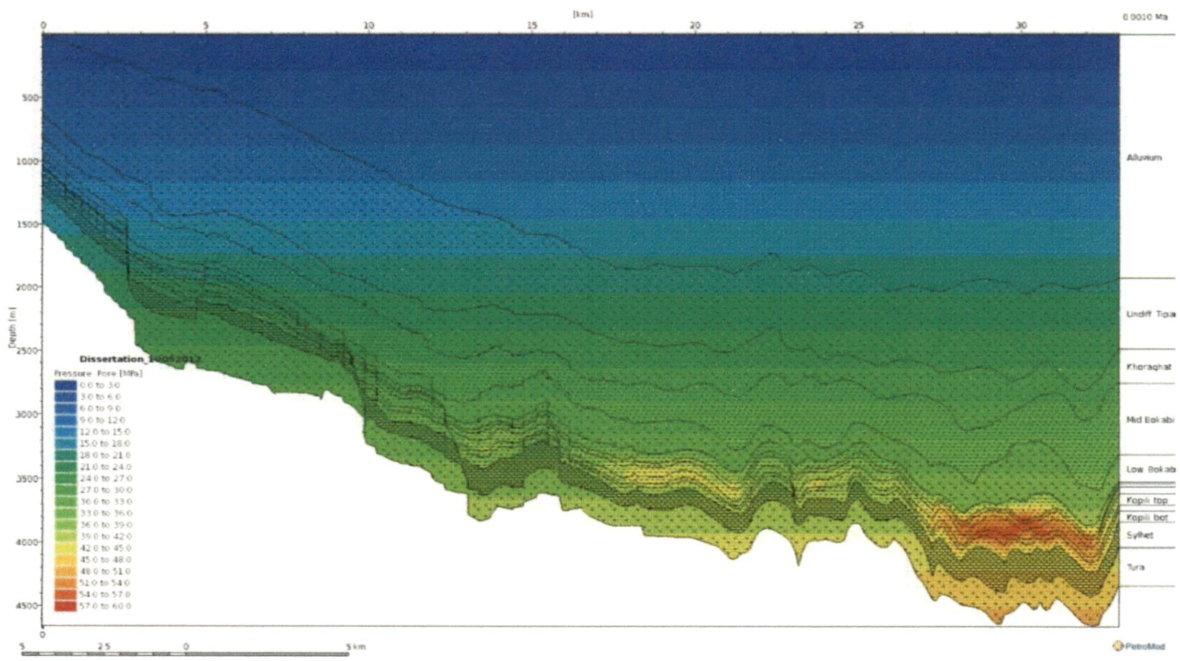


Fig. 7.4: Pore Pressure Distribution

The Pore Pressure cross-section from Fig. 7.4 shows the pressure to be too high at especially at the pores of the Kopili and the Barail formations. However from the Pore Pressure Gradient sectional view in Fig. 7.5, the negative gradient maxima is being generated at the Kopili bottom layer with an intermediate gradient in the layers of the middle and the top layers of Kopili, with the positive maxima gradient being noticed at the Upper Barail shales. The positive maxima is being noticed at the Upper Barails because the pore pressure keeps on increasing as the zone of the Mid-Barail and the Mid-Kopili is approached; at the same time as we move away from the zone of the higher pore-pressures of the Kopili to the lower layers of the Sylhet, we naturally have a decrease in the pore pressure and thus a negative gradient.

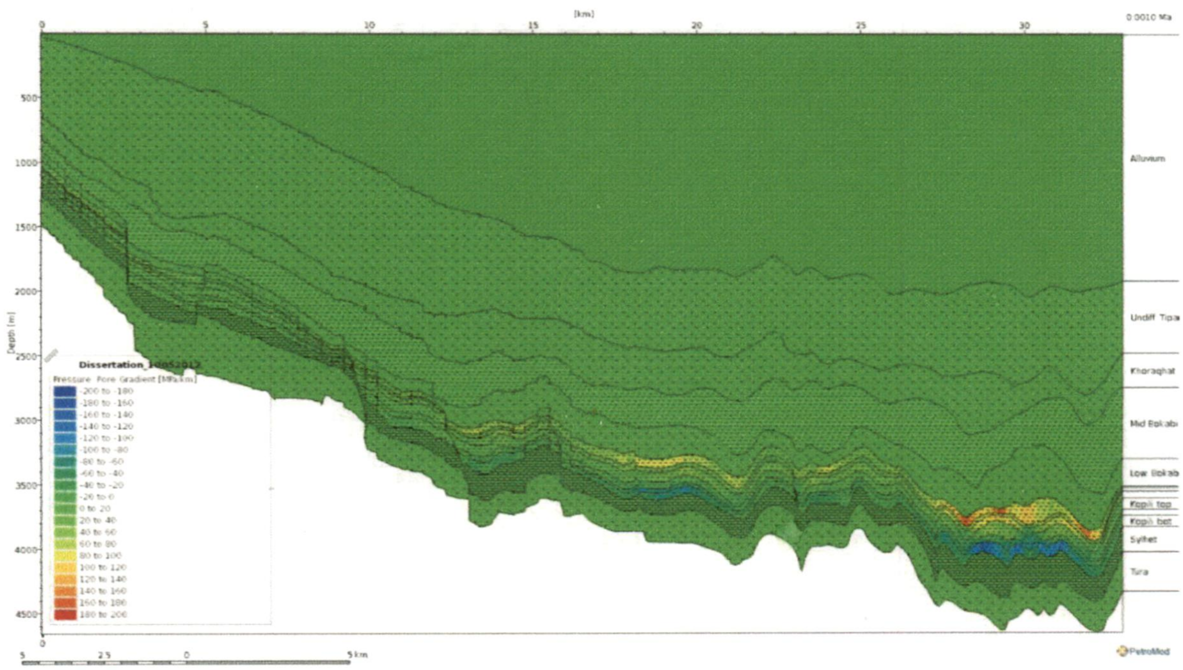


Fig. 7.5: Pore Pressure Gradient Distribution

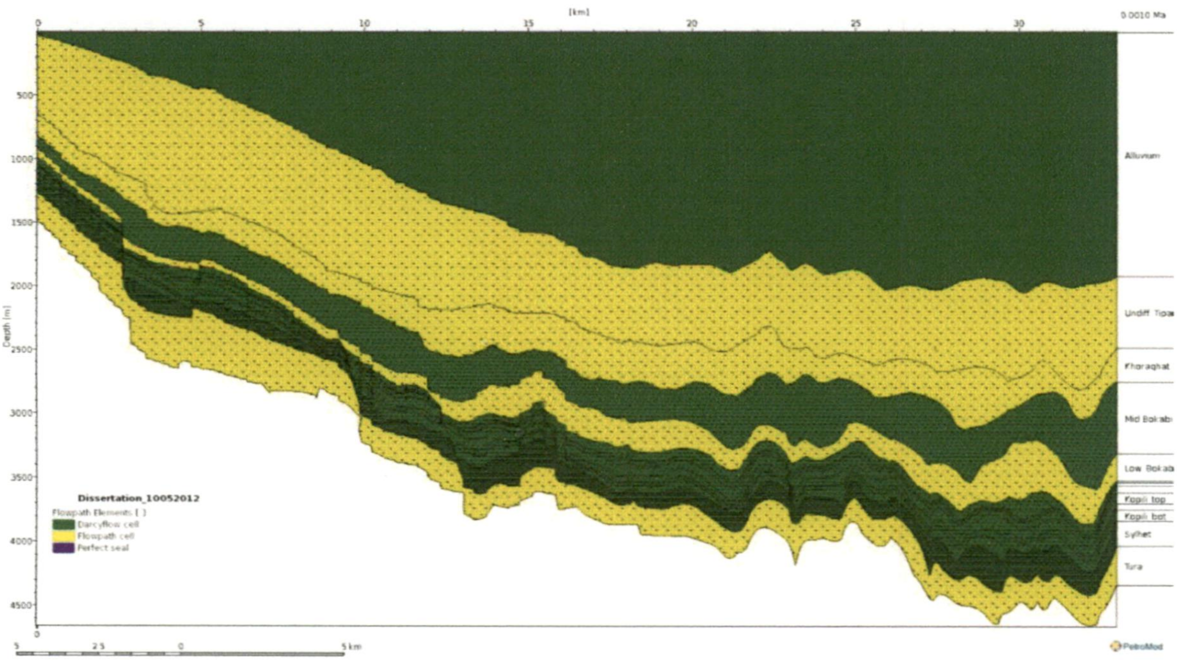


Fig. 7.6: Flowpath elements

The type of flow is generally decided to be Darcy flow where the situation demands detailed inspection; however the zones of lesser interests are opted for the easier Flowpath cell model which is also less time consuming. Such is being interpreted from the Figure showing the Flowpath elements. The Source Rock areas (in Fig. 7.6) require an intense study of the flow of the generated fluids rather than the other surrounding areas; as well as the Mid-Bokabil acts as the shale 'seal rock' which also requires further scrutiny. Hence they are being treated under the Darcy Flow cell elements.

7.2.2 TEMPERATURE:

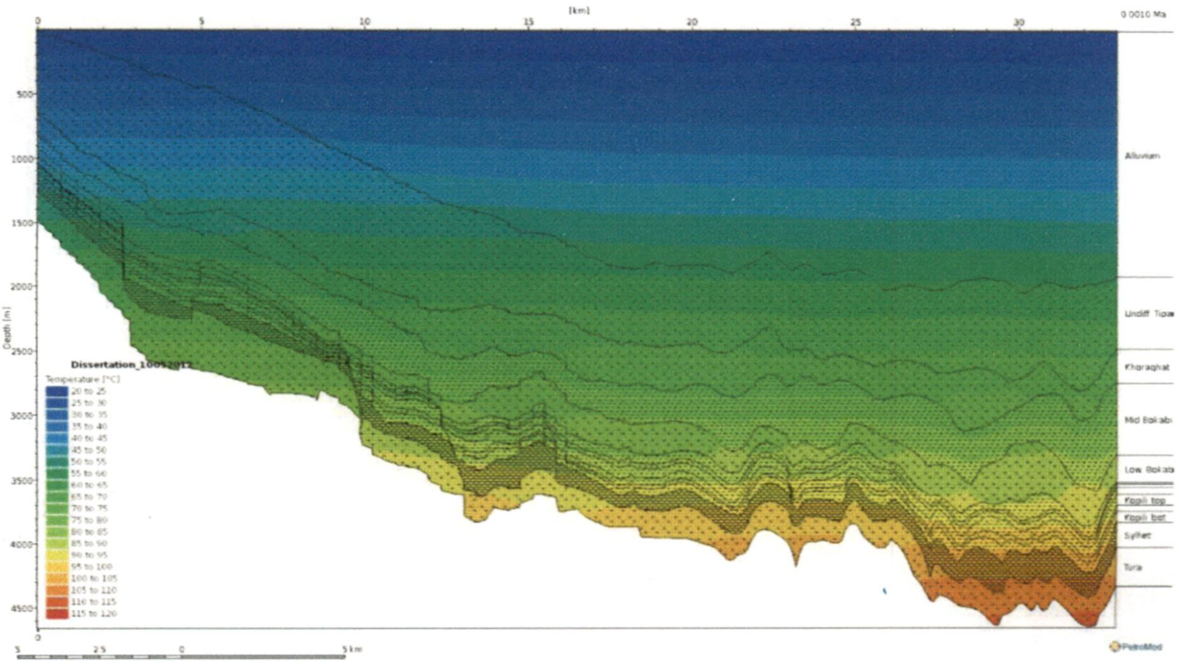


Fig. 7.7: Temperature distribution

The Temperature is one of the chief factors at the generation of petroleum. Adequate heat is being obtained at the greater depths. From the Fig. 7.7 the temparature is higher at the depths under the Naga Thrust region. The same sediments doesn't yield any hydrocarbons at the lower depths on the NW side of the section. The Heat Flow (from Fig. 7.8) characteristics doesn't show much variation at the given coordinates of the specific area of the study.

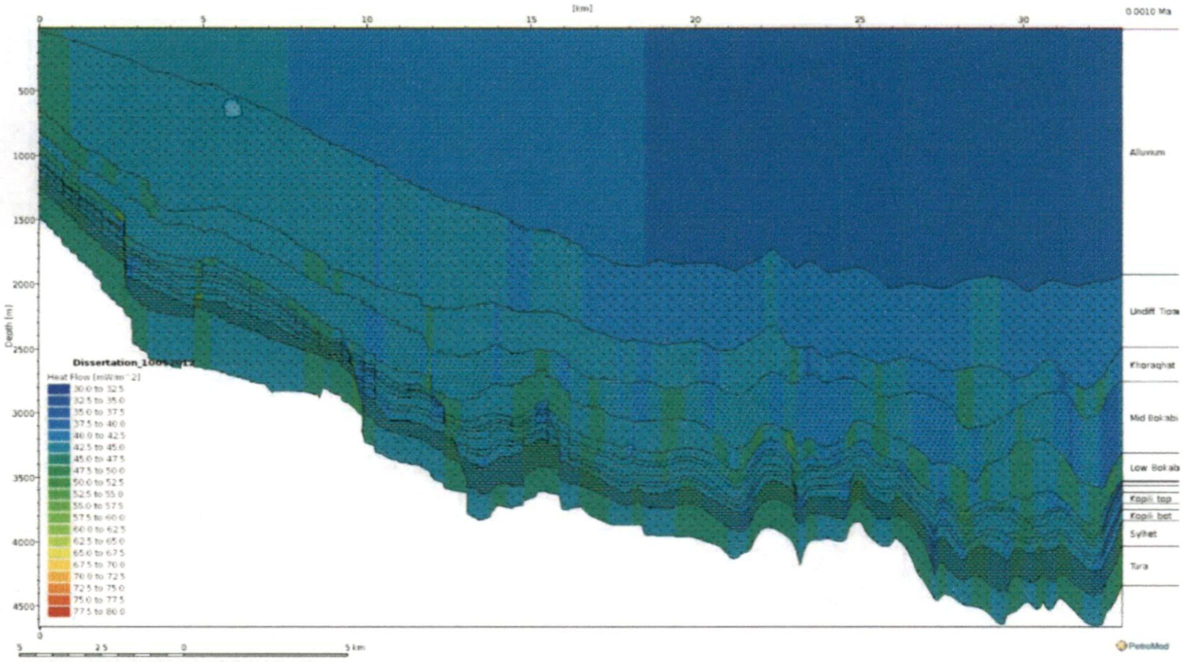


Fig. 7.8: Heat Flow Distribution

7.2.3 PETROLEUM GENERATION POTENTIAL:

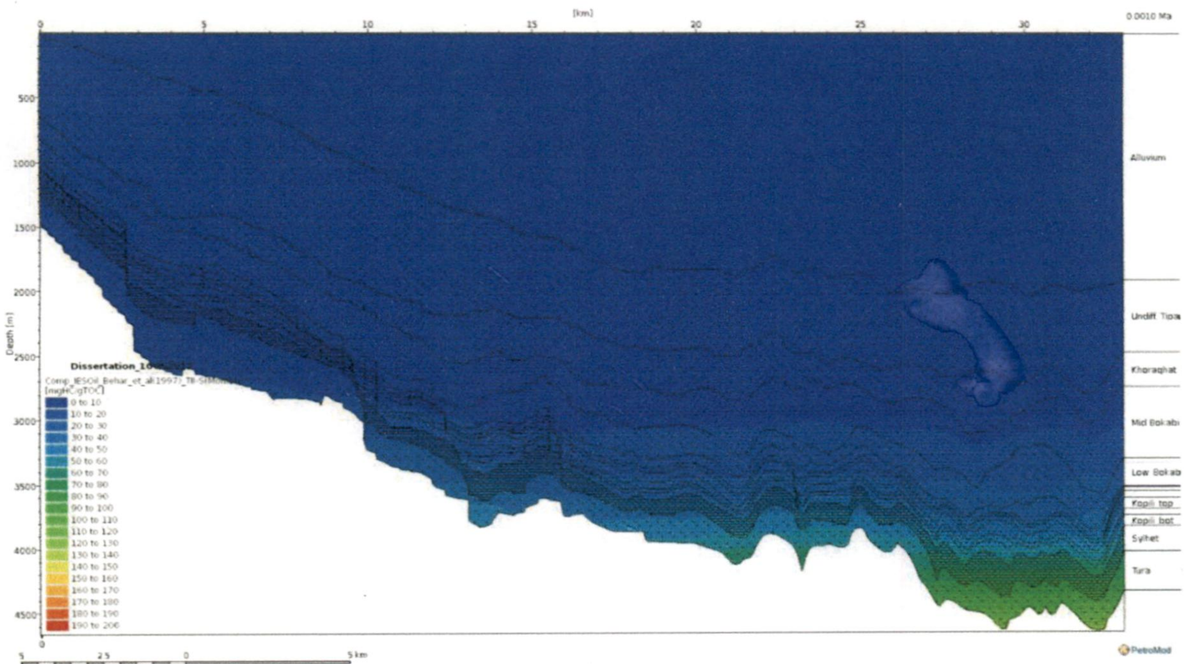


Fig. 7.9: Petroleum Generation Potential of oil with Kerogen II as chief OM

The Petroleum Generation Potential calculation has been carried out for the Kerogen Type I, II as well as III. However, from the past experiences by different workers, Kerogen II and III have a more prominent presence in the North and South Assam Shelf region. Hence the results of the figures presented here are particularly restricted to the hydrocarbons (oil & gas) generation potential from the Kerogen II and III. With Kerogen II as the chief Organic Matter, according to the resultant Figs. 7.9 & 7.10 the oil and gas has almost the same generation potential. On the other hand, with Kerogen III as the chief Organic matter, there is a higher probability of generation of gas rather than oil. These derivations are reached at from the Figs. 7.11 & 7.12.

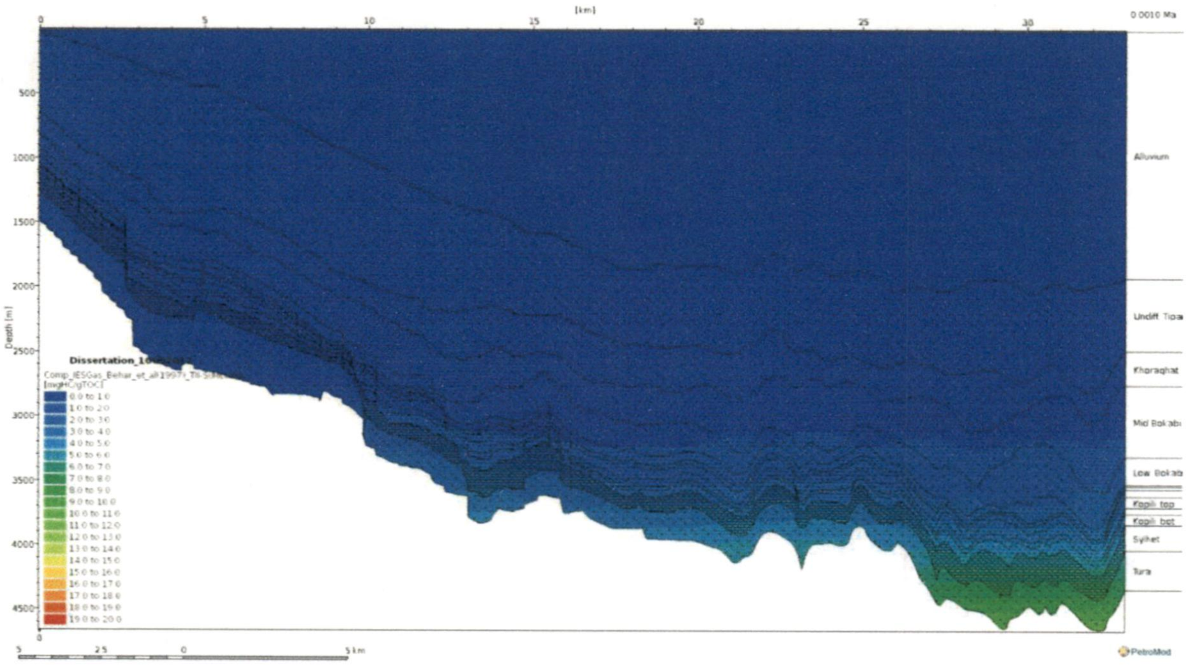


Fig. 7.10: Petroleum Generation Potential of gas with Kerogen II as chief OM

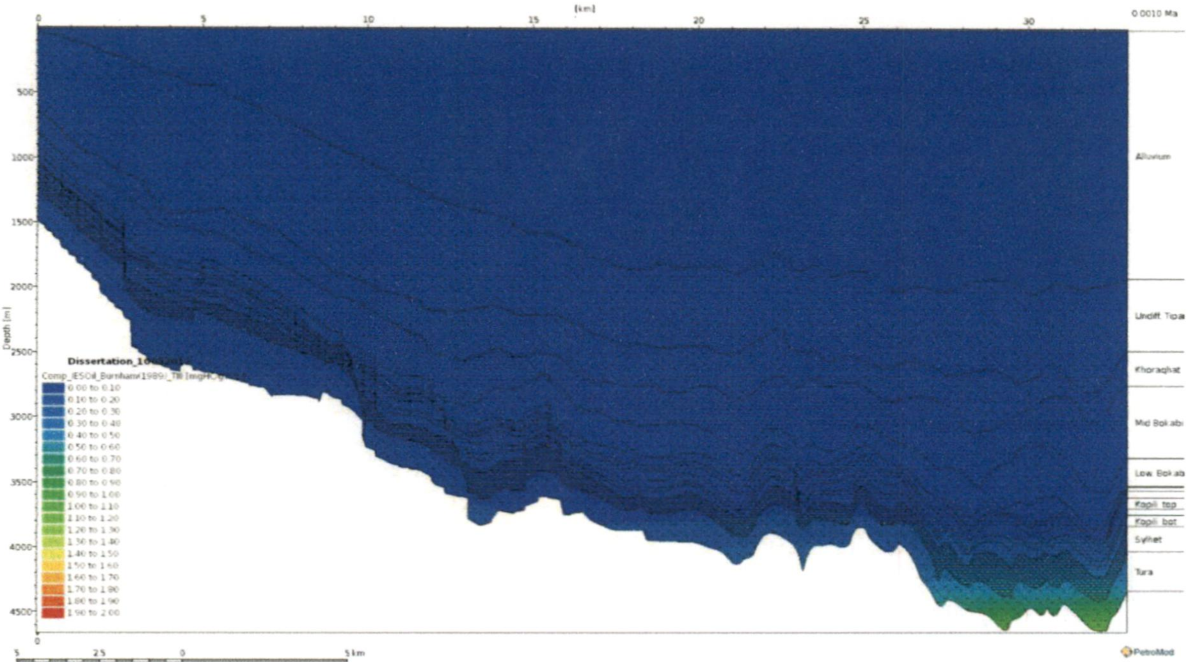


Fig. 7.11: Petroleum Generation Potential of oil with Kerogen III as chief OM

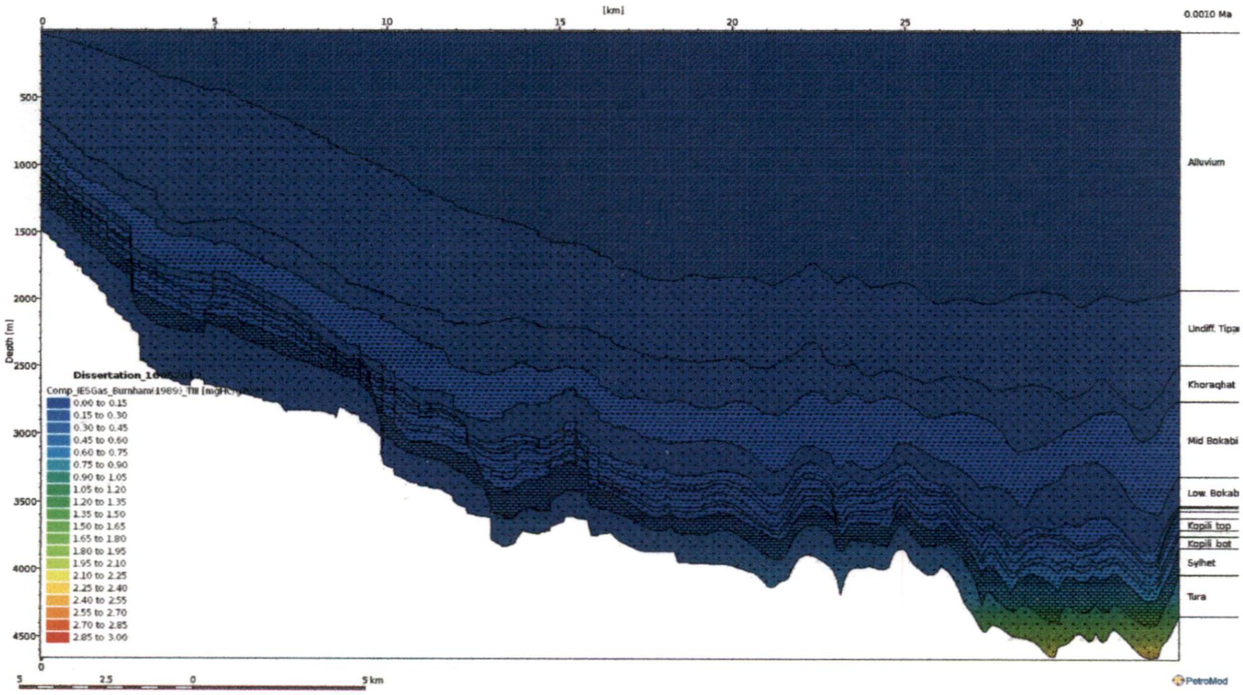


Fig. 7.12: Petroleum Generation Potential of gas with Kerogen III as chief OM

7.2.4 CALIBRATION:

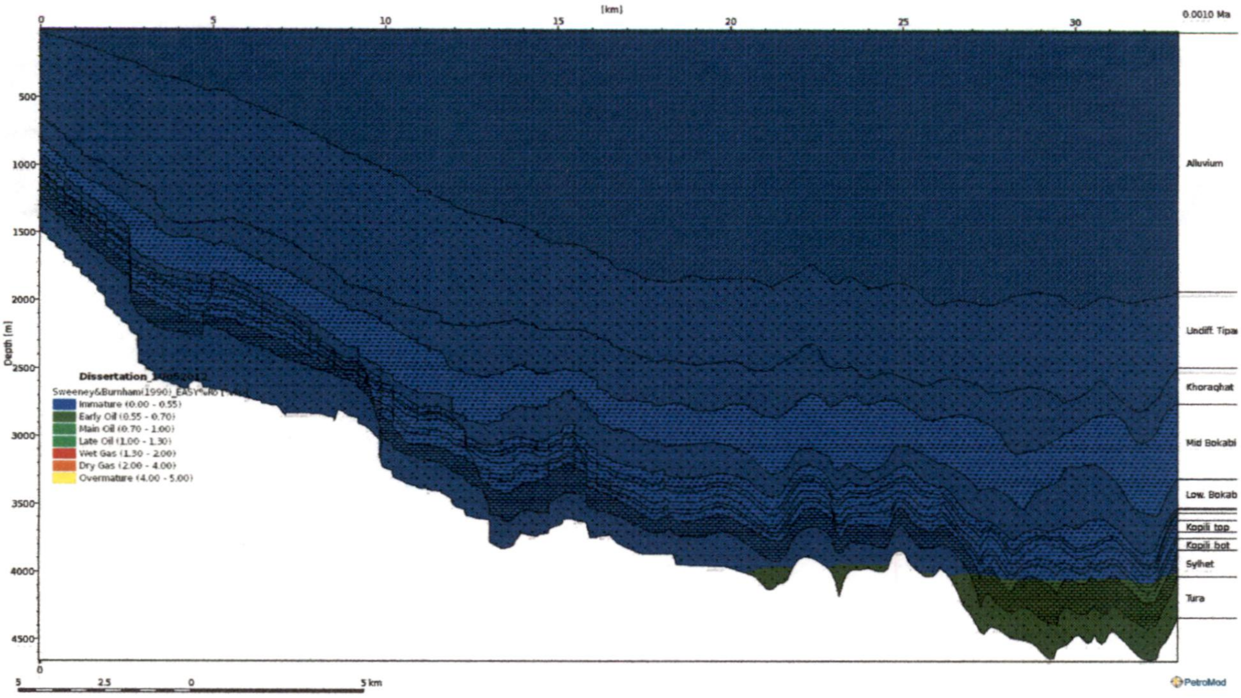


Fig. 7.13: Stages of the oil generation

The results from the simulation show (from Fig. 7.13) that the oil generated from the region is the early oil, while the rest of the region shows an immature behaviour.

7.3 SOURCE ROCK PROPERTIES:

Expulsion is only possible when the Transformation Ratio (TR) exceeds 50 percent. But from the cross-sectional view of the TR (in Fig. 7.14) with the Kerogen II as the chief organic matter, the TR never exceeds 15-20 percent. Hence, there is almost no possibility of expulsion from the pores of the region of the Source Rocks.

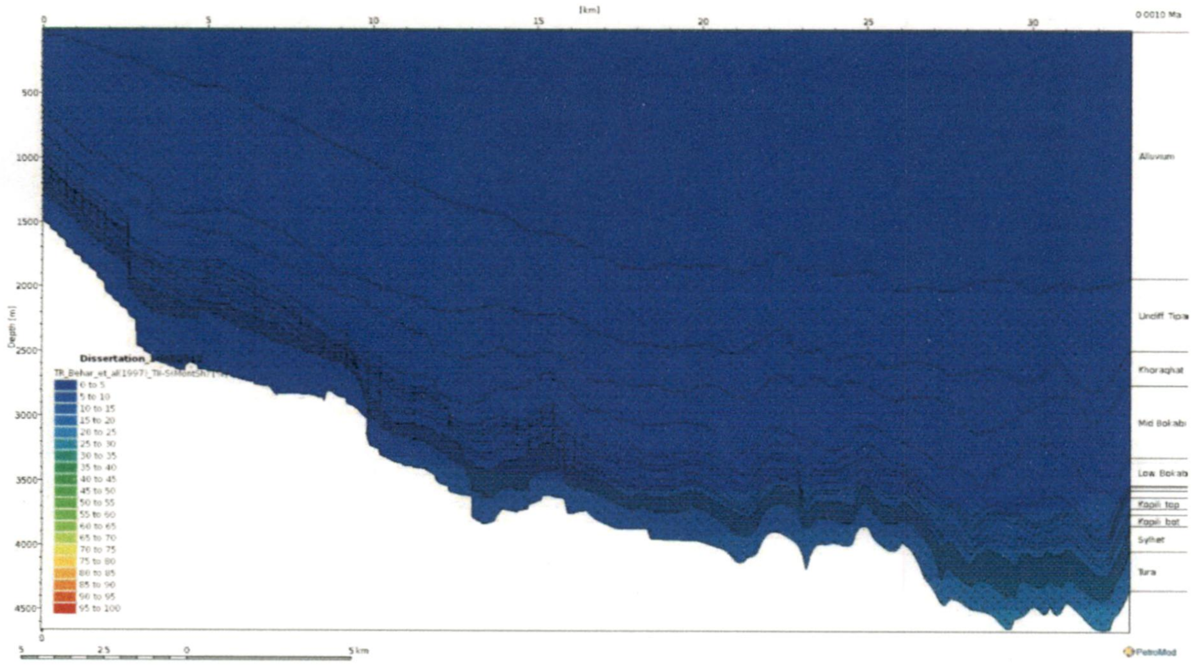


Fig. 7.14: Transformation Ratio distribution

7.3.1 SOURCE ROCK PROPERTIES: REMAINING KEROGEN

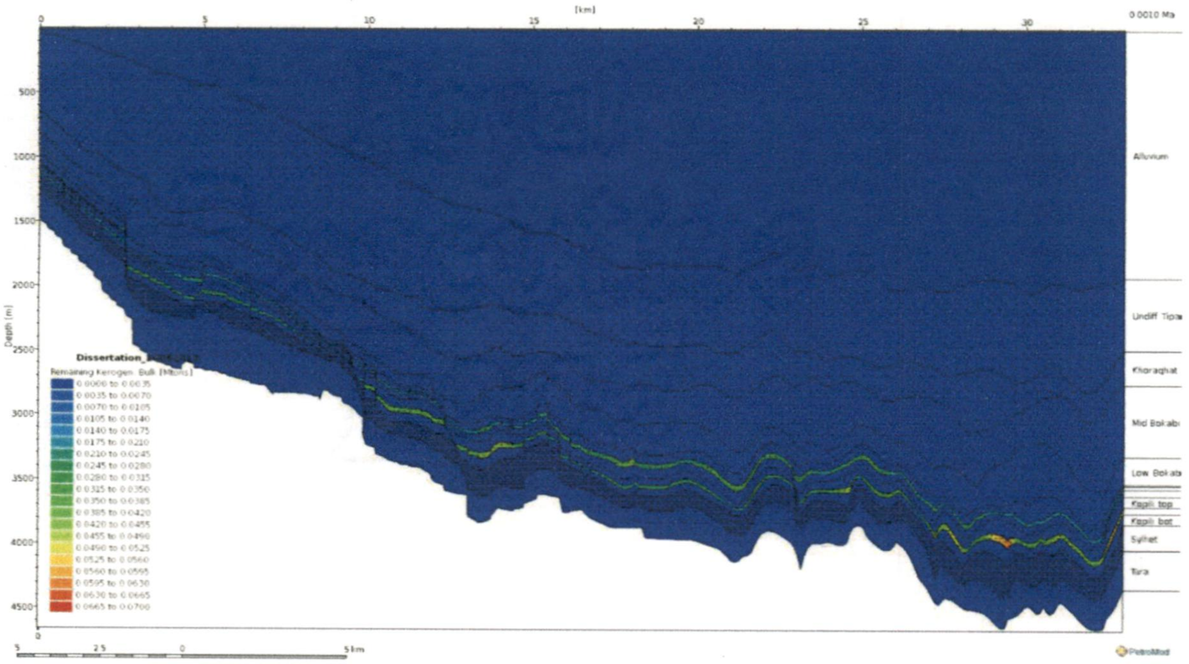


Fig. 7.15: The remaining Kerogen distribution

Since some of the factors haven't been conducive to the generation of hydrocarbons, there is almost little or no generation of the hydrocarbons from the region. Hence most of the organic matter from the source rocks has been left over as can be derived at from the Kerogen distribution diagram (Fig. 7.15).

7.4 MIGRATION PROPERTIES:

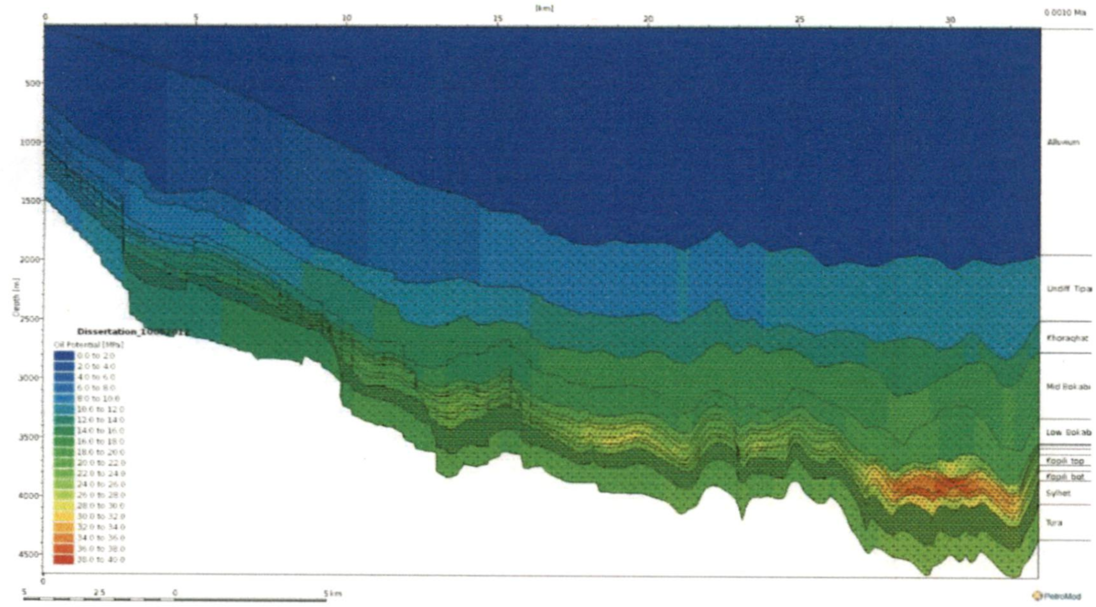


Fig. 7.16: Oil Potential distribution

Even though the regions cannot expel the oil from the pores, due to the low production of the hydrocarbons, but still the regions have a good potential to generate both the oil and gas as is clearly evident from the Figs. 7.16 & 7.17 showing the oil and gas generation potential. The formations of the Mid-Kopili and Barail show a good potential at generating the hydrocarbons.

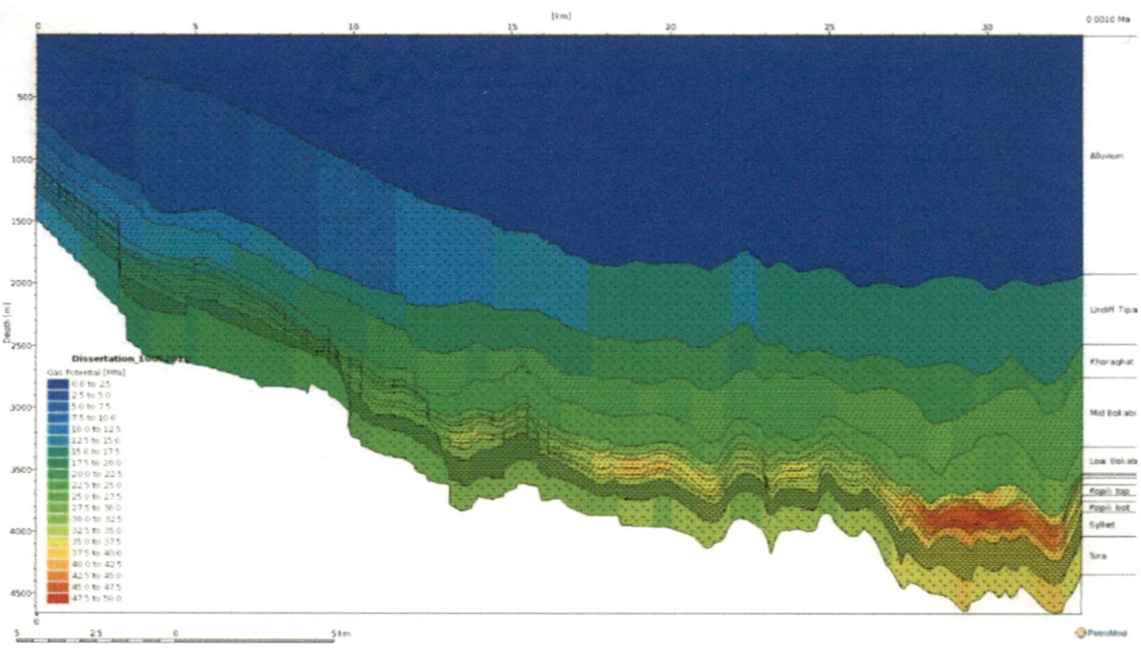


Fig. 7.17: Gas Potential distribution

CHAPTER 8: Results and Conclusion

The region studied has a moderate to good organic content. However, the temperature conditions are not good enough on the north western flank of the section; in contrast to that the southern eastern flank beneath the Naga Thrust has appropriate temperature-pressure conditions to generate petroleum. But, since generated petroleum also require a proper reservoir with an impermeable seal rock at the top to store the petroleum. Any deficiency in each of the factors can decrease the probability of the accumulation of petroleum. In the designated areas of study, there must lack of any or multiple number of factors that has led to the non-accumulation of the petroleum.

From the past modelling attempts by various workers from ONGC too, the close surrounding region has shown itself to be non-yielding. According to them several factors have attributed to the non-accumulation and thus non-yielding of hydrocarbons. Before the selection of study, there had been apparently a fair possibility of generation and accumulation of petroleum from the region. But, the results have shown that there is no accumulation of hydrocarbon in the region. However, the results from the present study have concurred with the past results and reaffirm the past findings only.

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