

# **An Analysis of Pre-Tertiary Plays in Matimekhana-Deohal Area - A Case Study from OIL's Operational Area in Northeast India\***

**Koustav Dasgupta<sup>1</sup>, Saqueba Samin<sup>2</sup>, and Bhagwan R. Bharali<sup>2</sup>**

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<sup>1</sup>Geophysics, Oil India Limited, Duliajan, India ([kdgiitr@gmail.com](mailto:kdgiitr@gmail.com))

<sup>2</sup>Geophysics, Oil India Limited, Duliajan, India

## **Abstract**

Occurrence of oil in Gondwana sediments of Cretaceous age in the drilled wells of East Lakhbari and Furkating areas in Assam Shelf has led to renewed interest in the Cretaceous sediments of the Upper Assam Basin. Sedimentation in the Upper Assam Basin started locally by the Campanian age (Cretaceous Period of Mesozoic Era), with deposition of Dergaon Group (and equivalents) of shales and sandstones. A case study has been presented here on the observed Pre-Tertiary sequence in Matimekhana-Deohal area which is expected to be equivalent of Dergaon Group (Cretaceous age). A critical examination of seismic data acquired over a period has revealed a mapable Pre-Tertiary thickness in Matimekhana-Deohal area. Seismic interpretation was carried out for three seismic reflectors which are equivalent to top of Langpar, base of Langpar (Eocene age), and top of Basement to analyse the prospective of the play. During the study it was observed the Pre-Tertiary sequence was deposited in a narrow north-south trending graben with maximum thickness of around 700 m to 800 m at a depth range of 3800 m and below. Hydrocarbon prospective of the Pre-Tertiary play is expected to be in situ generation of oil/gas from Cretaceous shale entrapped within the sand units of the Cretaceous Formation. The expected hydrocarbon generated for accumulation in the graben is of the order of 80 MMT as per 1-D modelling. The main objectives of this study are:

- To map the extra sediment preserved between the Langpar Formation and the Basement, and
- To establish the existence of pre-Tertiary petroleum system in this part of Upper Assam Basin.

It is envisaged that pre-requisite conditions for petroleum system viz. source, reservoir, cap rock, and entrapment condition exist in this deeper part of Upper Assam petroliferous basin.

## **Introduction**

The Upper Assam Basin in northeast India is a passive continental margin characterized by mainly Cenozoic hydrocarbon systems. Regional basement structure in the basin consists of tensional horsts and grabens active since at least late Permo-Carboniferous (Gondwana) time. The trends of these basement features in general are normal to the active continental margin.

Significant geoscientific data has been generated from the last fifty years of exploitation in the basin. A critical examination of 3-D seismic data has shown a mapable unit of Pre-Tertiary sequence in the Matimekhana- Deohal Area in the Upper Assam Basin. An approach has been made in this paper to map the extra sequence over Basement and make a prospective analysis. Seismically the preserved sequence is between Base of Langpar (Paleocene) reflector and Basement reflector. Sedimentation in the Upper Assam Basin started locally by the Campanian Period (Cretaceous age of Mesozoic era), with deposition of the marine Dergaon Group (and equivalents) of shales and sandstones. Pre-Tertiary sequence of Matimekhana-Deohal area is expected to be equivalent of Dergaon Group. During study it was observed that Pre-Tertiary sequence was deposited in a narrow north- south trending graben. Maximum thickness of the sequence is in order of around 700 m to 800 m. Hydrocarbon prospective of the Pre-Tertiary play is expected to be in situ generation of oil from Cretaceous shale entrapped within the sand units of Cretaceous Formation. The expected hydrocarbon available for accumulation in the graben is in order of 80 MMT as per 1-D modelling.

## **Geoscience Data**

About 400 sq. km of 3-D seismic data, covering the study area, was interpreted for Eocene prospects and Post-Eocene prospects especially focusing for Pre-Tertiary sediments. Although a number of wells were drilled in the study area, none has penetrated the Pre-Tertiary sequence ([Figure 1](#)).

## **Regional Geology**

Upper Assam Basin is a proven petroliferous basin which represents a classic example of passive continental margin that evolved simultaneously with other east coast basins of India concomitant with rifting followed by drifting of the Indian Plate from eastern Gondwanaland and its subsequent subduction underneath the Burmese and Eurasian plates. Geographically, the Upper Assam Foreland Basin is situated in the far north-east of India, within the curve of the Assam Syntaxis which is a major orocline in the Himalayan Orogenic Belt. The basin has thrust margins on three sides: to the south the Naga Hills Thrust Belt and Manipur Ophiolite Belt; to the east and north the Main Frontal Thrust of the Himalayas, which was active from the mid-Miocene to present day, bends around the Assam Syntaxis. As per sequence stratigraphic context, the shelf part of the basin consists of passive margin sediments of Late Cretaceous to Oligocene age and foredeep sediments of Miocene to Recent

age with Archean granitic metamorphics as basement. Gondwana sediments of Early Permian and Early Cretaceous age are locally confined between the Tertiary succession and granitic metamorphic basement.

### **Tectonic Evolution of the Assam and Assam-Arakan Basin**

Upper Assam Basin is essentially a Tertiary basin, although the oldest sediments reported at places are of Gondwana age. The same has been encountered in Borpathar, well within the Assam shelf part of the basin and a small outcrop found near Sigrimari. The sporadic presence of the upper Paleozoic and Cretaceous strata in the subsurface of the Assam plains may be only due to their local preservation in small intracratonic grabens or their erosion before Eocene deposition ([Figure 2](#)).

#### **Phase I and II - Mid to Late Cretaceous:**

The basin formation was initiated in the Early to Late Cretaceous due to rifting and drifting of the Indian Plate from the Indo-African–Antarctic Continent (Sub-Gondwana). Several horst and graben features formed in a tensional regime on the granitic crust. This was accompanied by sediment deposition in the grabens along with south-easterly dipping of the shelf during this period.

#### **Phase II - Paleocene – Eocene:**

Continued northward drifting of the Indian Plate resulted in initiation of subduction of the oceanic part of the Indian Plate below the Burmese Plate in the east. This caused the formation of the Indo-Burmese trench system east of the Assam Shelf where deep marine sedimentation along with deposition of Gondwana sediments took place.

#### **Phase III - Eocene to Late Oligocene:**

Continued northward movement and convergence of the Indian Plate during Eocene-Oligocene slowly closed out the intervening sea. Carbonate platform build-up continued intermittently from the Eocene through middle Miocene time on the shelves surrounding much of the Indian Plate. As the Assam Shelf continued to be evolved under a passive margin tectonic setup, deposition of the Barail Group took place followed by regional uplift and erosion during the Late Oligocene.

#### **Phase IV - Miocene – Recent:**

Oligocene uplift and erosion were followed by late Miocene through Pliocene extensive alluvial deposition under deltaic to shallow marine conditions.

The Gondwana sediments have been mainly deposited in paleo-gabnal areas oriented in linear fashion. The lithology mainly comprises of sand/shale alteration of mostly rift fill sediments of early Cretaceous age. The depositional environment is mainly shallow marine.

## **Generalized Stratigraphy of Assam Shelf with Special Emphasis on Pre-Tertiary Sequence**

Pre-Tertiary sediments were reported in the Assam-Arakan Basin as the Dergaon Formation in ONGCL's operational areas. Generalized stratigraphy of the Assam Shelf modified after Deshpande et al., 1993 and OIL's internal report ([Table 1](#)).

### **Seismic Interpretation**

A critical examination of the seismic of the present study area over a period of time has revealed a mapable Pre-Tertiary sequence which is expected to be similar to the Pre-Tertiary sediments of Dergaon equivalent. Pre-Tertiary sediments were deposited in a narrow north-south trending Mesozoic graben over 10 km in length and 4 km width from the Matimekhana to the Deohal area. The top of this sequence has been marked as Base Langpar reflector. A number of major and minor normal faults with dominant NE-SW and E-W trend are observed in the study area. The majority of the normal faults are affected from Basement to Eocene. One major fault trending in a NE-SW direction separates Chabua horst block and the study area. Another N-S trending fault separates Tinsukia Low and the Kharikatia and Okanimara high. The structural highs (anticlinal closures) are associated with normal faults. Interpretation has been carried out only for the graben area whereas flank of the graben is merged with the Basement surface. Expected thickness of Mesozoic sediments preserved in the graben is of the order of around 700 m to 800 m. The TWT contour values are in the range from 2920 m to about 3040 m at northern side of study area. Expected depths at this level may vary from 3770 m to 4070 m across the area. There could be seen some bright amplitude in small areas which could be inferred as some coal units locally. ([Figure 3](#)).

The existence of a graben trending in an N-S direction is also observed in the contour map close to Basement. The graben is terminated to the north by a NE-SW trending major fault. Isopach maps generated using depth grids for Langpar and Pre-Tertiary formations show the general thickness of the Langpar Formation to be around 100 m to 140 m over the area. It is observed that increase in thickness is towards the eastern side. Thickness of the Pre-Tertiary sequence is maximum to around 800 m at the central part of the graben. Dimension of the graben is about 10 km by 4 km extending from Matimekhana in the north to Deohal in the south ([Figure 4](#)).

Velocity analysis carried out for the study area showed interval velocity of the Langpar and Pre-Tertiary sequence is very much comparable. The increase in velocity of the Pre-Tertiary sequence is because of deeper depth. View this, it may be inferred that the velocity dependent reservoir properties are expected to be comparable to the Langpar Formation.

## **Hydrocarbon Potential and Plays in Pre-Tertiary Sequence**

There is a well-established proven petroleum system working in the different basins in India where commercial hydrocarbons have been established in Mesozoic rocks. Shale sequence within the lower Cretaceous Formation has been found to be the main regional source in rift basin like Krishna-Godavari Delta. Hydrocarbon prospective of the Pre-Tertiary play in the study area is expected to be in situ generation of oil from Cretaceous shale entrapped within the sand units of the Cretaceous Formation. The hydrocarbon generation and expulsion by Pre-Tertiary sediments has been determined using 1-D modelling. Assuming an expulsion saturation of 10% i.e. hydrocarbon expulsion starts taking place after 10% of the pore volumes is occupied by hydrocarbons, the amount of hydrocarbons expelled is 10 kg/ton of rock. The amount of hydrocarbons available for accumulation has been calculated in the order of 79.82 million tonnes assuming a migration efficiency of 25%.

## **Conclusion**

Seismic interpretation was carried out for three seismic reflectors which are equivalent to Top Langpar, Base of Langpar, and Top of Basement to analyse the prospective of the play. All the pre-requisite conditions viz. porosity development, source rock, cap rock, and entrapment are expected to be preserved in the Mesozoic graben. Interval velocity of the Pre-Tertiary sequence and Langpar Formation is comparable. Velocity dependent reservoir properties are, therefore, expected to be similar for both formations. Geological resource assessment has not been carried out due to non-availability of data required to calculate various parameters except structure size. 1-D modelling has been carried out using Cretaceous outcrop samples (TOC content 8%) of Meghalaya. The result of the analysis is expected to be about 80 MMT of hydrocarbons available for accumulation in the Pre-Tertiary play. Although expected thickness of Pre-Tertiary sequence is estimated based on seismic velocity, the validation of thickness could not be ascertained due to non-availability of well drilled down to the Pre-Tertiary sequence in the graben area.

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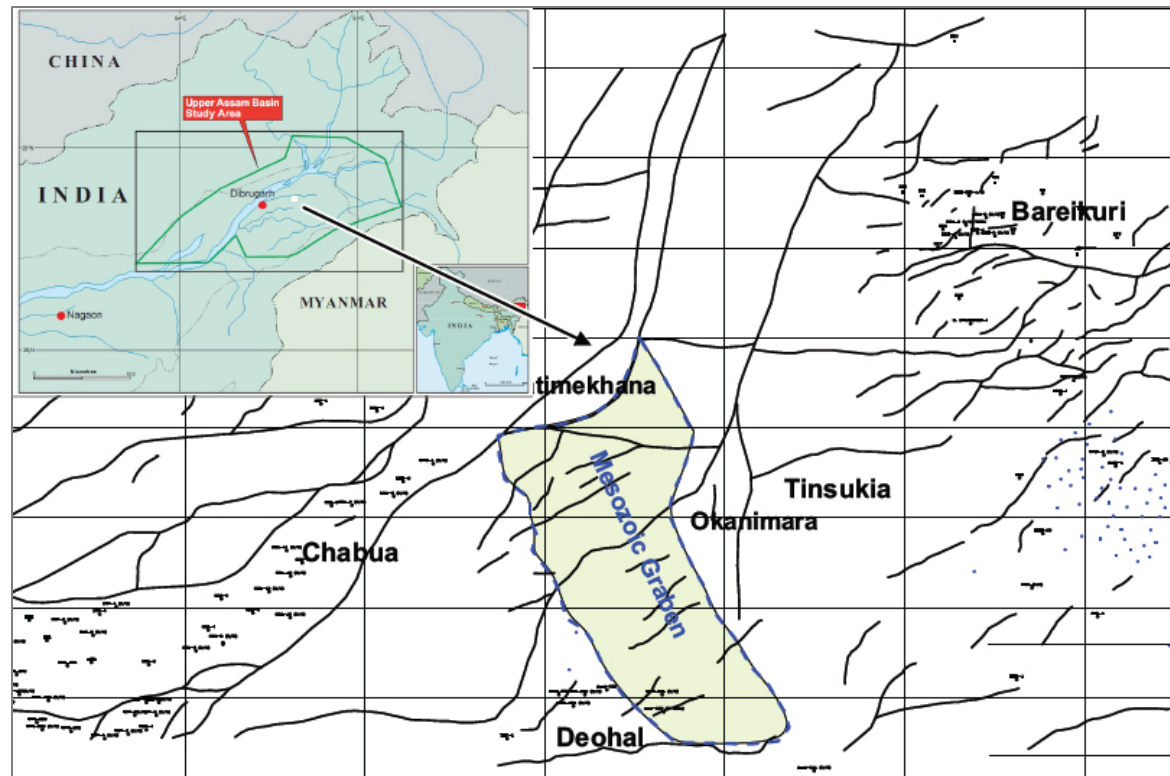


Figure 1. Index Map of Study Area showing outline of the Mesozoic graben (Black line showing the basement fault in the area)

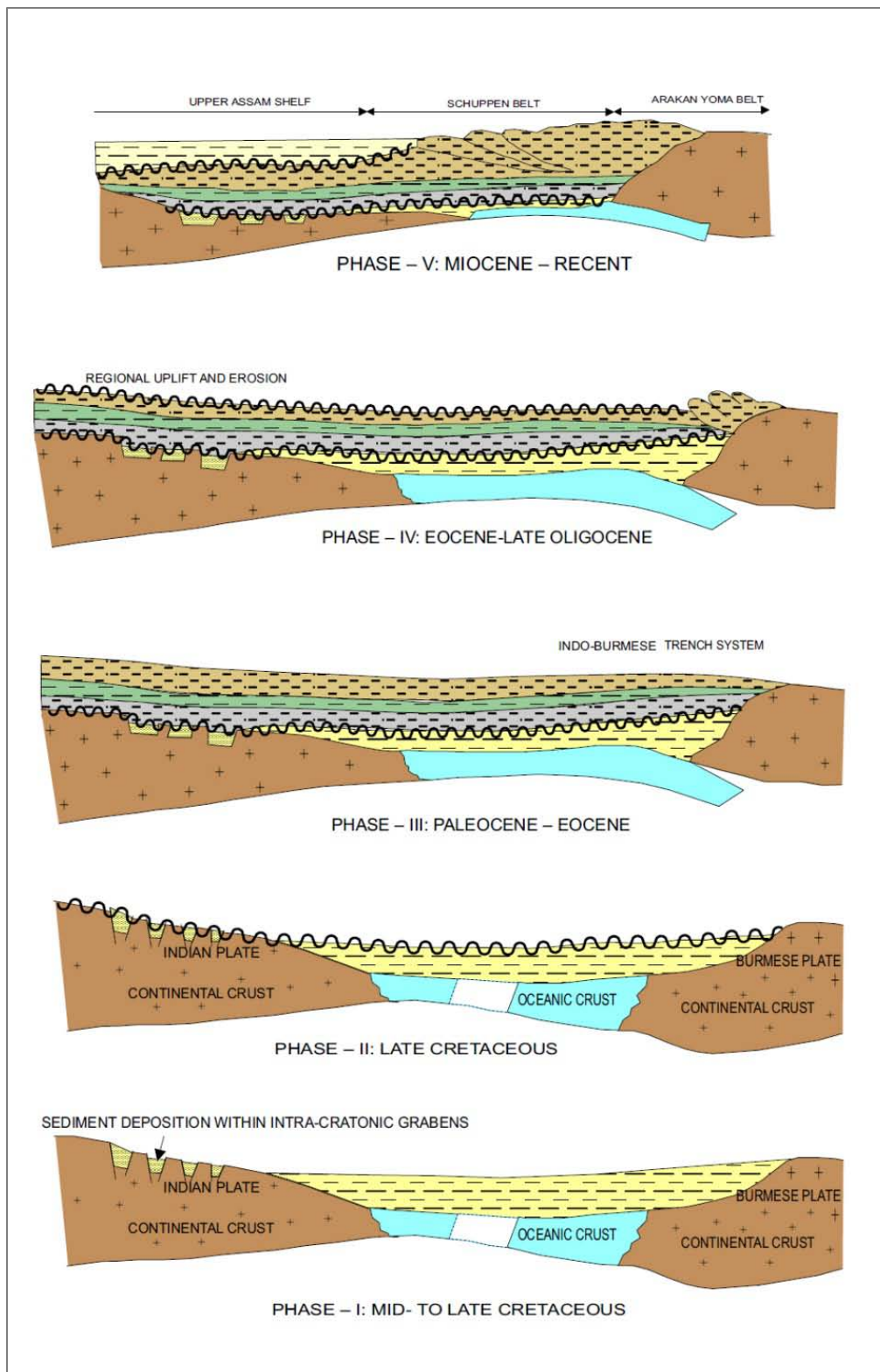


Figure 2. Tectonic Evolution of the Assam-Arakan Basin.



Age		Lithostratigraphic Nomenclature	
Pleistocene			Alluvium
----- <i>Unconformity</i> -----			
Tertiary	Pliocene	Dihing Group	Dhekiajuli Fm.
	----- <i>Unconformity</i> -----		
	Miocene	Dupitila Group	Namsang Fm.
		Tipam Group	Girujan Fm
			Tipam Fm.
	----- <i>Unconformity</i> -----		
	Oligocene	Barail Group	Argillaceous Unit
	Arenaceous Unit		
	Eocene	Jaintia Group	Kopili Fm
			Sylhet Fm <u>Prang M</u> <u>Narpuh M</u> <u>Lakadong+Therria M</u>
	Paleocene		Langpar Fm
----- <i>Unconformity</i> -----			
Cretaceous		Dergaon Group	Moabund Formation
			Bamungaon Formation
----- <i>Unconformity</i> -----			
Pre-cambrian		Basement	

Table 1. Generalized stratigraphy of the Assam Shelf modified after Deshpande et al., 1993 and OIL's internal report.

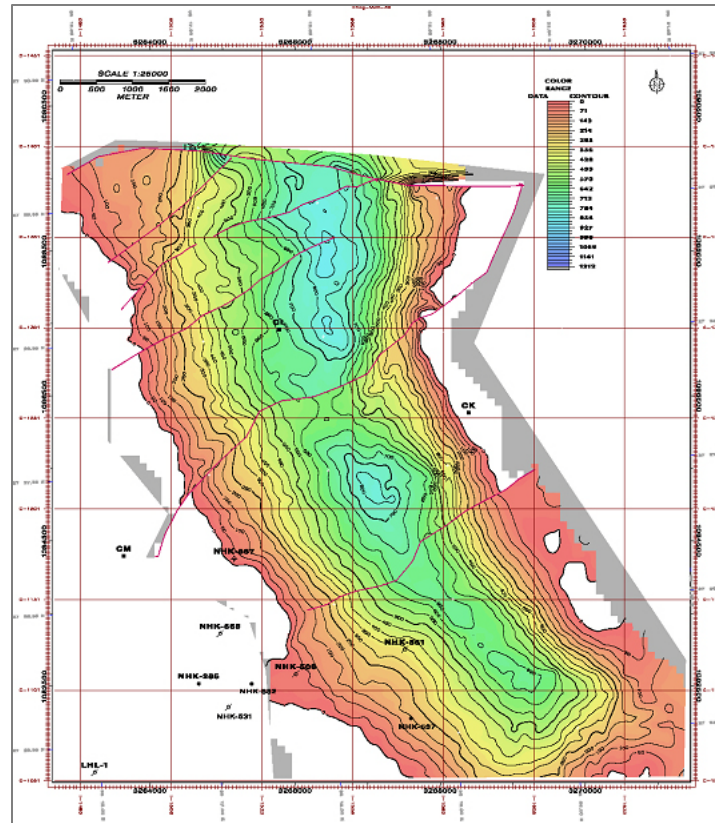


Figure 3. Matimekhana-Deohal Area: Seismic Section Passing Along the Pre-Tertiary Graben. i) yellow transparent colour showing cross sectional view of Pre-Tertiary Sequence, ii) colour lines over seismic section showing mapped horizons, and iii) blue lines represents faults

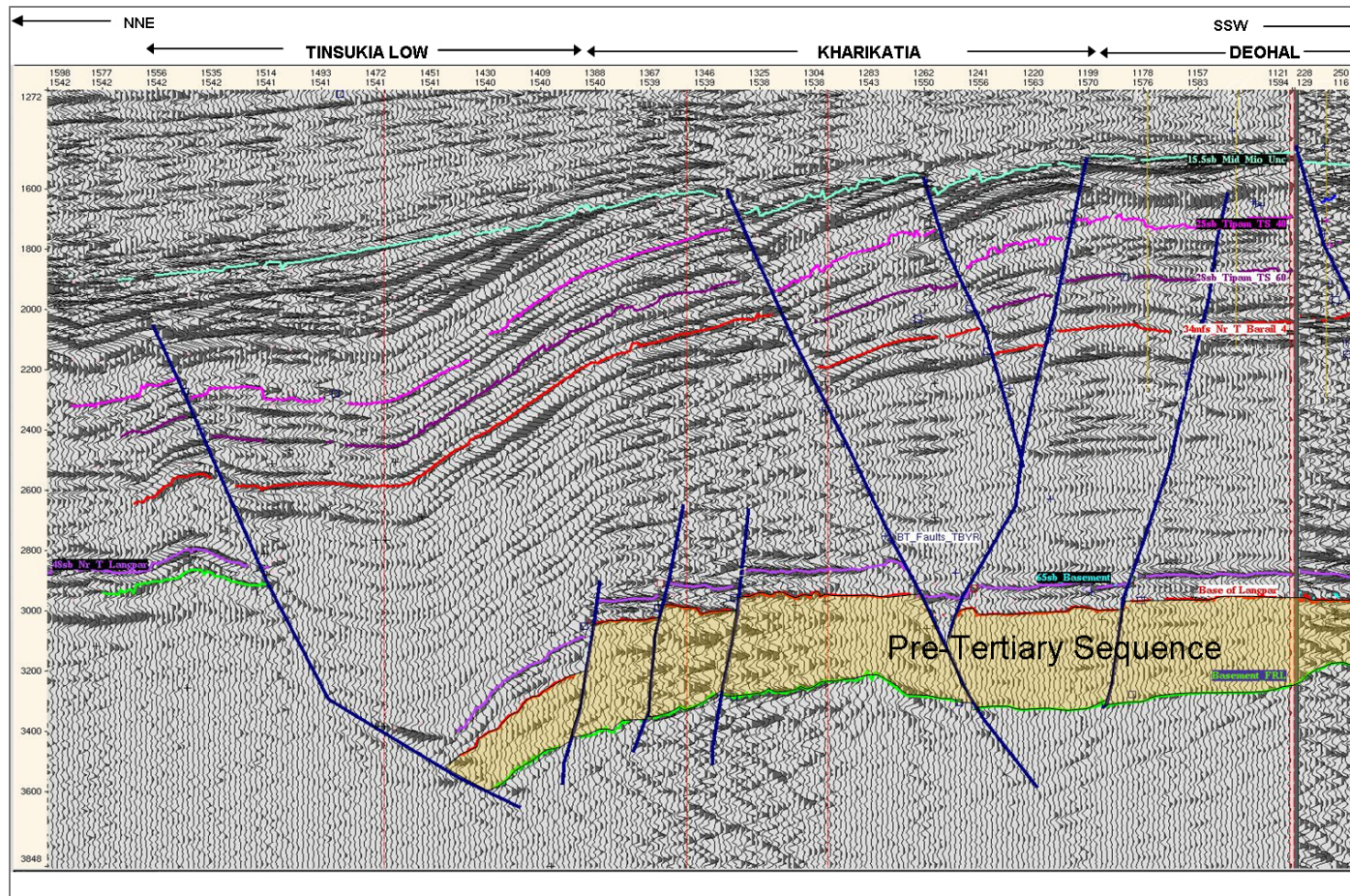


Figure 4. Isopach Map between Base Langpar and Basement showing deposition and thickness of the Pre-Tertiary Sequence (thickness increases from red to blue). i. Red line represents fault boundary across the graben which are aligned to regional basement fault