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Maturity Analysis of Pre-tertiary Sediments in Dhansiri Valley using 1D Basin Modeling Approach (a case study from East Lakhibari & Kalyanpur Area)

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Abstract

Dhansiri valley is a foreland basin, which is a proven oil and gas contributor from tertiary sequences. The major fields of the Assam Shelf is concentrated between the Schuppen belt in the East; Himalaya in the North and Mikir Hills in the west. Assam Shelf have multiple established plays, majorly the Tertiary pays and Precambrian basement contributing to the production, while the hydrocarbon prospectivity of the pre-tertiary reservoirs are yet to be determined. The occurrences of the pre-tertiary rift sediments of Upper Cretaceous and Gondwana age (Permian) are sporadic and are encountered in Dergaon, Barpathar, Jamuguri, East-Lakhibari and Furkating area. Pre-tertiary sediments are only found as remnants in the grabens developed during the rifting phase. Based on the available G & G data the prepared isochronopach map between Sylhet and Basement define the extent of rift-fill sediments. The present study has been taken up to bring out the maturity analysis of the rift fill sediments through petroleum system modeling to infer the source rock maturity and likely hydrocarbon accumulations. The constructed one-dimensional model in one drilled well and in a deeper pseudo-well in the rifted sediments brought out the maturity and generative potential of rift-fill sediments in South Assam Shelf based on source rock maturation study. This paper envisaged that rift-sediment are not acting as an independent petroleum system and the charging of the rift sediments are only possible by juxtaposition of rift fills with the mature source rocks under Naga Schuppen Belt.

Keyword: Gondwana, Dhansiri Valley, Horst-Graben, Rift-fill sediments

Introduction

Dhansiri Valley, the southern portion of the Assam Shelf, hosts some of the prolific areas for oil and gas producing fields. In Assam & Assam Arakan Basin Pre-tertiary sediments have been encountered in few wells. Mesozoic sediments globally contribute to the major oil and gas reserves, while in India K-G Basin & Cauvery Basin have been the prolific producer from the Mesozoic rift fill sediments. In north eastern part of the country the occurrence of pre-tertiary sediments are sporadic and discontinuous. Few wells in the Dhansiri Valley have encountered pre-tertiary sediments during drilling. The pre-tertiary rift-fill sediments deposited in the NNE-SSW oriented grabens in the Dergaon, East Lakhibari area and NW-SE in the Kopili Valley and Daladali area. The thickness of the Pre-tertiary sediments varies from 350 to 50m, found only in grabens. **Previous workers defined rift-fill sediments as an independent petroleum system.** However, source rock maturity of the pre-tertiary sediments in A&AA Basin is controversial.

1D basin modeling was carried out for source rock maturation study of the Pre-Tertiary sediments in one drilled well and also in a deeper pseudo-well in East-Lakhibari area integrating all geochemical data, corrected BHT data and Rock Eval pyrolysis data. The study also incorporates the well data and biostratigraphy data for formation tops, ages and lithology of the sediments. Paleogeography maps were also used to define the paleo-water depth in the model. A present day heat-flow of 52 mW/m^2 has been assigned and paleo heat flow is estimated from Allen and Allen (2005) based on tectonic history. During Cretaceous rifting, the heat flow is relatively high around 80 mW/m^2 which decreases gradually with thermal subsidence. The model has been calibrated with corrected BHT and porosity data. The results of the study have improved our understanding of the Petroleum system of Pre-Tertiary sediments.

Geology & Tectonic Setting

Assam & Assam Arakan Basin is situated in the North Eastern part of India which constitutes of three tectonic elements: Assam Shelf, Assam-Arakan Fold belt & Naga Schuppen Belt. The Indian Plate is subducting under the Burmese plate in the east and Eurasian plate in the North. As a result of the subduction the orogeny formed by closing of the Tethys Ocean and Assam & Assam-Arakan basin formed as a foreland basin. The East-West trending Jorhat fault divides the Assam Shelf in two parts: North Assam Shelf & South Assam Shelf (Dhansiri Valley). The basin evolved through multiple tectonic phases starting from Permian to Recent. During the Mesozoic time the NE India was part of the Gondwanaland Supercontinent. Further, it was rifted and drifted towards north east during early Cretaceous. Assam Shelf evolved as southeasterly dipping shelf/passive margin with normal block faulting up to Late Oligocene. Oligocene is marked by a profound unconformity in the South Assam shelf. Later erosion and upliftment took place followed by the deposition of Neogene alluvial sediments in the foreland tectonic setup. The dominant compression started during 1.8 Ma (Oliver et al. 2010). The generalized tectono-stratigraphy is as follows (Fig.1.)

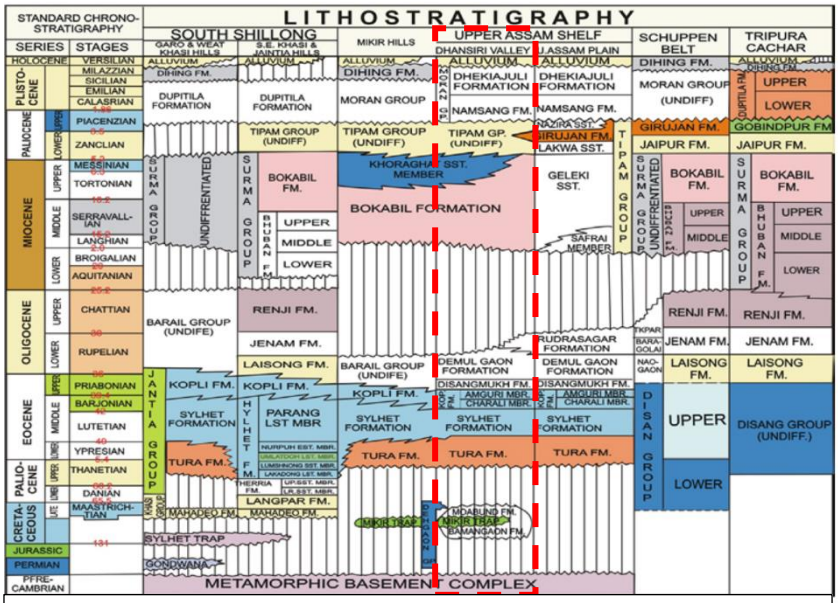

Fig.1: Generalized Stratigraphy of the Assam (after Moulik et al. 2009)

Pre-Tertiary Sediments

The Pre-tertiary sediments are defined as the rift fill deposits in the Dhansiri Valley. Some workers have considered the Pre-tertiary sequences as Gondwana sediments. Whereas, recent findings from the Paleo-depositional environments of the Pre-tertiary suggests that the succession of the sediments are further subdivided and are of different age. Dergaon formation, which dates back to early Permian age, is equivalent to the Talchir formation of Lower Gondwana. Only 3 wells have reported Early Permian sediments from Dergaon and East Lakhibari area. Dergaon formation is overlain by the Dergaon Group which is subdivided into Bamangaon formation, Mikir Trap and Moabund formation. Dergaon group dates back to Cretaceous age. The detailed succession of the Pre-Tertiary sediments is as follows (Fig.2).

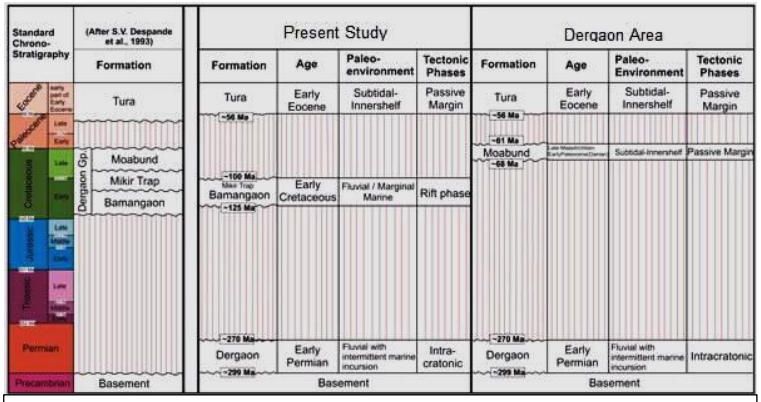

Fig.2: Stratigraphy of the Pre-tertiary Sediments (after Narsimha et al. 2021)

Details of Present study

In the study area, 15 wells have penetrated through Pre-Tertiary sediments. Based on the recent palynofossils study (Narsimha et al. 2021) it has been found that only 3 wells (i.e. 'GD', 'GA' & 'GB') have encountered sediments of Early Permian age whereas the oldest sediments of the rest of the wells are of Upper Cretaceous. Wells 'GD', 'GA', 'GB', 'GC', 'GD', 'GE', 'GF' & 'GP' shown in Base Map (Fig.3), the Pre-tertiary sediments are found at a greater depth in these wells which had been deposited in the pre-existing paleo-grabens oriented in NE-SW and NW-SE direction. The Isochronopach Map between Sylhet Formation and Basement shows the thickness and extent of the syn-rift sediments (Fig.4). The prepared sand isolith map of Pre-tertiary sediments based on the drilled wells shows two depositional trends, one is from the northeast-southwest and the other one branching out towards south-east direction (Fig.5). Sand Isolith map of Pre-tertiary sediments depicts good amount of reservoir facies in the study area with maximum sand thickness of about 145m in well 'GD'. The log correlation of wells 'GF', 'GC', 'GE' & 'GP' indicates that the basinal dip is towards south-east. (Fig.6)

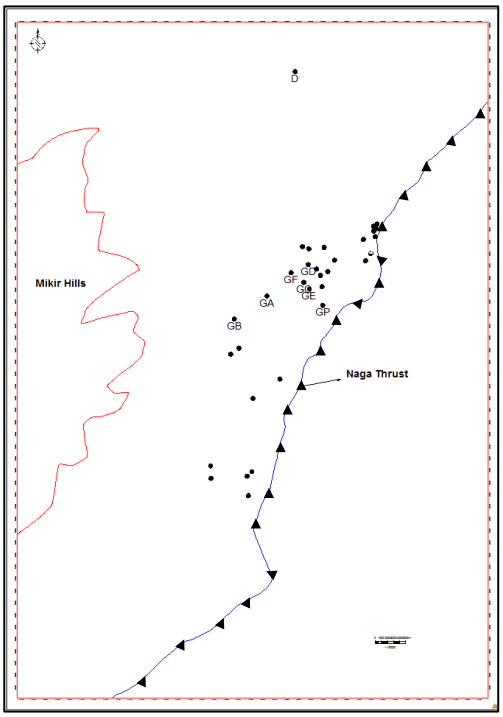

Fig.3: Base map of the encountered wells of Dhansiri valley

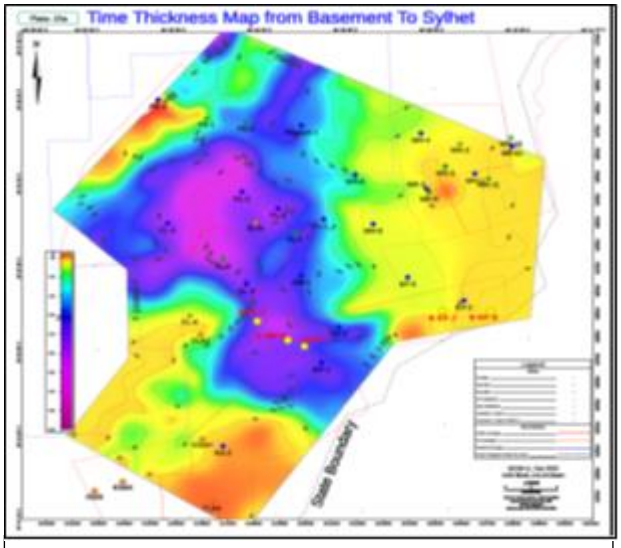

Fig.4: Isochronopach Map showing extent of rifted sediments

Fig.5: Sand Isolith Map of Gondwana

Source Rock Potential of Pre-Tertiary Sediments

Pre-tertiary sediments of shelf area have been tested and studied for Hydrocarbon Prospectivity.

In well 'GC' the tested objects in Pre-tertiary sediment have produced water with traces of hydrocarbon. Source rock evaluation has been carried out by RGL Sivsagar for one well 'GE' in the East Lakhibari area. Moreover one well of Barpathar gave gas indication while one well from Furkating showed Oil indication. Along with this well 'GD' & wells in Furkating and Nagaon area indicated hydrocarbon shows in the pre-tertiary sediments.

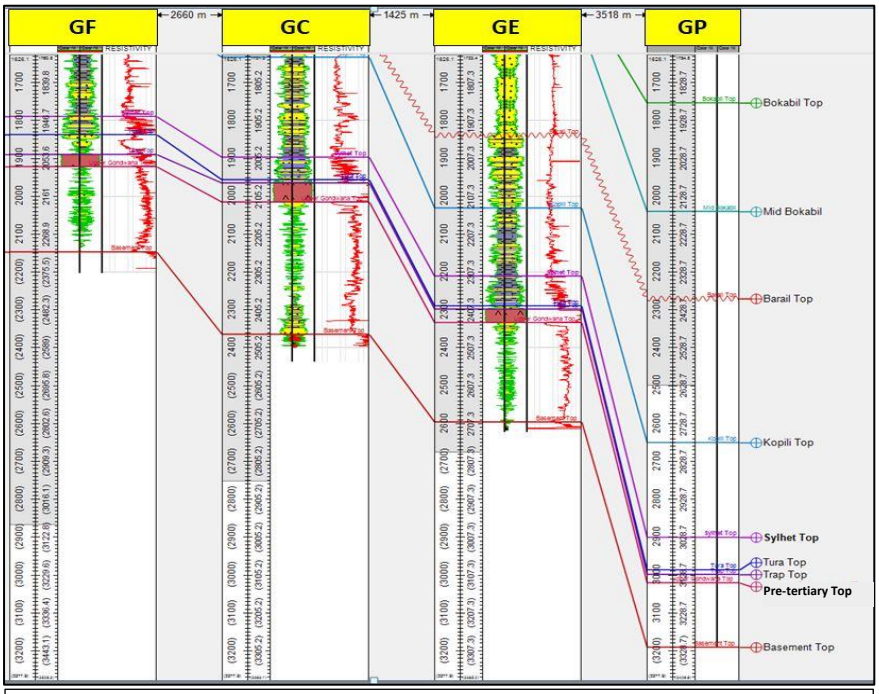

Fig.6: Structural Log Correlation between studied well 'GF', 'GC', 'GE' and pseudo well 'GP'

In the well 'GE' Pre-tertiary sediments were studied for source rock analysis, where only a 15m thick section exhibit fair potential source rock with very good TOC (avg. TOC: 2.8 wt.%) and fair generation potential (avg. S2:3.58mg HC/g rock). Maturity study based on T-max (avg. T-max 428 °C) indicates that the sediments are in immature stage. Better source rock characteristics have also been identified in wells 'GC' and 'GD', the sediments are immature but possess very good generation potential. The report (Purkait M. et al. 2010) suggested that the pre-tertiary sediments may act as source rock in deeper part of the basin where they would attain sufficient maturity to expel hydrocarbon.

Thus, integrating Rock Eval data, geochemical data, corrected BHT and porosity data of the studied well 'GE' and one deeper pseudo well 'GP' has been modeled to understand the maturity of pre-tertiary sediments in deeper part of the basin. Based on 1D basin modeling, it has been observed that the Pre-tertiary sediments enter the early oil window with 0 % transformation ratio (Fig.7 & Fig.8).

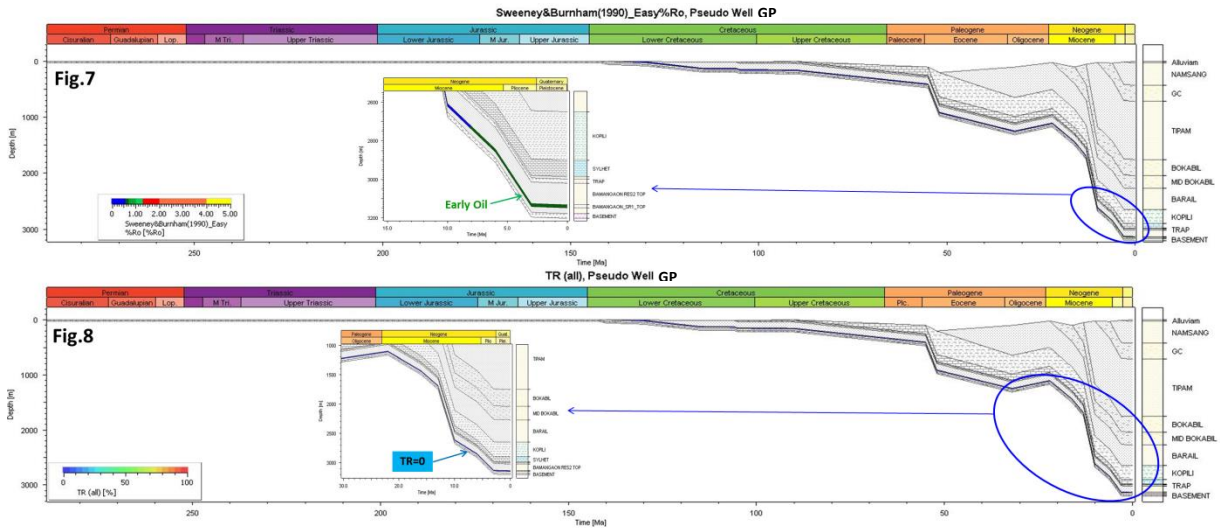

Fig.7: Burial History of pseudo-well GP overlain with maturity data.
Fig.8: Burial History of pseudo-well GP overlain with transformation ratio.

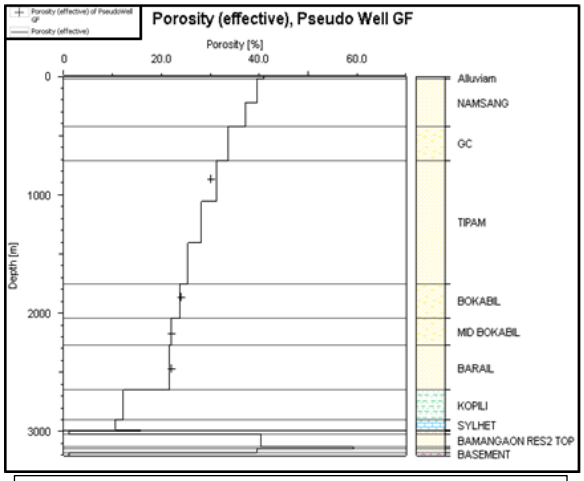

Fig.9: Porosity Calibration of the 1D Model

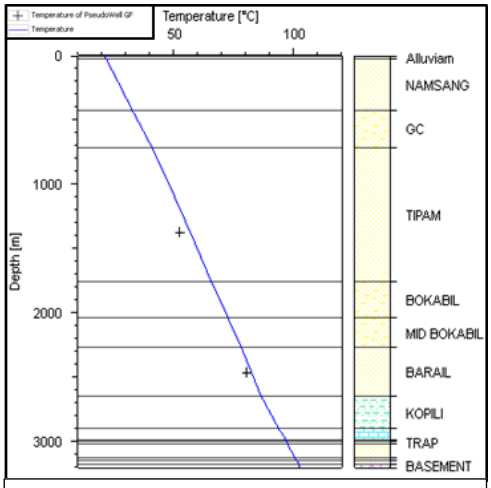

Fig.10: Temperature Calibration of the 1D Model

Pre-Tertiary Sediments as Reservoir Rock

Cores and cutting samples of the pre-tertiary sediments have shown different lithological and petrographic characters. The older units overlying the basement are mainly sandstone intercalated with shales. Shales having pebbles infer the initiation of syn-rift phase with marine influence, which correlates well with Lower Gondwana Basal Talchir Formation. The Early Cretaceous pre-tertiaries comprises of medium to coarse grained, poorly sorted, angular, feldspathic sandstone. Shales are carbonaceous with occasional coal lamination. The seismo-geological section (Fig.11) prepared along a dip direction shows the drilled well 'GE' along with the other Pseudo well which is deeper and close to Naga-Schuppen belt.

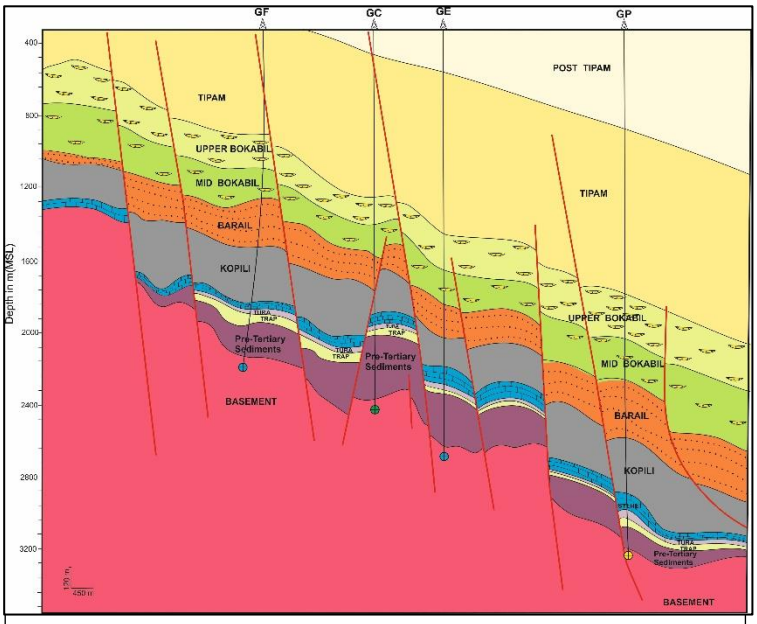

Fig.11: Seismo-Geological Cross section showing studied well 'GE' & Pseudo well 'GP' along the basinal dip towards Naga Schuppen

Conclusion

The Pre-Tertiary sediments cannot act as an independent Petroleum system based on the 1D basin modeling study. Hydrocarbon Prospectively of Pre-Tertiary Sediments can only be established where it is juxtaposed with Kopili and Barail level faults which acted as conduit for long distance lateral migration from mature shales of Naga-Schuppen belt. In order to understand the migration model, previously done regional 3D model was simulated coupled with low grid resolution model in the study area. Based on the source rock analysis data, the Pre-Tertiary sediments exhibit fair potential source rock with very good TOC and fair generation potential. The maturity of the source rock is low. The deepest pseudo well enters only early oil phase with zero transformation. So, Pre-Tertiary sediments acting as a Petroleum system cannot be ruled out. However, where the sediments are close to Naga-Schuppen belt, migration can be possible from mature shales of Barail and Kopili and hydrocarbon accumulation can be envisaged in those areas where it is juxtaposed with Kopili and Barail shales. 1D

Basin modeling approach and migration model improved our understanding regarding the maturity of the source rock of Pre-Tertiary sediments and also the migration directions from Naga-Schuppen belt.

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