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FUTURE EXPLORATION OPPORTUNITIES, ASSOCIATED RISK & REWARD AND WAY FORWARD IN FAIRLY EXPLORED ASSAM SHELF BASIN OF ASSAM-ARAKAN PETROLEUM SYSTEM

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Abstract:

The journey of oil exploration in the shelf part of the Assam-Arakan Basin dates back to the latter half of the 19th century. With passing time, technology and excellence, more discoveries were made in the foothills and plains of Upper Assam.

With an exploration history of more than 130 years, both OIL and ONGC have discovered numerous oil and gas fields, varying in size & hydrocarbon volumes and subsequently developed for greater recovery. With acquisition of every additional subsurface data, better understanding of basinal evolution, hydrocarbon generation, migration and entrapment has been established for future hydrocarbon exploration.

Assam Shelf Basin has both established and potential plays in different stratigraphic units across the basin. This technical paper explores the probability of occurrence of commercial hydrocarbon in different play units based on geological, petro-physical and drilling data. Probability zones with different probability of occurrence values for each individual play unit are then used to generate the Risk-Reward matrix. The potential chance of hydrocarbon occurrence with associated risk enables to identify exploration opportunities in matured Assam Shelf Basin based on the probability distribution as well as uncertainties with a better assessment of a field's sustainable exploration potential.

Introduction:

The global hydrocarbon scenario, over the last 30 years shows that the primary source of oil and gas from new fields has reduced from 20-25% to 7-10%. In spite of this reducing trend, the demand for hydrocarbon over last 30 years has increased by more than 30%. Hence, to meet the global demand for oil and gas, in addition to the existing oil and gas fields, new discoveries from both frontier areas as well as mature basins are required to contribute to the rising demand. This paper focuses on the Assam Shelf Basin as shown in **Figure-1** with highlights on the various plays and prospects in this basin. The hydrocarbon fields which are on production from one or multiple reservoirs may also have new plays which are yet to be discovered.

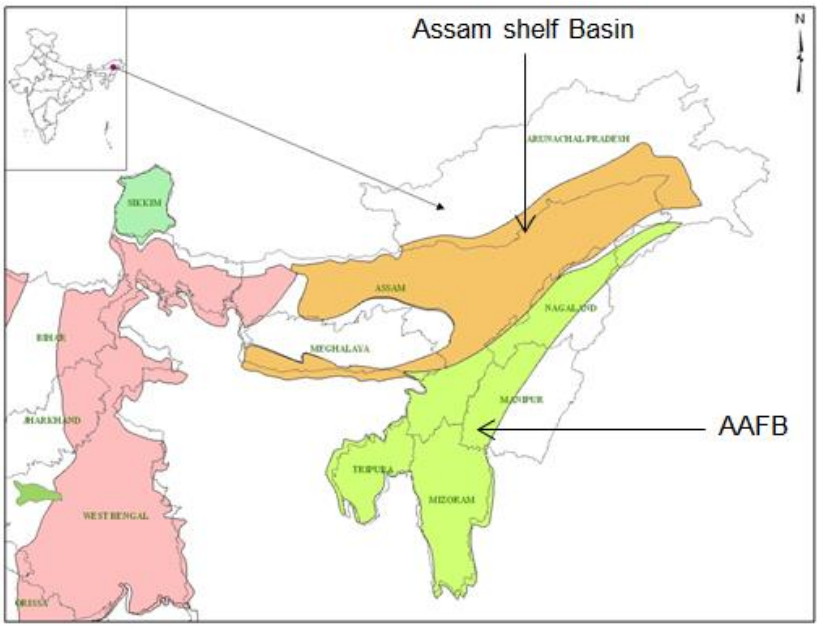


Figure 1: Assam Shelf Basin & Assam Arakan Fold Belt (AAFB) Basin (Source: NDR-DGH website)

In the Assam Shelf, Tipam (Miocene), Barail (Oligocene-Late Eocene) and Lakadong+Therria & Langpar/ Tura (Early Eocene- Paleocene; Lakadong+Therria comprises of Lakadong Member of Sylhet Gr. and Therria Gr. which are considered as a single unit of lithological classification in OIL's internal terminology) are the main reservoirs across which the hydrocarbon accumulation has been vertically distributed. Overlying the sequence of Tipam reservoirs are the Girujan Formation which varies in thickness across the basin from 0 – 2000+ meters. In most areas having suitable thickness, the Girujan formation which is composed of mostly mottled clay with intercalated thin sands acts as a regional seal for the Tipam reservoirs. However, towards the eastern part of the basin where Girujan Formation attains thickness of over 500+ m, there is good development of lenticular hydrocarbon bearing reservoir sands within the Girujan clays. Similarly, the Kopili Formation which overlies the Narpuh and Lakadong+Therria/Langpar reservoirs acts as a regional seal with its thick shale sequence. However, in few areas close to the thrust belt where good quality reservoir sands are present within the shales, hydrocarbon discoveries have been made. The upper part of Barail Formation, which is also known as the Barail coal-shale unit, is found to develop reservoir facies with commercial hydrocarbon presence, mostly in the form of channel bodies. Presence of commercial hydrocarbon is established in the entire sedimentary sequence of the Assam Shelf (*Reference-i*). However, as few of these plays are yet to be explored extensively across the basin, this provides ample opportunity for further exploration in the unexplored parts of the basin.

The stratigraphic Succession of Assam Shelf in **Figure-2** shows the regional lithology and potential Petroleum Systems Elements in the study area. The Barail coal shale unit is considered to be the primary source of hydrocarbon generation in the deep-seated Naga-Schuppen Belt which has then migrated to the shelf part with forward and backward migration, both vertically and laterally, entrapping hydrocarbon in suitable structural and stratigraphic closures at various stratigraphic levels (*Reference- i & iii*).

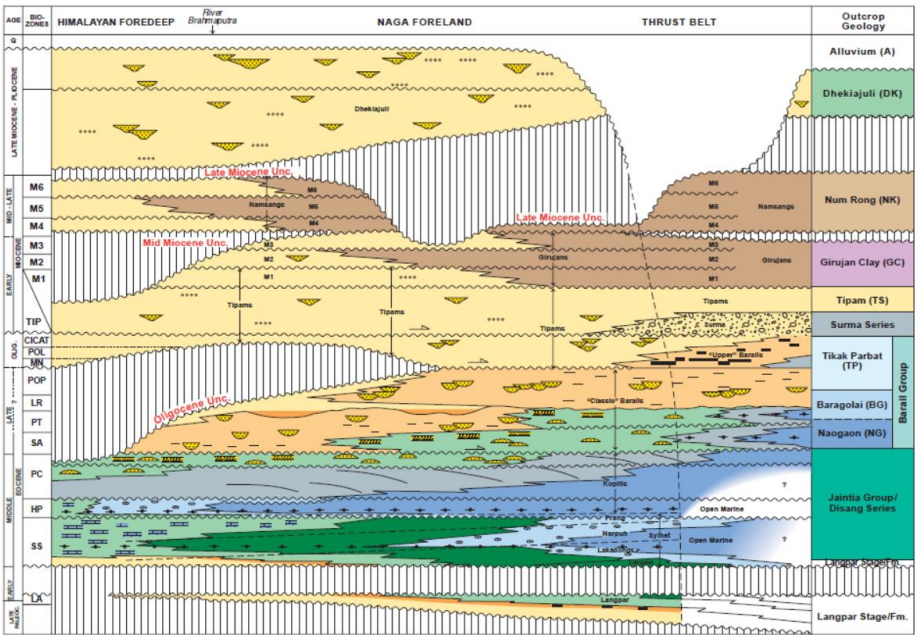


Figure 2: General stratigraphy of Assam-Arakan Basin (Source: ECL Report, OIL)

Future Areas for Near Field Exploration:

Exploration potential in Barails- Till 1990s, exploration was confined only to the shallower reservoirs which are mainly Tipams and Barails. Tipam reservoirs are massive fluviatile sand bodies, whereas Barail reservoirs are thick braided channel sands, which are parts of the classic Barails or the Barail Main Sand. However, the Upper Barail sequence also shows development of channel sands in few areas which have been tested for commercial hydrocarbon, these reservoirs are often isolated with variations in thickness and facies, both vertically and laterally. Due to their depth (often below 3000 m) as well as their limited extent (approximately < 2 sq km) and thickness (5-15 m), these sand bodies are difficult to trace in the seismic volume. The problem is further compounded in areas having vintage or low-fold seismic data. With potential for many new prospects, Upper Barail exploration in different parts of the basin remains a new avenue for exploration.

Exploration potential in Paleocene-Eocene- With advancement in technology, the operational challenges in targeting deeper Eocene-Paleocene reservoirs have been reduced. The Central Basement High region of OIL's operational area, comprising fields such as Dikom, Chabua, Kathaloni and Tengakhat were extensively explored and produced in the last 30 years and have proved the commerciality of the deeper reservoirs in the Basin. But these were still shallower with reservoir depths less than 4000 m. With new data coming in, deeper reservoirs were discovered with greater depths than those in the Central Basement High. With discovery of commercial hydrocarbon in fields like Baghjan, Barekuri, Shalmari etc. oil was established below 4000 m in the deeper Paleocene-Lower Eocene reservoirs. Oil was struck below 5500 m depth in a well drilled in one of the OIL's field in Mechaki. With Sadiya, exploration for hydrocarbon is set to go beyond 6000 m. The deeper plays towards south, i.e. close to the thrust belt is yet to be probed which are likely to reach > 6000 m depth and present an opportunity for aggressive exploration close to the source area. Narpuh reservoir, which overlies the Lakadong+Therria sequence, shows encouraging reservoir development in fields like Baghjan, Borhapjan, North Makum etc. Narpuh sands are good reservoir for hydrocarbon accumulation and merits exploration through detailed mapping and geological model building.

Exploration potential in Girujans- Girujan Formation, which is a thick sequence of clay with intercalated sand bodies in the southern and eastern part of the basin, is a potential play to establish, as presence of commercial hydrocarbon has been proved in adjacent fields of Kumchai, Kherem, etc. in the basin.

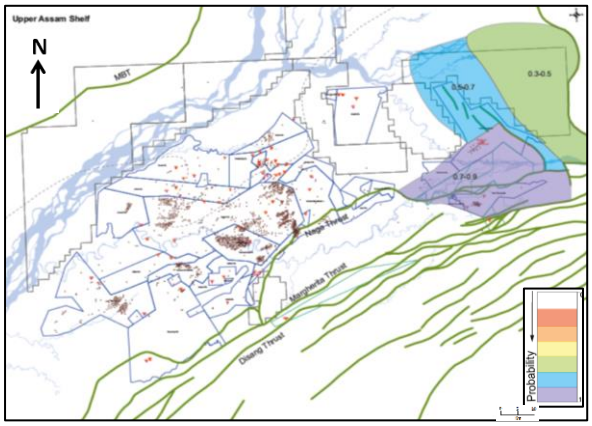
In addition to above, thick sequence of Namsang/ Lowang levels, towards extreme eastern part of the basin as well as in the sub-thrust formations below thrusted part of the basin are also very less explored. Presence of hydrocarbon in few sands of Namsang Formation in Kharsang area provides the opportunity for discovery of new plays within the basin.

Play Probability Maps:

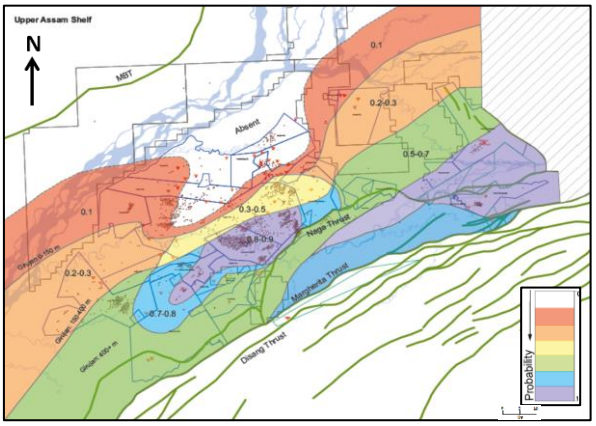
The Assam Shelf Basin has well-established plays such as Tipam, Barail, Lakadong+Therria and Langpar as well as potential plays such as Girujan, Kopili, Narpuh and Namsang. A detailed assessment has been carried out to estimate probability of occurrence of different plays within the basin. Play Probability Maps have been generated for six major plays viz. Namsang, Girujan, Tipam, Barail, Narpuh and Lakadong+Therria to ascertain the chance of success for hydrocarbon exploration in these plays. While carrying out this study, only the area under operational control of OIL is considered for evaluation. Input data used for generating these maps include regional depth maps prepared on the basis of both 2D and 3D seismic data, isopach maps for regional caprock (Girujan & BCS), formation thickness from well data of more than 200 wells drilled in the study area as well as log interpretation and testing results for different reservoir formations.

The Play Probability Maps have been prepared for each play level based on structural configuration and tectonic elements, thickness of the stratigraphic levels and their variation, depositional environment and likely extension of the reservoir facies within the basin. These factors are then categorized with varying geological risk parameters such as presence of reservoir, thickness of top seal and presence & effectiveness of trap. This multi-variable matrix has provided various probability scenarios of occurrence of a particular play and has enabled the demarcation of several compartments in the basin having different probability of success values.

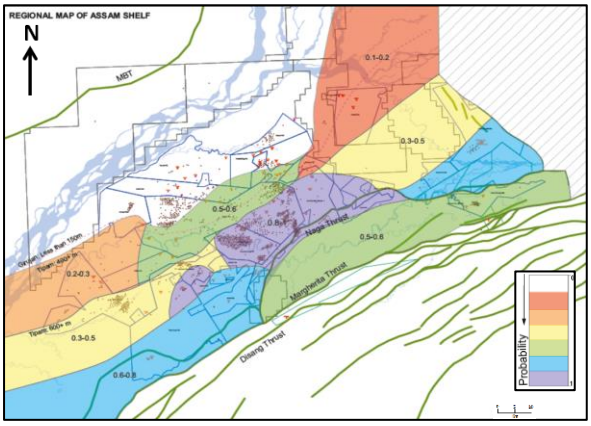
The play probability maps generated for the six (6) different play levels viz. Namsang, Girujan, Tipam, Barail, Narpuh and Lakadong+Therria provide a fair idea of the areas with high probability for hydrocarbon accumulation in all the six different levels.



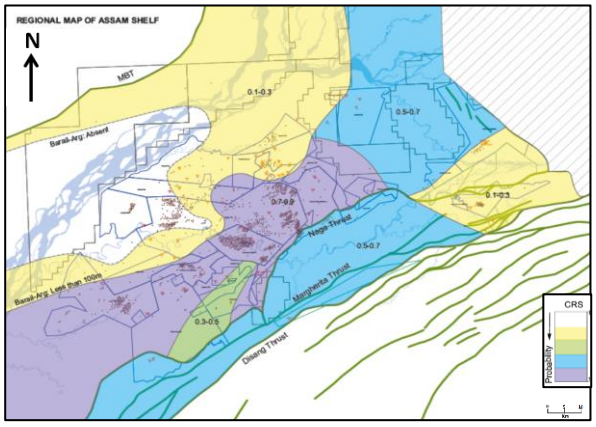
Namsang Level



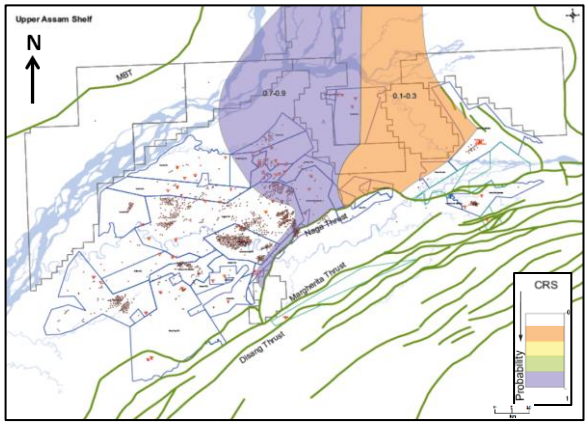
Girujan Level



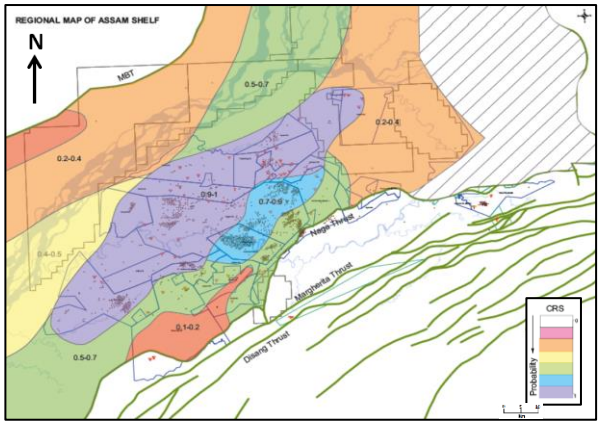
Tipam Level



Barail Level



Narpuh Level



Lakadong+Therria/ Langpar

Figure 3: Play Probability Maps at six (6) Different stratigraphic levels

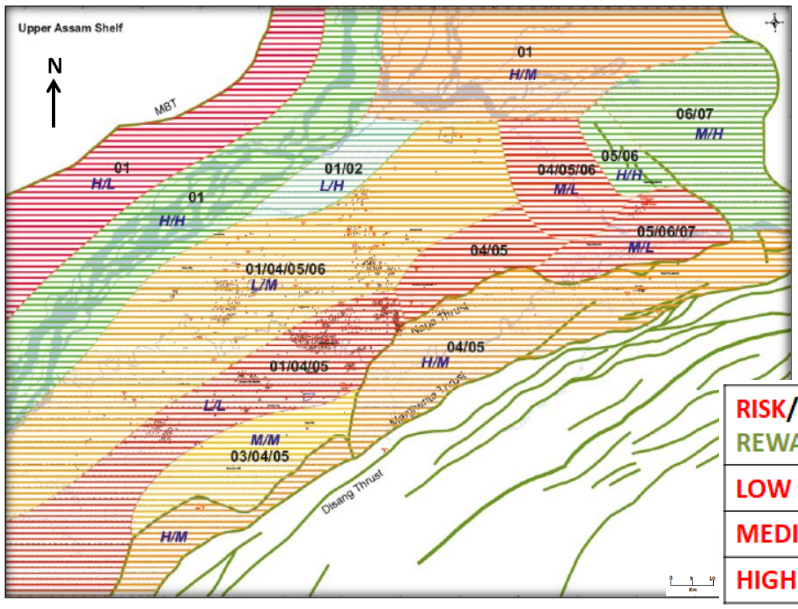
Brief description of Play Probability Maps:

Deeper plays within the basin viz. Lakadong+Therria and Langpar level show highest probability in the Central Basement High (CBH) region and in the north along the alignment of Brahmaputra Arch. Decrease in probability in the North Bank region and north eastern part is ascribed to greater depth, reducing shale content, uncertainty in source & migration as well as deteriorating reservoir quality due to compaction and overburden. Overlying Narpuh play is limited towards the northern part of the basin where thick reservoir sands are seen to be developed based on wireline log characteristics. Absence of wells in the southern part of the basin makes it difficult to predict its occurrence in this region. The Oligocene Barails are prolific producers in the south of the Brahmaputra Arch, but absence of regional cap rock viz. Barail Coal Shale (BCS) unit renders the northern part of the river devoid of hydrocarbon accumulations within the Barails. Similarly, the absence of Miocene Girujan Clay in parts of the basin limits the extent & probability of the Tipam play. The Namsangs present a new exploration opportunity towards the eastern part of the basin where it consists of thick sequences of clays inter-bedded with

sands. Proximity to the source area and presence of thrusts acting as conduits for migration increases the probability of success in this region (Reference-ii).

Risk-Reward Scenario:

The risk has been broadly classified as Low, Medium and High for each play level based on the Play probability maps. For areas with hydrocarbon potential in more than one play, risk-reward category is assigned by superimposing Play Probability Maps of the different play levels. Associated risk has been derived from already identified structures and drilling results of wells drilled in those fields. In addition, about 35-40 dry wells drilled in different structural closures targeting different plays have also been carefully analyzed to categorize risk. Reward has been associated with the three (3) risk levels based on exploration maturity within a risk segment, production history of discovered fields/ wells and future possibility of exploration success. Trap geometry, structural configuration, exploration history and geological complexity also affected the risk-reward matrix in various segments. All the existing fields/ structures of OIL were considered for the analysis of risk reward relationship.
Eg: The riverine part of the basin, which is in the northern flank of the Brahmaputra arch and north of OIL's prolific Paleocene-Lower Eocene fields, falls in the high risk and high reward zone of the Risk-Reward matrix. High risk is associated with the migration limit further north of discovered fields on the northern flank of the Basement High, lack of seismic and well data as well as absence of commercial hydrocarbon as observed in the seven (7) wells drilled in the North Bank region. However, based on the understanding of the geological setting of the area derived from recently acquired FTG data and one regional seismic line across the BRB (Brahmaputra River Bed) region, presence of gravity highs and proximity to producing Paleocene-Eocene fields of Bhogpara and Greater Khagorijan, this region has been assigned a high reward scenario. Further seismic and drilling campaign would enable to ascertain the actual potential of the region.



01	Lakadong
02	Narpuh
03	Kopili
04	Barail
05	Tipam
06	Girujan
07	Namsang

RISK/ REWARD	LOW	MEDIUM	HIGH
LOW	LL	LM	LH
MEDIUM	ML	MM	MH
HIGH	HL	HM	HH

Figure 4: Risk-Reward Distribution of different play units across the study area

Application of the Risk-Reward Matrix for Identification of Near-field Exploration Opportunities:

As per recent hydrocarbon resource reassessment data, more than 68% of hydrocarbon in the Assam Shelf Basin and about 89% in the Fold Belt Basin are still undiscovered. This indicates that even after years of continuous exploration, mostly in the shelf part of the basin, a large amount of hydrocarbon is yet to be discovered and produced. On careful analysis, it has been observed that large structural closures have already been identified and produced and various plays have been extensively studied and exploited. Exploration way forward for one such play, viz. the Girujan level has been explained below.

The Girujan Formation, which is considered as a regional seal and present in most of the Assam Shelf, is another potential play with great possibility of hydrocarbon occurrence. Fields such as

Kumchai and Kharsang in Arunachal Pradesh and Dirok in Assam are already on commercial production from lenticular sands of Girujan. On a regional scale, it has been observed that thickness of Girujan varies from few meters in the north to more than 2000+m towards eastern part as well as in the thrust region, from which it is producing hydrocarbon. In shelf part also, high thickness of Girujan (400+m) with discontinuous sands in between is a favorable play to explore. However, combined study of the Play probabilities along with Risk-Reward distribution will help to identify suitable areas for Girujan exploration, with additional information of hydrocarbon presence available in few wells in the shelf part. Proper diagnostic study of seismic data in terms of its amplitude variation and feature mapping along with log evidence is likely to provide valuable exploration inputs. **Figure-5** presents a schematic representation of variation in Girujan thickness along with possible hydrocarbon bearing reservoir facies in the eastern part of the basin. This area is a good candidate for exploration in Girujan Play as also observed from the Play probability map and Risk-reward Matrix.

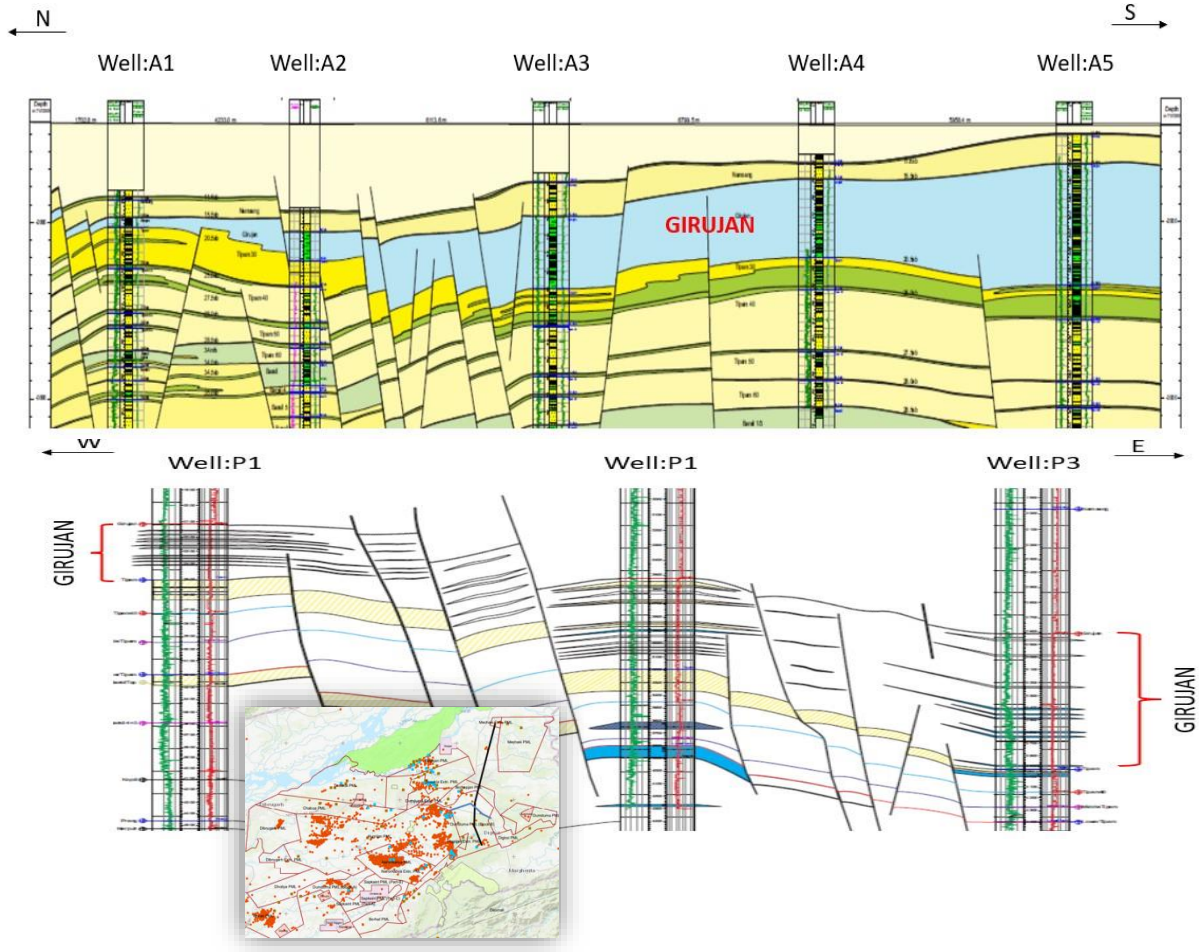


Figure 5: Gradual thickening of Girujan Formation along N-S & E-W direction in Assam Shelf

Conclusion:

The results of the study clearly categorize exploration priority in the part of the basin both vertically as well as laterally. With the inherent risk and uncertainty associated with oil exploration, geo-scientific processes such as play chance mapping or risk assessment helps to a great extent in decision making for future exploration campaign. The Play Probability Maps and risk-reward matrix that have been generated in this study has incorporated number of essential elements for categorization of the basin in terms of exploration success with associated risks. Hydrocarbon migration, structural complexity, reservoir heterogeneity along with exploration maturity and overall basinal configuration has greatly influenced the study results. The outcome of this experimental analysis along with other geo-scientific information/ data is expected to help identify priority areas for future exploration in the basin.

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