Deeper Eocene Prospects Revisited in Time and Space -A Case History from North Assam Shelf

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Summary

With the discovery of oil in Barail (oligocene) reservoirs of Rudrasagar field(upper Assam), in 1960 hydrocarbon exploration got a fillip in North Assam shelf. Lead for deeper eocene prospects was obtained be drilling of a well in Lakwa field during 1986 followed by a commercial discovery in the same area in year 1995. The Eocene play in this area is mainly controlled by structure apart from few levels which are strati-structural in nature.

During last couple of years North Assam shelf has been extensively covered by 3D surveys apart from existing 2D campaigns which has given an insight into structural configuration and reservoir distribution of the area.

Majority of structures in North Assam shelf are basement involved inversion which led to reactivation and rotation of the of present day blocks .The major deformation and structuring of this area occurred from early to middle Miocene time during which the existing longitudinal normal faults got reactivated and reoriented due to younger compressional episodes. Variability of the fault throw is significant when we are looking at present day fault bounded structures.The redistribution of the accumulated hydrocarbons due to slope reversal during late Plocene is another critical factor which needs to be kept in mind for prospect identification.

At the critical moment of expulsion during Late Miocene-Early Pliocene period some of the these early-formed structure which remained relatively unaffected with later deformation were available for charging but could not get exploration attention due to their present day low amplitude nature. The late formed structures on the other hand attracted immediate exploration attention as these were more pronounced but did not yield dividends for exploration of the deeper play as seen in the fields like Rudrasagar.

As hydrocarbons from Paleogene prospects of this area remain under explored, future exploration needs to be guided by paleo structural picture at the time of migration and the the reservoir distribution in the area.

Introduction

The North Assam Shelf area(Fig 1) lies in a trans-tensional tectonic regime up to Tertiary period which got dissected by high angle extensional faults trending in NE-SW direction depicting a horst and graben geometry. The prospects in the area during Eocene period are mainly structural in nature.

During Paleocene-Middle Eocene Period, sedimentation in the Assam Shelf took place in a passive margin set-up, represented by the basal clastics of Tura Formation, followed by widespread transgressive carbonate dominated Sylhet Formation

Case History: North Assam shelf

Basin Architecture

A poly phase history of deformation is responsible for the development of the present day structural setup of North Assam shelf.

Edge detection map (Fig 2) clearly brings out the fault disposition in the study area. At least three tectonic episodes were involved. An early cretaceous rifting created horst and graben super imposed by a compressional episode in early Miocene resulted inversion / compressional structures. The third phase of another compressional episode of plio-pliestocene modified the earlier structural setup.

The North Assam shelf area can be divided into three mega tectonic blocks. One block comprising Nazira low, Geleki-Charaideo high trend including Nahorabi and Sonari area is highly influenced by the compressional force from south-east direction and is also largely influenced by the Naga-Schuppen orogeny.

The northern part of North Assam shelf can be divided into two mega tectonics blocks separated by NW-

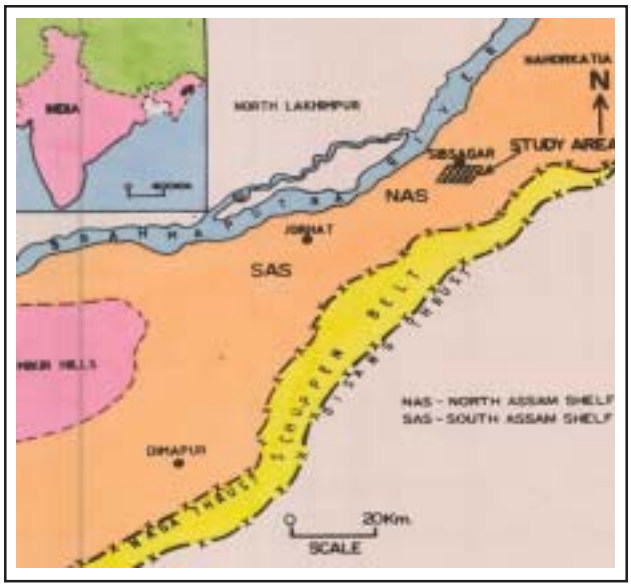


Fig.1: Index map

SE trending Rudrasagar north bounding fault, one in the north north-east and the other in the south-west of the area. The intensity of deformation in the entire area south west of Rudrasagar seems to be less in comparison to the area of Rudrasagar and further north-east, within the third mega block.

The compressional episodes during Himalayan upliftment occurred during Plio-pliestocene time. This compressional force from North and North-East modified the structural pattern subsequently.

During the last phase of SE-NW compressional movement the transverse system of faults generated. Due to lateral/Strike-slip movement along these cross faults dissects/ offsets the earlier longitudinal fault system.

The lateral movements along the cross faults offsets the hinges/axes of the structures. Lakwa- Banamali area existing over a large paleo high block as seen in paleo sections and time structure map on top of sylhet level. The Rudrasagar and Charali - Changmaigaon structures are younger structures and formed in late Miocene to early Pliocene. The aerial extent of Rudrasagar structure in sylhet level is relatively very small and the extension of the structure gradually increases in the younger tertiary sequences. A rotational clockwise movement along the Rudrasagar north bounding fault, resulted by a compressional force from south west can be visualized for the development of this structure.

Methodology

About fifteen 3D campaigns along with regional 2D seismic lines were used for the study. Some of the data on which PSDM was done were also studied. Correlation of deeper seismic events in Eocene section calibrated with the well logs available in the study area using 2D/3D data for the entire shelf part led to generation of regional relief and structure maps. Correlation of the seismic data of deeper horizons Sylhet, Tura and Basement has been carried out after calibration with twenty deep wells in the area. Sylhet top has been taken up as a peak and Tura, Basement as trough for correlation. Isochron maps and Depth maps were generated.

Paleo structure and thickness maps along with the multi attributes have brought a regional understanding of the area along with the prospectivity perception in the area.

Reconstructed seismic lines (Fig-11) across the north Assam shelf flattened at a level near girujan formation (late Miocene) i.e. the time of migration have given an insight to the prospectivity of deeper levels. Structure available at this time at prospective level which remains unaffected with later tectonic.

Paleo-Depositional Environment vis-a vis Hydrocarbon Prospectivity

Tura formation (Late Paleocene-Early Eocene) in the North Assam Shelf constitute mainly of kaolinitic sandstones and clay stones while Sylhet formation (Early-

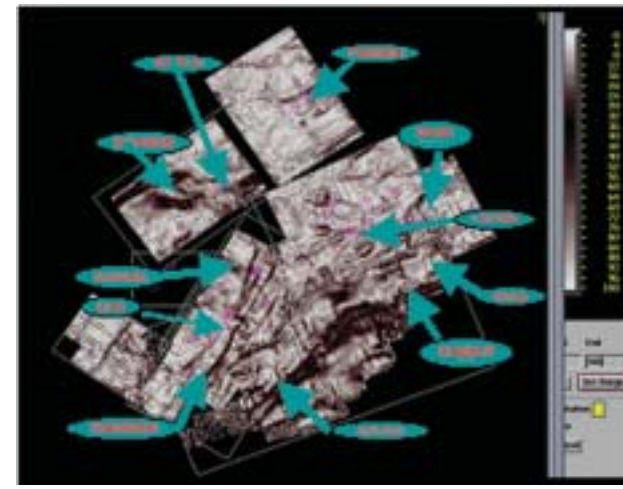


Fig. 2: Edge detection map depicting faults and relief

Middle Eocene) was found to consist of calcareous sandstones with presence of glauconite and shales in the lower portion overlain by dominantly limestones and intervening shales with occasional sand streaks in the upper portion.The environment of deposition in Tura is mainly active deposition in alluvial fans/braided channel system in mainly continental to inner shelf environment whereas sylhet formation suggest a shallow marine environment of deposition .The typical log response of the wells drilled in the shelf having good areneceous reservoir units S0 , S1.S2 a & S2b as shown in (Fig 3) are hydrocarbon bearing.

Dip profile alomg Rajmai - Kuargaon and Lakwa areas (Fig4) depicts the lateral continuity of these thin reservoirs across the North Assam Shelf.

Seosmogeological section drawn across the North Assam shelf (Fig 5) depicts the disposition of Disangmukh , Rajmai ,Demulgaon and Lakwa structures. It can be seen that the reservoirs in the Eocene formation are likely to extend and get preserved over the paleo highs .Later deformation along with redistribution has not affected the poolsas these are bounded by separate fault blocks having significant throw.

Seismic evidences

Time structure map on top of Sylhet formation shows Lakwa, Panidihing, Disangmukh, Rudrasagar, Charali, Changmaigaon and Geleki structures are highs and Nazira a

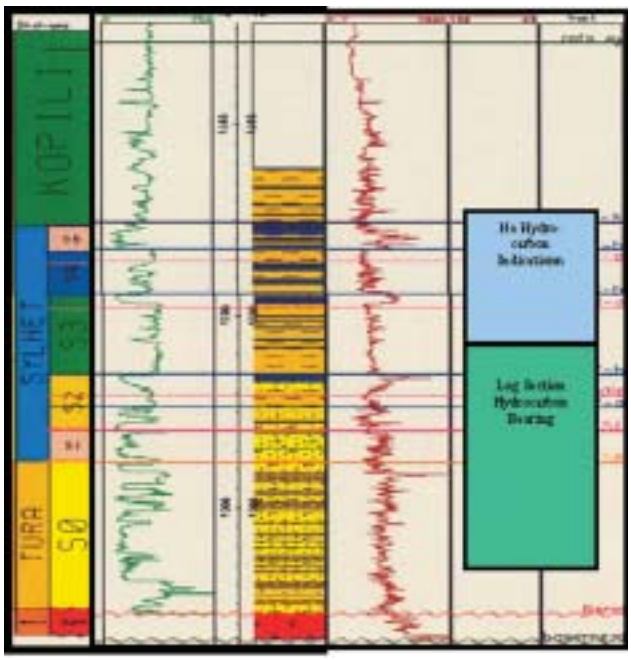


Fig.3: Log motiff Sylhet-Tura Section

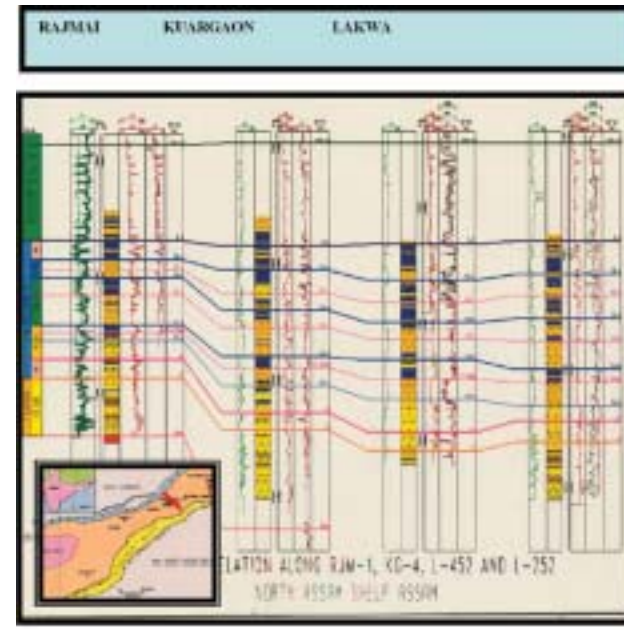


Fig. 4: Log Correlation

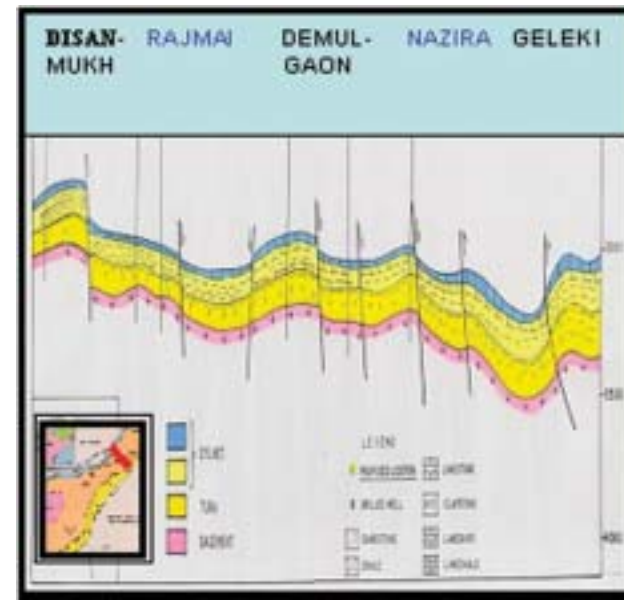


Fig.5: Seismo-Geological Section across North Assam Shelf

big low and several small lows in the area (Fig- 6). Most of these structures and lows have already been studied by different authors at different times. Perhaps for the first time an area with this much of 2D and 3D data has been studied giving a regional picture of the whole area.

This highs and lows as shown above are present day configuration in which fields like Rudrasagar are quite pronounced. This configuration gets changed when we draw a paleo-relief map flattening a horizon near to late Miocene

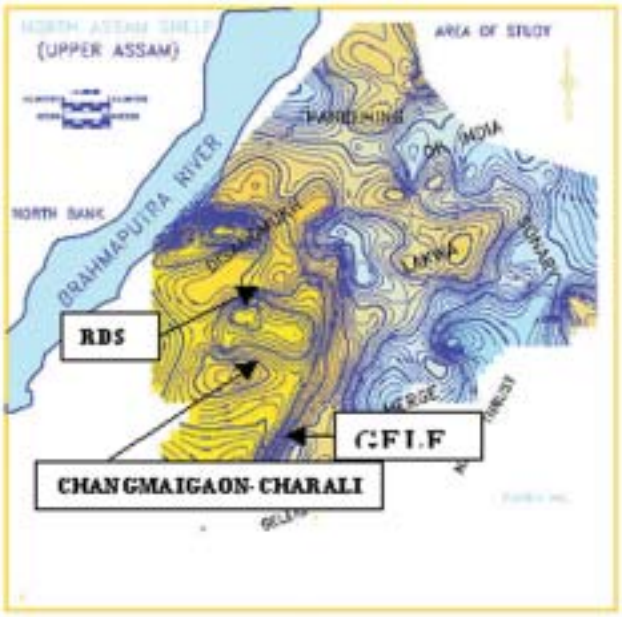


Fig.6: TWT. Relief map at a level near top of Sylhet fm. Yellow colour depicts a high and Blue colour is represented by a low

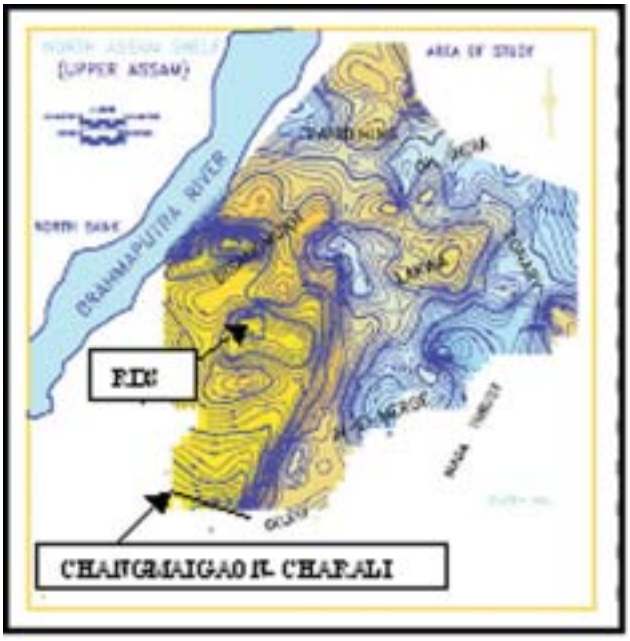


Fig: 6a. TWT. Relief map at a level near top of Sylhet fm. showing the study area

(Girujan clay level i.e the time of migration). Structures such as Rudrasagar and its adjoining areas which were highs get subdued and areas north of this structure gets uplifted and was available for charge during that period. (Fig-7).

Isochronopach map of Sylhet Formation deposited

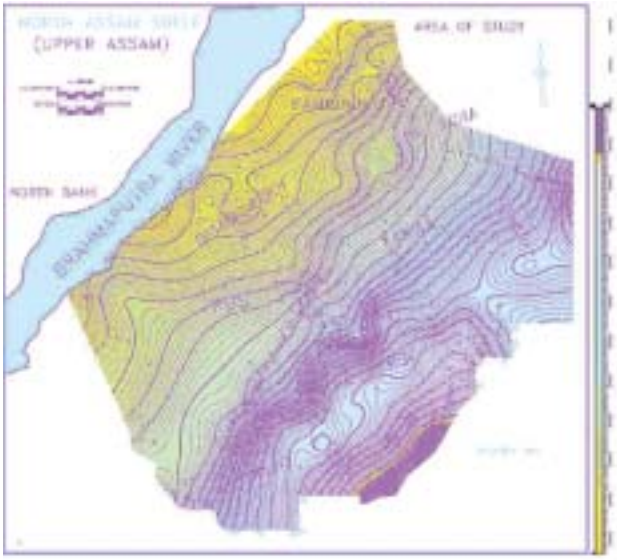


Fig.7: Paleo-Relief Map at Sylhet after flat Girujan Clay. Yellow shows Paleo high Blue Low.

during Mid Eocene (Fig:-8) conforms the paleo highs and lows as brought out in the Paleo relief map discussed earlier.

The Paleo reconstruction which brought out the significance of deeper prospects gives leverage to the understanding to re-look the deeper horizons more objectively. Authors then identified the prospective areas in and around Rudrasagar, took up the PSDM data of Charali and Changmaigaon area scaled in depth and time (Fig: 6a) and extracted multi-attributes over a window supposed to house the reservoir sands to see the spatial distribution of

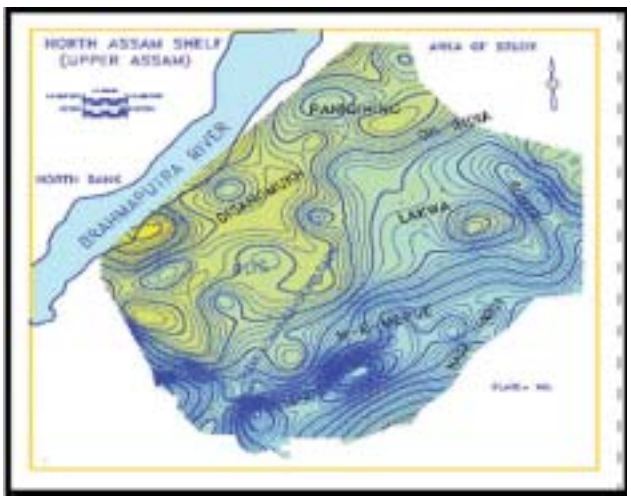


Fig.8: TWT. Isochronopach map of Sylhet fm. Yellow colour depicts thin areas whereas blue depicts thick areas.

these sands. The results are quite interesting and are as follows.

Out of several attributes extracted, two attributes Absolute Amplitude attribute and Instantaneous frequency attribute are presented below.

Average Absolute Amplitude attribute map (fig- 9) has been computed for the lower most sand packs within a window of 40 m.sec. above and below Tura formation top.

The map shows a moderate to high amplitude anomaly trending NE-SW spread over the entire area depicting the distribution of reservoir sands.

Instantaneous frequency attribute maps (Fig-10) of the same window has been computed and it shows low frequency anomaly of similar trend as observed in amplitude map.

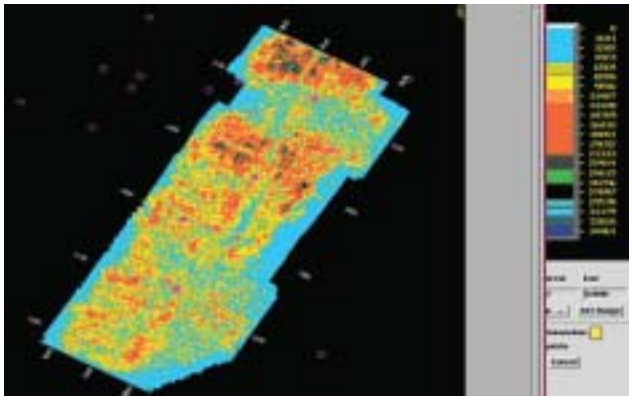


Fig.9: Average Absolute Amplitude Attribute within 40 msec window above and below Tura Formation. High amplitude anomaly depicting Spatial dispersal of reservoir sands.

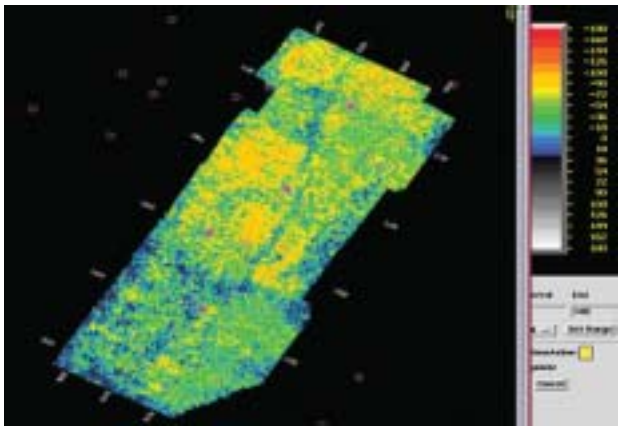


Fig.10: Instantaneous Frequency Attribute 40 m.sec above and below Tura Formation .

High amplitude and low frequency anomaly distinctly demarcates the areas of thicker sands against thinner or sand against shale. This anomaly has been calibrated with drilled wells in the area where better reservoirs are expected. Areas which were a low during flattening of Girujan time are also devoid of these sands. This difference has been observed in the wells drilled in prospect 'B' for deeper prospects, have gone dry. The spatial and temporal extent of the sand can be tied up with the paleo-structures for future exploration.

As an example a reconstructed section has been drawn across the North Assam Shelf (Fig. 11) from Lakwa to Demugaon & Rudrasagar stuctures, it has been observed that Prospect, "C"in Lakwa field which is still producing was available as a paleohigh in the different fault block and on flattening at the time of expulsion prospect"A" becomes more pronounced and a likely exploration target.

Although in this proven field Prospect "B" is on production from Oligocene-Miocene reservoirs.

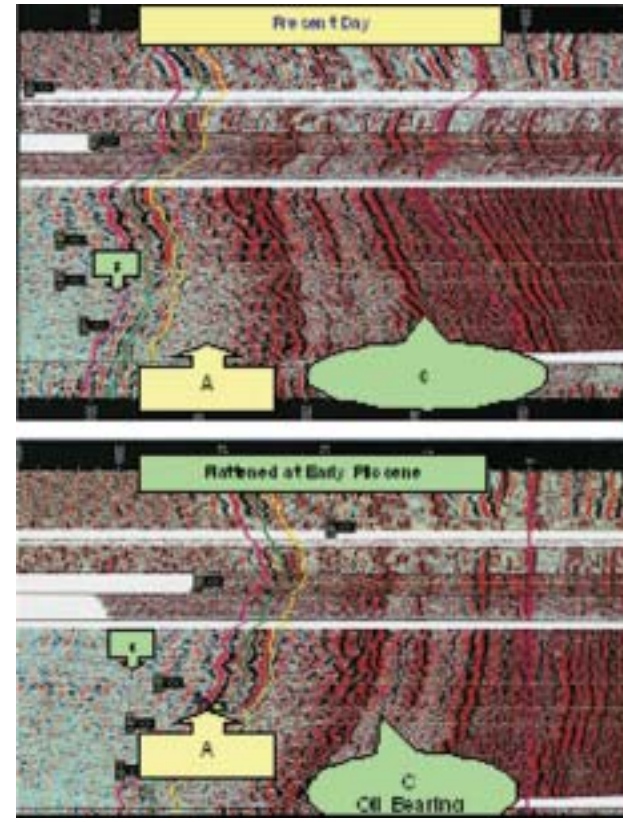
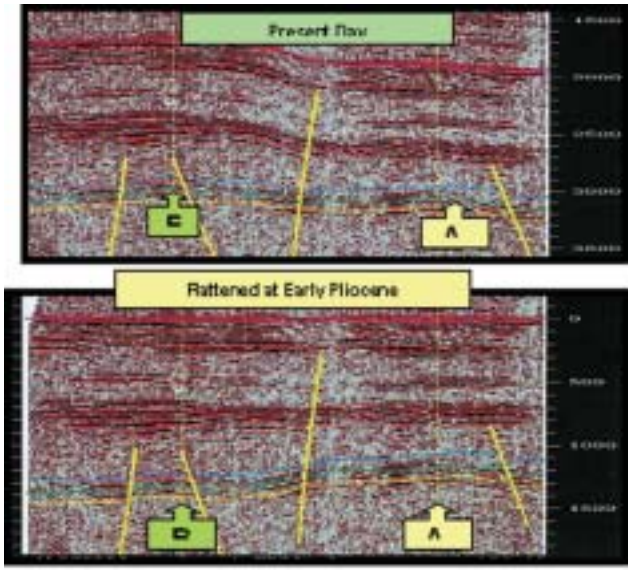


Fig.11: Reconstructed Seismic line across Rudrasagar(A),Demulgaon (B)and Lakwa (C)Structures

The normal seismic section shown in detail (Fig. 12) demonstrates that Prospect "B" has high amplitude with respect to prospect "A" which attracted exploration attention earlier proved to be devoid of charge whereas after flattening prospect "A" appears to be promising for exploration.

A regional perspective view can be seen in Fig 13 clearly bringing out the relief at sylhet level. .To bring out future exploration targets it is necessary to tie up with areas of good reservoir distribution along with the availability of structural relief after modifying tectonics and redistribution. Similar prospects may likely exist in other petroliferous basin and could be productive hydro carbon point of view.



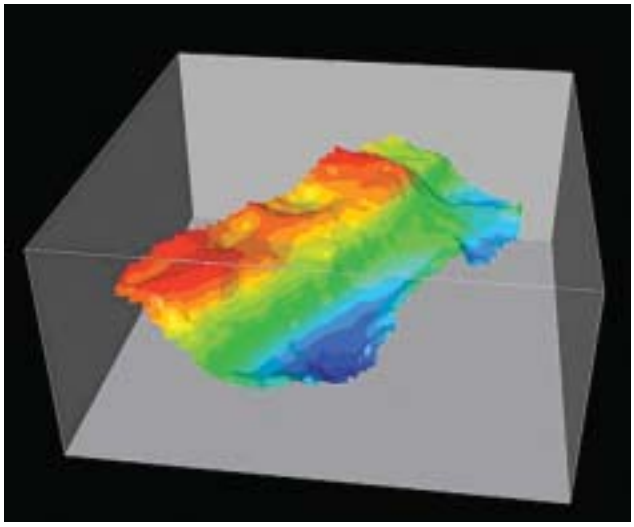


Fig.13: 3D perspective view of the study area showing relief at sylhet level.

Conclusion

Exploration focus in North Assam shelf over three decades have been to probe the Oligocene and Miocene reservoirs which were relatively easy targets. With the advent of new techniques and enhanced quality 3D data the subtle traps of Eocene play have emerged as a potential target .

The case study brings out a prospectivity perception of hitherto unexplored early formed structures which were available during migration and remained unaffected with later deformation but could not get the focused attention due to their low amplitude nature. The late formed structures attracted exploration attention but were found devoid of charge. The environment of deposition in Eocene reservoirs of Tura formation is mainly active deposition in alluvial fans/braided channel system in continental to inner shelf environment whereas sylhet formation suggest a shallow marine environment of deposition .

The redistribution of the accumulated hydrocarbons due to slope reversal in late Miocene needs to be seen for prospect identification depending upon the variability of the fault throw.

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