OLIGOCENE PROSPECTIVITY IN ICHAPUR-JAGULI AREA IN BENGAL BASIN

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Keywords

Distributaries, delta, sandbars, systems tracts, horizon slice, volume rendering, seismic attributes.

Summary

Deltaic deposits are proved to be prolific reservoirs of oil and gas throughout the world. Exploration of delta in any basin therefore demands attention for which the present study is focused around Ichapur-Jaguli area of Bengal Basin. Exploration history in Bengal indicates Oligocene sediments as the prime prospect for oil and gas as proved by testing in a few wells. Taking the lead from hydrocarbon bearing well E-1 a detailed study has been carried out to bring out the prospective play. 3D seismic data are used to extract and isolate high-amplitude anomalies to interpret geological features. Different seismic attributes have been generated and interpreted through volume rendering and the geometry of anomalies has been curved out for identification of distributaries during Oligocene period. Presence of Delta is identified in the form of distributary channel network which on further analysis has been identified as a prospective area for hydrocarbon exploration. Reservoirs are envisaged as the inner distributary sand bars and delta flat with marine shale as seals.

Introduction

In the base map (Fig-1a) paleo rivers like Ajay, Damodar, Kasai, Subarnarekha and others suggest their flowing direction from north-west and formation of deltas to the south-east before debouching their sediments into the sea. On the basis of the concept ñPresent is the key to the pastò these paleo rivers suggest transportation of sediments from northwest and their deposition towards southeast in a deltaic set up near the shoreline during the time of Oligocene. Taking the lead from this concept one merged 3D volume has been studied in details. The only oil bearing well E-1 along with other gas bearing and water bearing wells, present in this 3D volume, are also considered. Oligocene sand was tested to be oil bearing in the well-E1 and in well C-1 water with inflammable gas. One RC line through well E-1 and C-1 suggest a change in seismic

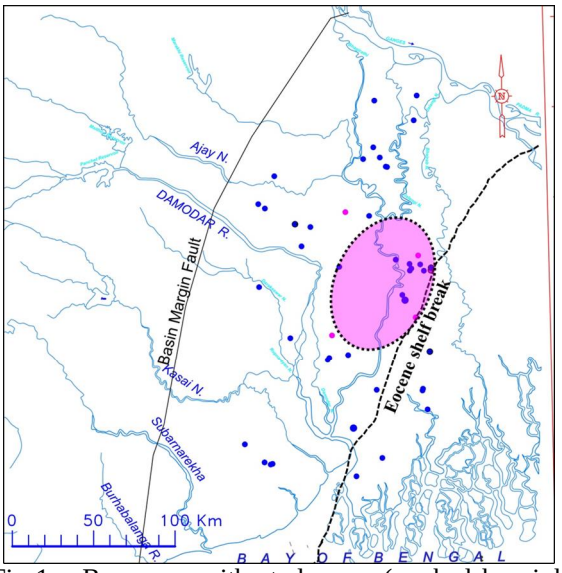

Fig-1a Base map with study area (marked by pink color) showing NW-SE trending paleo rivers, Basin margin fault and Eocene shelf break

characters of the sequences towards south of well C-1 compared to the section between well C-1 and E-1. This change in seismic character prompted to interpret the Oligocene sequence in detail which resulted in the identification of deltaic set-up in Oligocene. All other attribute analysis, special studies and facies modelling have culminated in identifying a prospective delta.

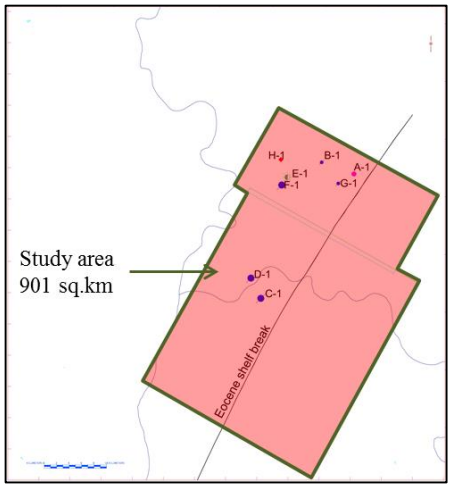

Fig-1b. Zoomed Study area with drilled wells

Tectonic Setting and Depositional Architecture

Bengal Basin, a polycyclic basin, has evolved through two distinct tectonic episodes. First episode was initiated as an intra-cratonic rift basin within Gondwana land during Late Paleozoic ï Mid Mesozoic time and received the continental Gondwana sediments. This phase of basin development was over with eruption of Rajmahal trap. The second phase took place with separation of Indian craton from Gondwanaland followed by drifting towards north. During this journey of the Indian plate Bengal Basin evolved as a rift controlled extensional basin along the NNE-SSW trending Basin Margin Fault with concomitant subsidence and deposition of colossal volume of sediments in a passive margin set up during Late Cretaceousï Paleogene-Neogene times. The provenance was towards north & west during this time. The Indian plate started colliding with Eurasian plate to the north since Late Palaeogeneï Neogene times and north-south trending rivers started pouring sediments. Overall dip of the basin is towards SE.

The Bengal basin is traditionally subdivided into four NE-SW trending tectonic zones (Fig. 2). These zones from west to east are as follows:

a) Basin Margin : Characterized by shallow depth of Proterozoic rocks with down to basement en-echelon fault system.

b) Shelf : Where Proterozoic basement maintains a uniform low gradient towards east and south east.

c) Slope : Characterized by sudden increase in the gradient which is distinct at the level of Eocene limestone top.

d) Deep Basin : Where basement is not identifiable in available seismic section upto a depth of 6 sec.

Data Input

Till 2009 in the Pre-NELP regime, eight exploratory wells were drilled in the study area in a span of 35 years. Out of these, two wells A-1 and B-1 were drilled under Indo-Stanvac Petroleum Project (ISPP) in late ó50s/early ó60s. Subsequently, remaining six wells viz. C-1, D-1, E-1, F-1, G-1 & H-1 were drilled by ONGC up to 1994. The drilling and testing results of these wells suggest Oligocene sequence is prospective for further exploration in Bengal Basin. One merged 3D seismic volume with electro-logs and litho-logs of all these wells are taken up for analysis. Studied interval in the 3D seismic is from 2900 to approx. 3250ms, as the zone of interest in Oligocene. Analysis of Seismic facies and geomorphology are important tools for the study of depositional elements in subsurface. Different types of seismic facies are identified to be present within this interval and detailed here. No structural grain is present in this interval. Lithologies are inferred from drilled wells and analysis is extended towards undrilled part.

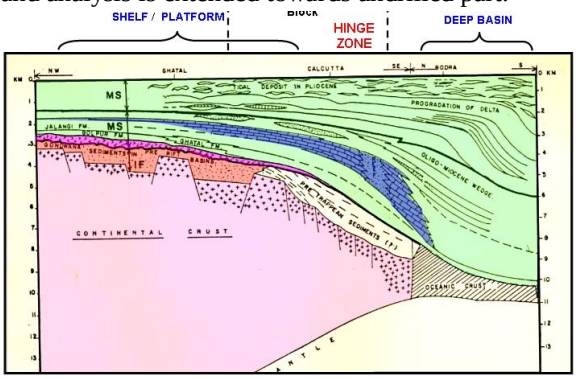

Fig. 2. Geological section of Bengal Basin

Methodology

The entire 3D volume has been interpreted and mapped from Cretaceous to Recent after correlation of drilled wells present in this volume. Different seismic traverses were then taken up through oil bearing Well E-1 and one such representative traverse section is presented in Fig-3. The zone of interest is restricted by Oligocene top and bottom and the observation of the said zone reveals differences in seismic reflector patterns from north to south. Towards the north reflectors are continuous, straight and parallel but to the south those are wavy, discrete and irregular. This difference prompted to isolate this part for the detailed analysis. The 3D volume has been trimmed accordingly and several seismic attribute cubes like Amplitude, Sweetness, Spectral decomposition and Variance have been prepared and studied in details. Seismic probes of different attribute cubes are generated to extract geomorphological features at different time intervals. These probes were oriented along the structural dip NW and branching out further down towards SE (Fig-4). The trimmed seismic volume has been dissected by six windows (40ms each) with the help of proportional slicing and attributes are extracted from these windows to match and correlate the information obtained from rendering of seismic probes. This technique helped to identify the hitherto unknown distributary channel network present in Oligocene. Spec-D volumes of different frequencies are made and horizon slices extracted to explore geometry of channels with different thicknesses (Fig-5).

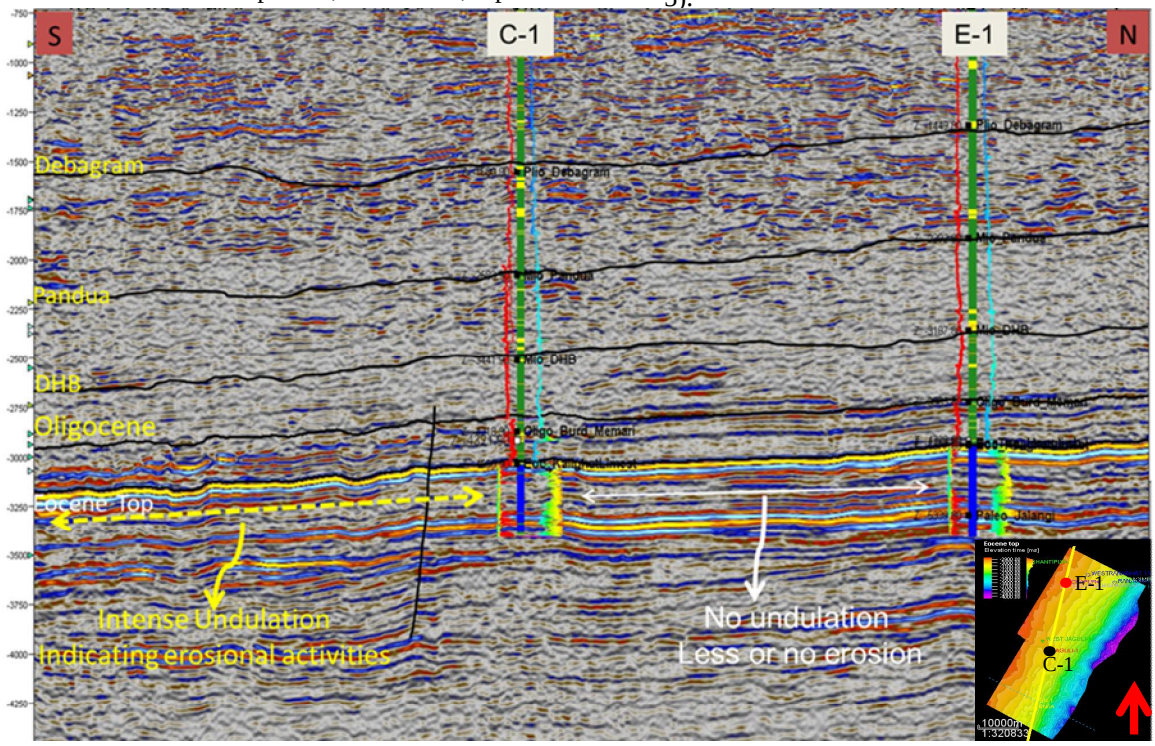

Fig-3 RC line passing through well E-1 and C-1 (map in the inset) marked with Formation boundaries and superimposed with Lithologs and electrologs on the seismic.

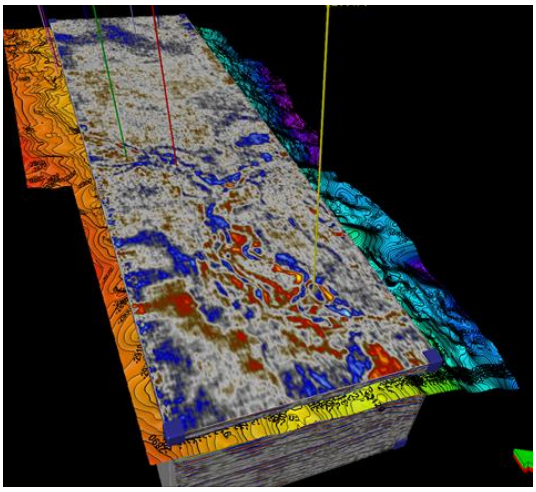

Fig-4. Volume visualization and rendering reveal the total course of the channel network from NW and branching out further down towards SE. TWT map of Eocene Top inserted in the volume.

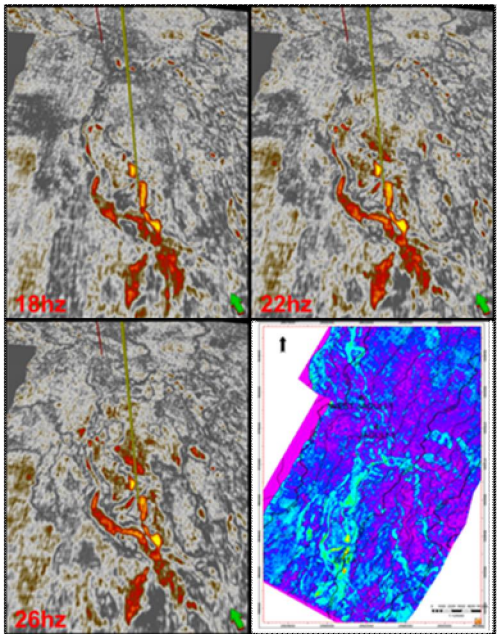

Fig-5 Horizon slices extracted from Spec-D volumes of different frequencies to find out the channel-geometry.

Interpretation

The base map of Bengal (Fig-1a) is considered as the key to decode the information buried deep in time, following the Law of Uniformitarianism. The map shows paleo-rivers flowing from NW to SE with their tributaries. These tributaries and their distributaries formed delta near the shore before debouching their sediments in to the sea towards SE. Eocene onwards these rivers were joined by the Ganges and her tributaries flowing from north to south. Present fluvial and deltaic set up has therefore been considered as the key element to envisage the paleo-depositional set up.

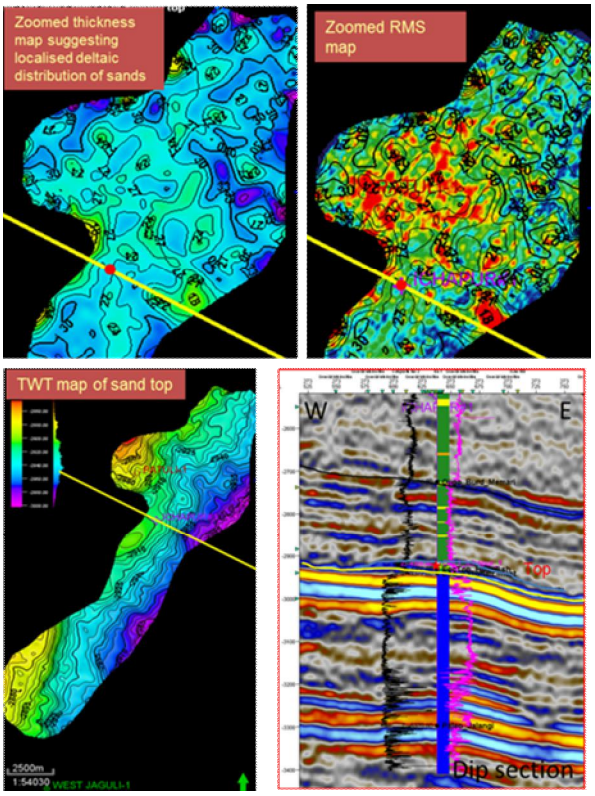

Fig-6 TWT map of pay sand top, thickness between pay sand top and bottom, superimposed thickness with RMS and seismic section with electro and litho-logs of well-E. Red dot showing the position of well - E and the yellow line, position of seismic section.

Well E-1 has been taken up as the lead well and integrated with the seismic. The top and bottom of hydrocarbon bearing interval in Oligocene has been mapped. The thickness map between two mapped surfaces suggests localized deltaic distribution. This is again superimposed with RMS map which suggest preferential distribution of reservoir facies (Fig-6). This hydrocarbon bearing interval with very small pool limit suggests probable presence of larger pool in some other area within Oligocene. Eocene Top has been considered as the base for deltaic deposits of Oligocene time. TWT map of Eocene Top suggest a localized low towards south (Fig-7) which under subaquous condition can accommodate a delta.

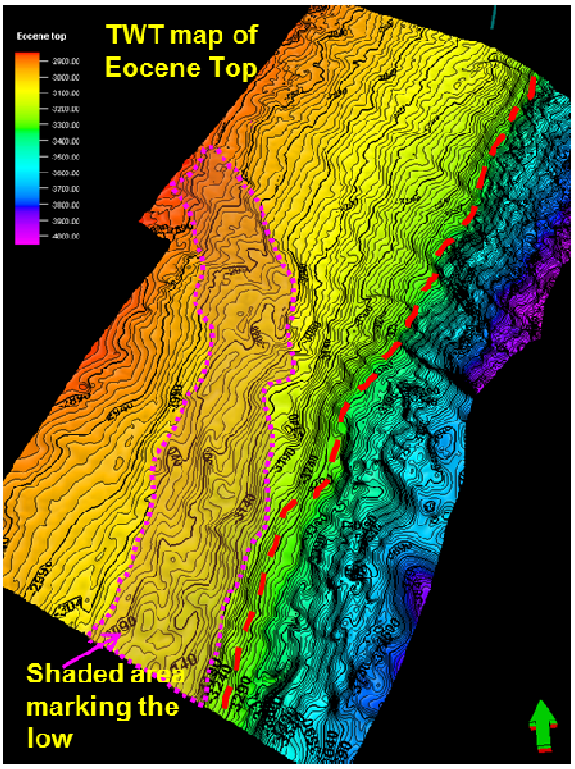

Fig-7 TWT map of Eocene top shows the surface dipping monoclinally from west to east with a variation towards south where one localized low is present as shown by dotted line. Red dashed line demarcates the shelf break zone.

The top and bottom enveloping surfaces of Oligocene hydrocarbon bearing interval have been mapped. The TWT surfaces suggest NE-SW oriented strike with monoclinal dip towards ESE. Shelf break is present along the strike towards the eastern boundary of the block. But within this overall ESE monocline dip pattern there is one subtle variation towards the southern part of the 3D volume where the beds apparently dip towards south suggesting a N-S oriented low (Fig-8) following the same low observed on Eocene Top surface. The AAA map, extracted within these two surfaces also suggests the southerly dipping pattern of the distributaries.

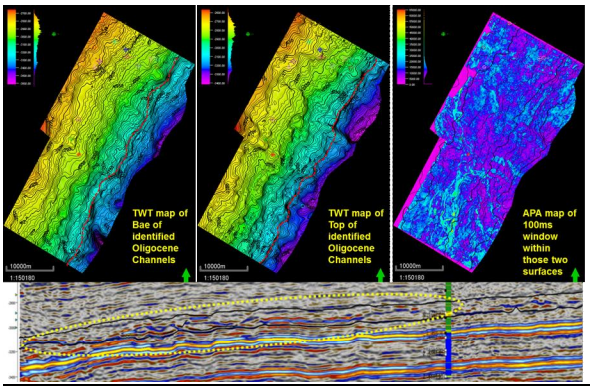

Fig-8 TWT surfaces at top and bottom of Oligocene channel complex suggest NE-SW oriented strike with monoclinal dip towards ESE. Shelf break is present along the strike shown by red line. Within this overall ESE monocline dip, the southern part indicates southward dipping bed.

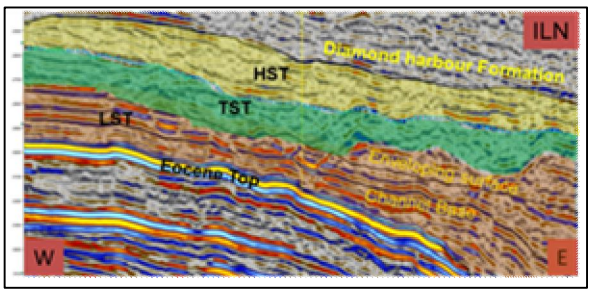

Fig-9 Sequence stratigraphic sequences on the dip line

The low lying area at the end of Eocene on the south (Fig-7) in subaquous condition helped in formation of distributaries in Oligocene time. In Bengal Basin, Eocene is marked as the time for widespread deposition of Kalighat Limestone on Bengal platform. This is overlain by very thin Hooghli shale with its top interpreted as maximum flooding surface. This is followed by Diamond Harbour Formation of Oligocene time. The pack of entire Diamond Harbour Formation has been weighed by sequence stratigraphy and distributed into three systems tracts like LST-TST-HST (Fig-9). The marks of incisions shown by the reflectors are interpreted to be under LST. TST phase is marked by the transparent package of reflectors. This is followed by HST which is marked by the forward stepping reflectors at the top.

The seismic expression of the channel network has been identified as high amplitude anomaly observed within the LST. Two surfaces at the top and bottom of these high amplitude anomalies are mapped as enveloping surfaces and attributes are extracted within those two envelops. Absolute positive amplitude extracted within top and bottom enveloping surfaces matches well with the geomorphology presented by the horizon slices of Spec-D volumes (Fig-5 and 10).

At frequency 22HZ Oligocene channel complex have been tuned at the maximum. Horizon slices within Oligocene from Sweetness volume and Spec-D volume at 22Hz reveal distribution of lowering of frequency and the geomorphology of distributary channel network respectively (Fig-10).

To understand the channel dimension, Eocene top surface has been flattened and cross-section of channels from up-dip to down-dip are observed (Fig No-11). The Geological model of distributary network has been prepared on the basis of results obtained from Spec-D horizon slices at different frequencies, attribute slices and channel dimensions

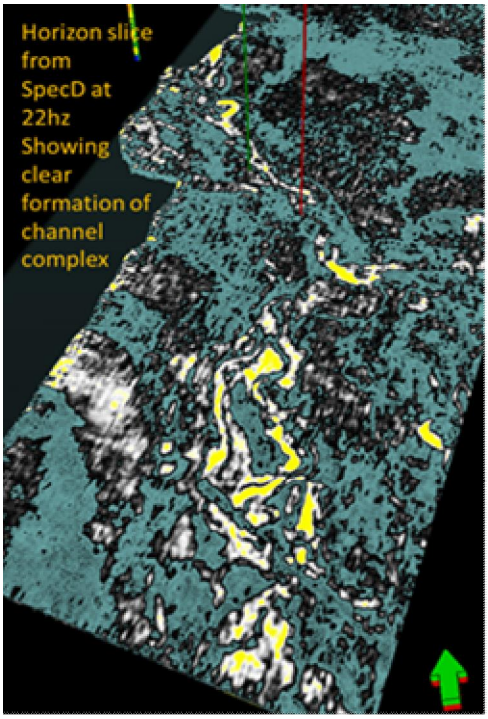

Fig-10 Horizon slice at 22hz of spec-D volume showing distributaries flowing from north to south

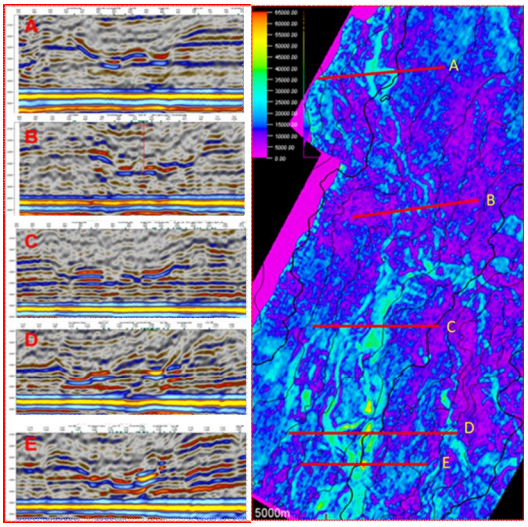

Fig-11 Channel dimension on flattened Eocene Top in the left and RMS attribute map on the right. Positions of seismic sections displayed by yellow lines on the attribute map.

from the seismo-geological section. Multiple entries as interpreted on seismogeological section (Fig-12) and networking of channels as observed at different frequencies or attributes suggest a distributary network in deltaic setup. The variation in aspect ratio as observed in seismogeological section is also reflected in the horizon slices of different frequencies. Different channels are visible at different frequencies indicating variation in thickness. All these inputs clubbed together lead to construct the reservoir model (Fig-13) which suggest the depositional environment as subaquous lower delta plain with formation of distributary channel network where sand deposition is expected as inner distributary fill and encased within clay from all other sides. These distributary channels are about

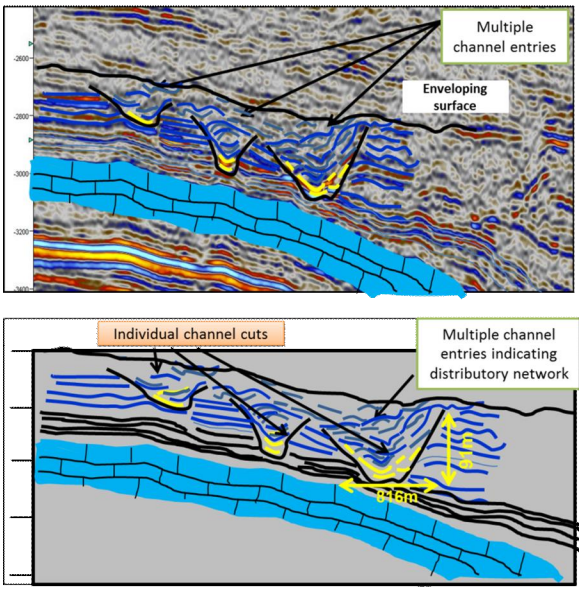

Fig-12 Seismogeological section showing multiple channel entries with aspect ratio varying from 1:9 to 1:5. This scenario suggest the suspended type channels of delta where sand : mud is moderate to low indicating good entrapment scenario of the reservoir sand.

28 km long, 300 m to 800 m wide and 30 to 91m deep. The average thickness of sand bodies is expected to be 10 to 30m. Velocity analysis indicates the depth of these prospects at around 4800m. The petroleum system modeling studies consider Hoogly Shale on the top of Eocene carbonate as the source rock and indicate good transformation beyond shelf break. The close proximity of the depocentre near Eocene shelf break area enhances the chance of presence of hydrocarbon in these reservoirs through short distance migration. However, existence of high pressure near the shelf break area may be studied thoroughly prior to exploring these prospects.

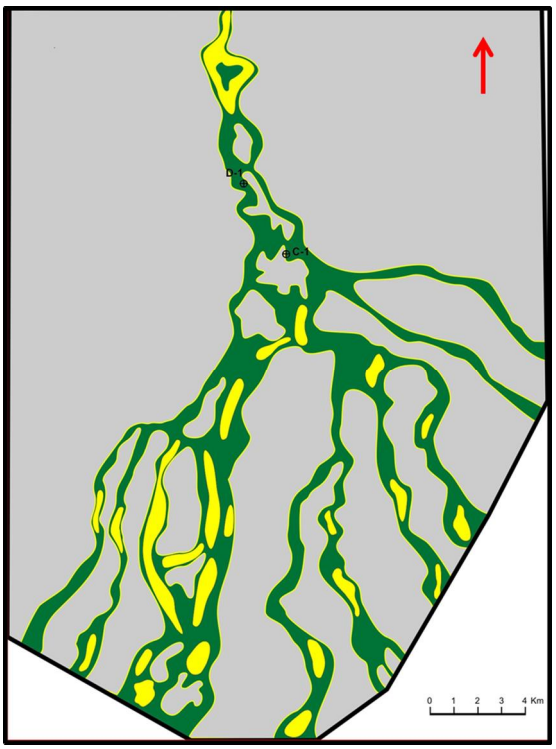

Fig-13. Reservoir model suggesting sand deposition (yellow) as inner distributary fill which is encased within clay (green) from all other sides. Grey indicates the bed rock.

Conclusion

The depositional system for Post Cretaceous sediments varies from marine carbonate platform of Eocene to transitional-continental fluvial-deltaic through Oligo-Miocene up to Recent. The 3D seismic

interpretation indicates development of the distributary channel network in NNW-SSE direction near the shelf-slope break at the onset of Oligocene. Considering the Law of Uniformitarianism, the presence of deltaic reservoir sands in the wide network of distributaries of Bengal Basin supports the presence of Oligocene distributary channel deposits.

From hydrocarbon point of view this area seems to be prospective and may open up a new horizon for oil & gas exploration in Bengal. The high amplitude standouts have been identified within distributaries of Oligocene. The study area near shelf-break zone being close to the depocentre enhances the probability of short distance migration of hydrocarbon. The probing through drilling of this type of stratigraphic trap at a depth of approximately 4800m in Bengal Basin should be taken up judiciously considering the various risk elements mentioned in the study.

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