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Analysis of Hydrocarbon prospectivity of Neogene and Paleogene sediments of shallow water blocks of Mahanadi Basin

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Mahanadi offshore basin is one of the passive margin basins off the east coast of India, flanked by producing KG Basin to the SW and prospective Bengal basin to the NE. The study area lies within shallow water part of the basin, south of present day coast line, wherein the Eocene Shelf edge runs parallel to the present day coast from east to west through the south central part of the block. The early drift phase, in Mahanadi Basin, was marked by deposition of Late Cretaceous shales followed by deposition of coarser clastics. Further basinward tilt was followed by gradual transgression and high stand of sea during Paleocene to Early-Middle Eocene. Oligocene is found to be absent in the shelf part as seen in the drilled data and probably indicating period of non-deposition. The Neogene period, in general, is marked by basinward progradation. The Miocene sequence, which un-conformably overlies the Eocene sequence was deposited in shallow marine to deltaic environment. Overlying Neogene, the sequence comprises of clastics belong to a prograding delta system.

The study area is covered with extensive 2D seismic as well as 3D seismic data. A prominent wedge out to the north west of block area is seen for Lower Miocene. In the Upper Miocene, erosional unconformity is observed which demarcates Miocene and Pliocene sections. Another prominent stratigraphic feature is a Carbonate build up at Paleogene level beyond shelf edge.

3D Seismic data are interpreted volume wise and total six prospects are identified which are as follows: (i) A slope fan associated with high amplitude stand out in Mid Miocene sequence (ii) Erosional geomorphic high of upper Miocene iii) Mio-Pliocene cut and fills towards western part of 3D area (iv) Slope channels and fan Complexes (v) Paleocene wedge out feature below Eocene sequence on Eastern part of study area,(vi) Late Miocene Basin floor fan (convex upward) on the eastern part of the study area.

Drilling data of all the old and new wells, did not suggest any viable prospectivity from hydrocarbon point of view in shallow water blocks of Mahanadi Basin. The only silver lining in the block is the presence of gas in MDT sample in the recent shallow water well from a very thin sand with a small aerial extent which offers an important exploration lead.

INTRODUCTION

Mahanadi offshore basin is one of the passive margin basins off the east coast of India, flanked by producing KG Basin to the SW and Bengal basin to the NE. This basin has hitherto been explored for hydrocarbons, by many agencies. During 80s' seven exploratory wells (MAA-1 to MAG-7) were drilled in the offshore part of the basin but failed to strike commercial hydrocarbons except a number of hydrocarbon indications in the form of gas readings and fluorescence in cuttings and side wall cores in Miocene and Eocene sections. These indicate that the basin is capable to generate hydrocarbons.

The present study area falls within the shallow water block of Mahanadi adjacent to NEC block.. The study was carried out in two areas (Area-I & II), covered by 3D seismic (Plate-1) of 240 and 160 sq. km respectively for evaluating the hydrocarbon potentiality and identification of areas of interest. The

study has brought out cut and fill, remnant, slope and basin floor fans prospects within Miocene in area-1 and Eocene shelf margin build up, slope and basin floor prospects within Miocene in area-II.

Three exploratory shallow water wells were drilled namely XSW-1, YSW-2 & ZSW-3 but failed to strike commercial Hydrocarbon. The only silver lining in the block is the presence of gas in MDT sample in the well YSW-2 from a very thin sand with a small aerial extent which offers an important exploration lead. In view of the hydrocarbon indication, the potential of the block needs to be considered particularly for stratigraphic plays within Mio-Pliocene sequences.

GEOLOGICAL SETTING AND STRATIGRAPHY

The Mahanadi offshore basin, along with other east coast passive continental margin basins, came into existence during the break up of Gondwanaland. The basement configuration of the basin shows NE-SW to ENE-WSW trending horst and graben morphology. The synrift phase of the basin is characterized by predominantly volcanic sequences and intertrappeans of Early Cretaceous age. The early drift phase, in Mahanadi Basin, was marked by deposition of Late Cretaceous shales followed by deposition of coarser clastics and basinal tilt towards southeast. The hinge zone represents a prominent tectonic element in the area providing slope, which increases from 1-2 degrees at the shelf edge to 6-12 degrees on the slope. Beyond the slope, it flattens out to 1-2 degrees in the basin fore deep Oligocene is found to be almost absent in the shelf part as seen in the drilled data and probably indicating period of non-deposition or erosion throughout the shelf part of the basin. As a result of non-deposition of during Oligocene in the shelf part, upper Paleogene section was subjected to erosion. Channel cut and mound type features are present at many places. The Neogene period in general, is marked by basin ward progradation. The Miocene sequence which unconformably overlies the Eocene sequence was deposited in shallow marine to deltaic environment. The depositional system during Miocene was affected by three major cycles of sea level changes (Dasgupta, U., et al 1985). The upper Miocene/Pliocene was deposited in prograding highstand regime with comparatively rapid rate of sediment supply.

SEISMIC EVENTS IDENTIFICATION AND MAPPING

In Area-I and Area-II seven seismic events have been identified and mapped. Among these, the seismic events corresponding to Eocene top and within Mid. Miocene are common in these two 3D areetailed analyses of seismic events, mapped area wise, are enumerated below.

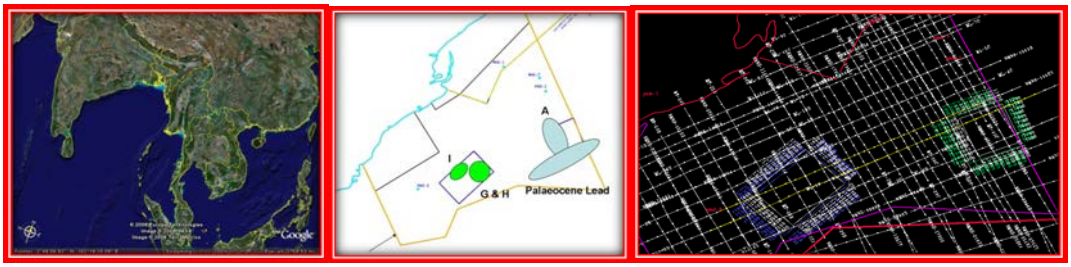

Fig.1(a,b,c): shows study area within shallow water blocks of Mahandi Basin

Horizons are correlated with the nearest well MAC#3, MAB#2 and MAG#7. Sea bottom has been tracked and correlated for bringing out of bathymetric configuration in the block.

An attempt has been made to integrate the 2D seismic data of the block with the present 3D seismic data. The major reflectors have been correlated in few 2D lines. The geomorphic high continues up to 2D line XAT-27 where it is again cut by another canyon. Shelf edge is marked parallel to the line MAAL-14. Beyond, the seismic package is basically represented by chaotic, low amplitude facies.

Area-I

Besides the above mentioned common reflectors, few more horizons corresponding close to Early Miocene, within Middle Miocene, within Late Miocene, within Lower Pliocene and top of Pliocene are tracked and correlated (Fig.2) with the nearest well MAC#3. Miocene top is close to the major cut surface (G horizon of 3D interpretation) and Pliocene top (H horizon of 2D interpretation).

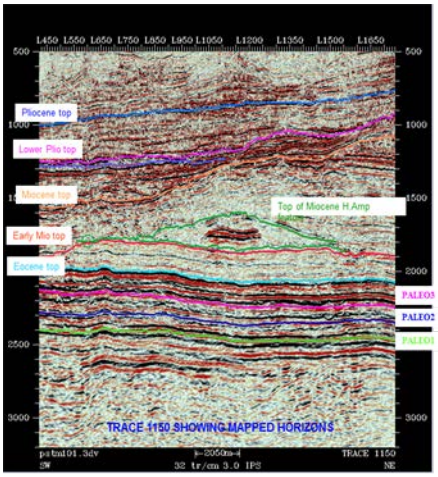

Fig.2 shows Trace 1150 showing mapped horizons

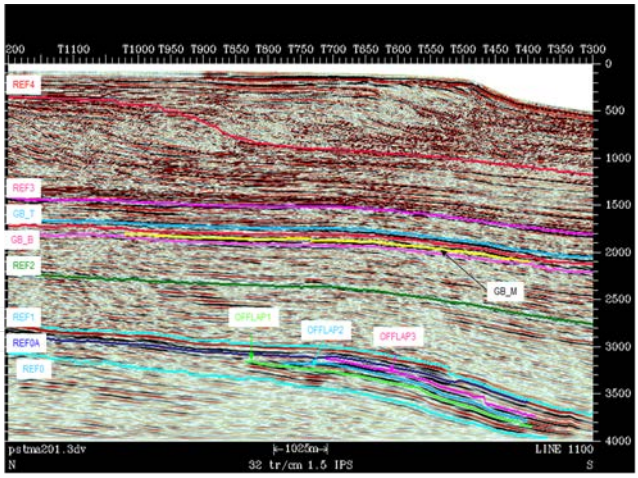

Fig.3 shows line 1100 of Area II showing mapped horizons

Area-II

In area-II seven seismic events, falling within various stratigraphic levels, have been identified and mapped. These seismic events were tied up with the well data of MAB-2, falling in the north and outside of present 3D area, and correlated throughout the volume. These events, corresponding to the tops of identified seismic sequences, have been taken up for mapping from Early Palaeocene to within Pleistocene through Late Palaeocene, Eocene top, Mid. Miocene, Late Miocene and Miocene.

FEATURES MAPPED AND DEPOSITIONAL SET UP

To build up viable depositional model in the area as a first step sequence stratigraphic study was carried out in association with SE extension of the block area. Total 6 sequence boundaries were mapped above Mid-Eocene carbonates. Mapping of paleo shelf edges of Neogene section (20 Ma above) was carried out using 2D seismic data for three different packages, that is Early Middle and Late Miocene

The study areas are located towards base of paleo slope/shelf edge of Miocene. The deep marine clastic depositional system is envisaged with subsequent reworking..

3D Seismic data were interpreted volume wise and total six prospects were identified.

Area-I

(i) A slope fan associated with high amplitude stand out in Mid Miocene sequenc (I-Prospect)
(ii) Erosional geomorphic high of upper Miocene (G-prospect).
(iii) Mio-Pliocene cut and fills towards western part of 3D area (H-prospect).
(iv) Slope channels and fan Complexes (J prospect)

Area-II

(i) Paleocene wedge out feature below Eocene sequence(S-proospect)

(ii) Late Miocene Basin floor fan (convex upward) (A-Prospect).

Slope fan (I-Prospect): The Slope Fan is a high amplitude feature identified within basal part of Middle Miocene. The time thickness map shows a NW-SE linear trend for this high amplitude feature. The trend of the body suggests the sediment supply is from NW that coincides with sediment input direction of Mahanadi delta. Internally the feature contains high amplitude parallel reflection. The high amplitude package possibly indicates presence of sandy facies encased within low amplitude probably a shaly facies. This feature is approximately 6.35 km wide (along cross line) extends 6.5km (along inline) and might indicate submarine fan formed during Middle Miocene.

The envisaged slope fan and other seismic features within Mid-Miocene section in area-I has been viewed earlier through Voxel Geo to firm up the prospectivity of the area. A high amplitude feature was identified within basal part of Middle Miocene. The high amplitude package possibly indicates presence of sandy facies encased within low amplitude probably a shaly facies. (Figs enclosed)

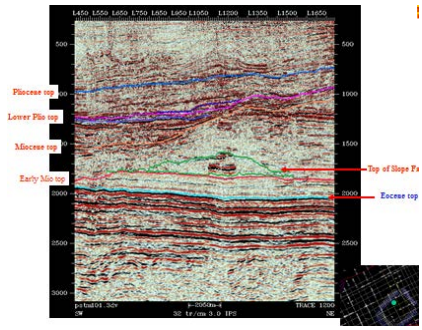

Fig: 4. Trace 1200 shows Slope fan

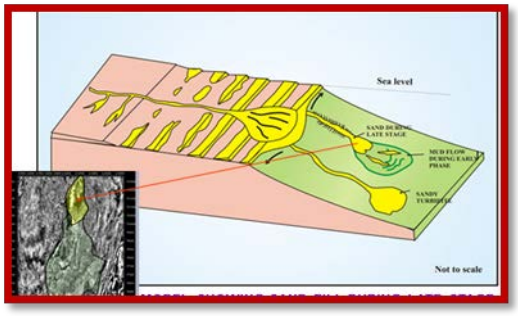

Fig:5.Model of slope fan showing sand fill during Later stage

Relict feature within Late Miocene (G-prospect): Below Mio-Plio unconformity surface the late Miocene feature having high amplitude parallel reflections show nosal feature in the time structures map towards the NE part of the study area. The high amplitude reflections truncate against the Canyon cut surface at Miocene top. The clustering of high amplitudes in RMS amplitude map indicates possible presence of coarser clastics in that part of the area.

Channel fill within Early Pliocene (H-prospect): The stacked channel fill sequence of Early Pliocene within the major canyon cut at Miocene top level shows the orientation of sand bodies in NW-SE direction in time thickness map. This shows the sediment distribution pattern from Mahanadi Delta.

East of well MAC-3 within Miocene section one mega, erosional cuts, prospect' H' with fill surface showing reversal in strike is observed beyond shelf edge. Time map on top of the fill appears as a southerly plunging nosing feature with swing of contours at the channel axis. Depth Conversion made after considering the low velocity layers has brought out a well defined structure with an adjacent westerly low.

Slope channels and fan Complexes (J-prospect): Development of slope channels and fan complexes were found within Pliocene sequences in the western part of 3D volume. At places vertically stacked one over another and often coalescing with each other. Though the contorted reflection characters within the lower fan body indicate that it may be slump deposits. But above this, a body with high amplitude reflection character between traces 1100 to 850 and inline 350 or 334 around time level 650 msec(TWT) at position-Inline 334 & trace 1020 may be interesting. These are proven play types in KG and Mahanadi sector with potential biogenic/ non-thermogenic dry methane charge. The combined aerial extent of the two channels is more than 13Km2 and vertical thickness of the package is about 100ms (TWT). (Figs enclosed).

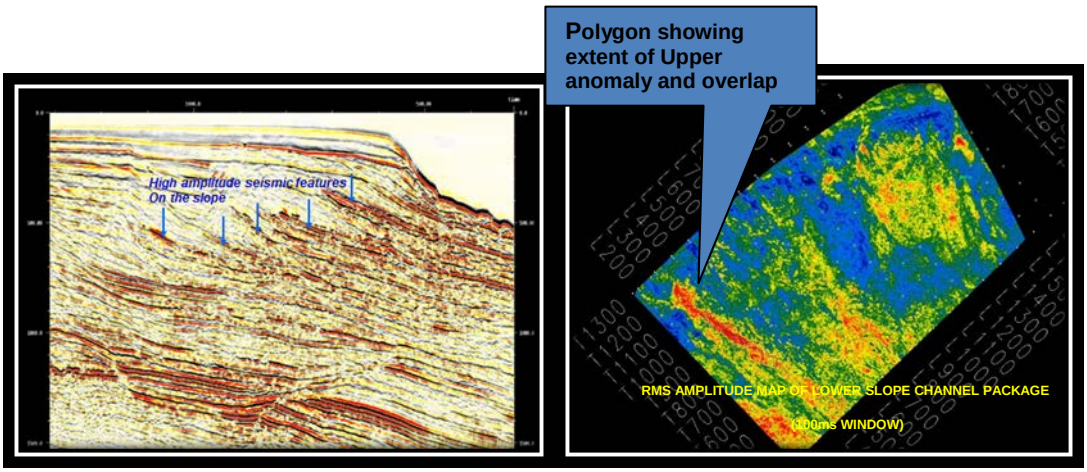

Fig-5(a) . DIP SECTION ACROSS THE AREA SHOWING SLOPE CHANNEL AND FAN ON SLOPE. **Fig.5b: RMS amplitude of Slope channel packge (50ms window)**

AREA2

Palaeocene feature : After PSTM Off-lap slope wedges were identified within Early Eocene, Late Palaeocene level (Fig.6a) Earlier interpreted Carbonate build-up along with the hinge zone was negated by this off-lap slope wedges. Three horizons off-lap1, 2 and 3 were correlated to delineate possible sand bodies and attributes were generated out of these horizons. The energy half time attribute and slope of reflection strength attribute suggest major sand bodies present near the off-lap 2 surface

.Spectral decomposition slices at different frequencies show the turning of discrete sand bodies along the hinge zone (Fig.6b).

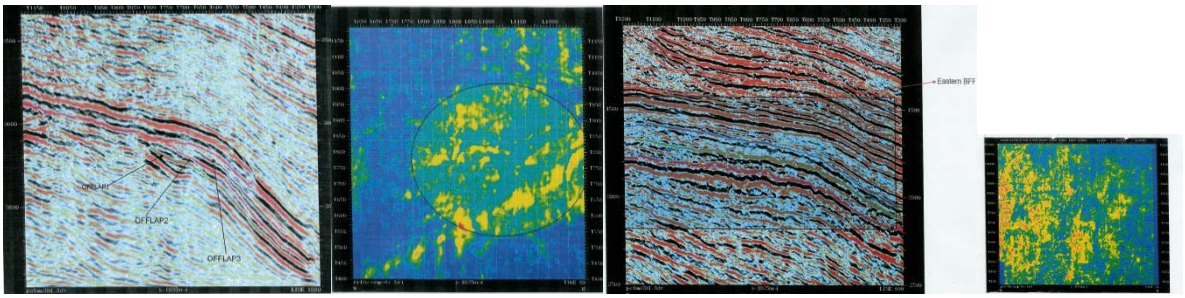

Fig.6a: Inline 1060 showing offal Fig6b. Spectral decomposition slices Fig.7a: Eastern Basin floor fan **Fig. 7b: SD slices at 24Hz slope wedge within paleocene**

Mio-Pliocene feature: One geo-body was identified and 3 horizons were correlated to generate attributes and static structural disposition. Average absolute amplitude suggest the disposition of a basin floor fan body. The fan body in the eastern part of the area lies on the terrace portion of the area (Fig.7a). Spectral decomposition(SD) slices at 10 HZ to 24 HZ (Fig.7b) suggest very thick sand bodies all over the area.

` CONCLUSIONS

1. The present area, restricted within the block represents low shelf gradient, thereby low energy. The absence of any significant amplitude variation within the reflectors in case of G- prospect (XDW-1) reflected the shadow of low energy environment, under which was deposited clay or shale.

2. Highstand System Tract (HST) phase away from the land-side belong to low energy facies and as per interval or time period of deposition in Miocene, HST phase continued for a longer time interval with intermittent Transgressive System Tract (TST) phase.
3. During transgression, waves and tides eroded sediments from the substrate at the shoreline and transport them both landward and seaward.
4. The geo-body "I" of the well ZSW-3 was made up of reworked storm deposits and present on the shelf seaward of the shoreline at or below wave-base. These depositional environments yield fine grained sediments that were transported by suspension seaward by storms.. The reservoir-quality of these deposits seemed to be inferior due to finer grain size of sand.
5. In general in Mahanadi Basin Miocene sequence experienced concomitant subsidence and deposition. Therefore, very thick Miocene sequence never experienced any sort of sub-areal exposure to give rise to Low Stand Tract (LST) phase in Early, Middle or Late part of Miocene. So this might be another reason for the absence of coarser clastics and thereby the good reservoir.
6. There is an absence of four way dip closures within the 3D survey area and a paucity of leads. No fault closure is present in the block. The overall prospectivity of the shallow water block, based on current data is low and exploration risk on the block is presently considered to be very high.

RECOMMENDATION

As per the results of the early and recently drilled wells no commercial hydrocarbon discovery is met with. But there is an unexplored and interesting area for exploration left within the block, the Gahirmata sanctuary. This area cannot be explored from environmental point of view.. The only silverlining in the block is the presence of gas in MDT sample in the well YSW-2 from a very thin sand with a small aerial extent which offers an important exploration lead. In view of the hydrocarbon indication, the potential of the block needs to be considered particularly for stratigraphic plays within Mio-Pliocene sequences.

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REFERENCES

1. Ahr, W. M., 1973, The Carbonate ramp : an alternative to the shelf model. Trans. Gulf Coast Ass. Geol. Soc.23, p.221-225.
2. BEICIP., 1989, Report by Oil India Limited on basin modeling; Mahanadi-North east coast Basins
3. Brown, L. F., and Fisher, W. L, 1976, Seismic Stratigraphic Interpretation of Depositional Systems: Examples from Brazilian Rift and Pull-Apart Basins, AAPG Memoir.
4. Dasgupta, U., 1987, Seismostratigraphic evolution of Miocene depositional system in Mahanadi basin (offshore), AEG V-III (2), p.81-88
5. Fuloria, R. C., 1993, Geology and hydrocarbon prospects of Mahanadi Basin, India, Proc, Second Seminar on Petroliferous Basins of India, Vol.1
6. Mitchum, R. M., 1985, Seismic Stratigraphic Expression of Submarine fans, Seismic Stratigraphy II, An Integrated Approach to Hydrocarbon Exploration, AAPG Mmoir 39.
7. Stephen J King., 2005 Review of Mahanadi Basin, NELP I Block MN-OSN-97/3, consultant,Akron International Pvt. Ltd