Mapping of Sub-Aqueous Canyon And Channel Fill Reservoirs of Kamalapuram Formation: A New Exploration Target in Ramnad Sub basin, Cauvery Basin

Chandan Chakravorti*, Sushil Chandra, M.S.Rana, B.M.Juyal & N.D.Gideon
BSG, KDM Institute of Petroleum Exploration, ONGC, INDIA
E-mail : chamchak2@yahoo.com

Summary

Hydrocarbon exploration in Ramnad sub basin and Palk bay offshore in the Cauvery basin were mostly confined to Nannilam and Bhuvanagiri play as primary exploratory targets over a decade till the discovery of Paleocene pay (Lower Kamalapuram Formation) in well P-E. The Kamalapuram reservoirs occur principally as sub-aqueous fill deposits within canyon / channel cut over Cretaceous unconformity (K/T) having charged from Older Cretaceous source facies through deep seated faults. This study mainly deals with sub-aqueous canyon /channel system over K/T and Paleocene erosional activities, suggesting probable exploratory target for Kamalapuram reservoirs and is a part of comprehensive study covering basement to Paleocene level, carried out at KDMIPE on a regional scale (Juyal et.al,2005) . The integrated relief map over top of Cretaceous and Paleocene reveals a network of sub-aqueous canyon and channel system mainly originating from Pattukottai-Mannargudi ridge, with erosional activities more prominent over K/T. The coarser and eroded clastics from Pattukottai-Mannargudi ridge carried through these sub-aqueous canyons proved the reservoir in the basinal dip for hydrocarbon accumulation. The identification of network of sub-aqueous canyon and channel fill deposits associated with structural component will lead to discovering of prospects.

Introduction

Cauvery basin, essentially a pericratonic rift- sag basin is made up of a suite of 'en-echelon' NE-SW trending grabens separated by three rows of ridges. Ramnad sub basin, one of the south easternmost graben limited by Pattukottai - Mannargudi ridge to the west and Mandapam delft ridge towards the east. Both the ridges specially the former one primarily acted as provenance for the sedimentation in Ramnad, Palk bay offshore and Gulf of Mannar sub basins. This sub basin accommodated sediments over 5000 m in thickness at its depocentre, ranging in age from Lower Cretaceous to recent. There were two more depocentres observed at basement level, one at Western Palk bay and the other at Eastern Palk bay separated by a median high aligned in a NNE-SSW direction (fig. 1). The pace of exploration in Ramnad sub basin has increased after the commercial gas discovery in P-A well from Nannilam Formation corresponding to Late Cretaceous age. Earlier studies in the sub basin were confined to the Nannilam and Bhuvanagiri play as they were initial targets. The entrapment in Nannilam Formation is strati-structural in nature whereas in Bhubanagiri Formation, it is mainly structural. The deposition of these reservoir is through mass transport mechanism viz. debris flow under deep water marine sedimentation process. With the discovery of gas in well P-E, the Lower Kamalapuram pay corresponding to Paleocene age has brought into focus and suggest a strati-structural entrapment with stratigraphic component being prevalent .Lower Kamalapuram Formation is a proved play in other parts of Cauvery basin and is a prolific producer in Kamalapuram field of Nagapattinam sub basin (Gupta et.al,1999).In the broader canyon set up reserve growth has

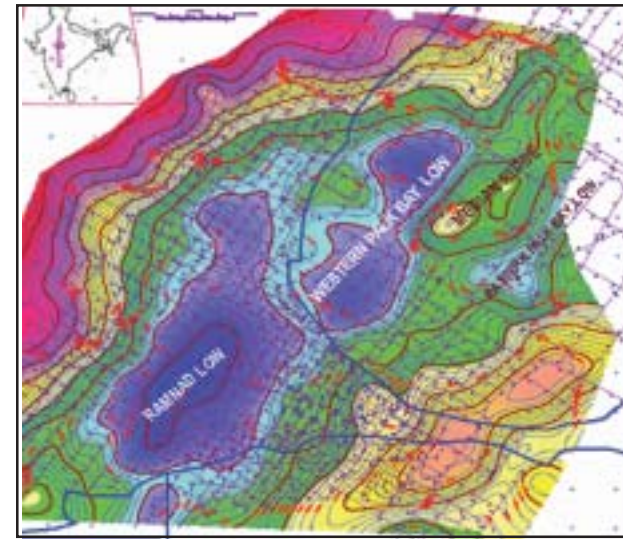

Fig.1: Relief map close to top of Basement showing basin configuration and depocentres of the Ramnad and Palk Bay offshore areas.

been proved as anticipated on the basis of reservoir model in Kamalapuram field (Gupta et.al.2004).In the study area, the dominant mode of deposition envisaged is fill deposits within sub-aqueous axial channel flowing along the downthrown fault blocks. The canyon and channel system anticipated to accommodate lower Kamalapuram reservoir, has been mapped. This Paleocene play, may lead to the future target of exploration.

Methodology

- Electrologs of all the wells were integrated with the help of biostratigraphic and lithologic data. The stratigraphic boundaries of the drilled wells were transferred to representative seismic line using VSP data of the well.
- The reflectors corresponding to different chronostratigraphic units within Cretaceous were mapped for the comprehensive study, which helped in understanding the initiation of canyon building process.
- The reflectors corresponding to close to top of Cretaceous and Paleocene were correlated and relief maps were generated.
- The network of canyon/ channel system has been demarcated and with the analogy of P-E play can be explored as future targets.

Discussions

The presence of commercial quantity of gas in well P-E has been established the Lower Kamalapuram Formation as a new play, a sandstone units of about 100m thickness encountered in the interval 1758-1858m. Based on the last appearance of Globotruncaniids, the K/T boundary, a major unconformity has been fixed at 1860m (P.Ramesh.2005). The 100m sandstone unit above K/T is populated with M Pseudobulloids and Planorotolites compressa leads to assignment of the pay sands in P-E to Paleocene age with its deposition in middle neritic to bathyal system. A relook of geoscientific data of P-E and the core available from lower Kamalapuram Formation in well PF (1786-1795m) is represented by inverse grading, normal grading, massive sandstone and parallel laminae. Other sedimentary features observed are rafted clay clasts, sharp contacts and selective calcite cementations suggesting the deposition by debris flow process with bottom current activity (RGL, Chennai). Consequent upon P-E discovery, two wells drilled in Ramnad sub basin to chase the Kamalapuram play confirmed the reservoir though the failure in finding hydrocarbon in these two wells could be ascribed to structural fall (P-F) and away from the migration path (K-F) respectively. Fig 2 shows the position of well PF and PE on seismic section M-HE-DI. Log correlation along the dip profile (M-HE-DI) (Fig-3) reveals the presence of Lower Kamalapuram reservoir in wells P-F, P-E whereas it is absent in R-A, P-B & R-B wells suggesting the reservoirs are the product of turbidity and channel fill deposits. From the log and seismic section it is quite evident that deeper incised canyon fill had been further cut by broad wider channel, also depositing reservoirs on its shoulders where hydrocarbon accumulation has been proved (PE). Therefore the prospectivity lies along the channel axis with structurization , as well as on shoulder part of the channels.

Cretaceous-Paleocene sub-aqueous channel network

The Cretaceous top is a first order erosional unconformity surface. The global sea level fall during the

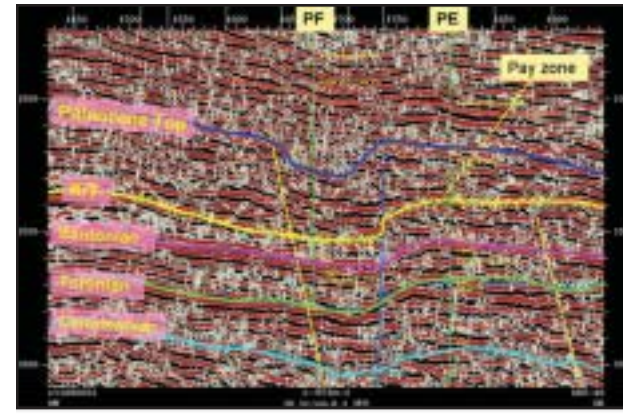

Fig. 2: Part of interpreted Seismic Section showing the channel and drilled locations P-F & P-E on line M-HE-DI

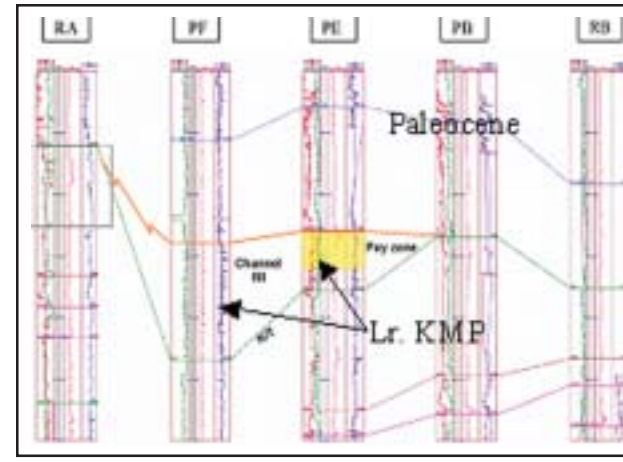

Fig. 3: Log correlation along M-HE-DI showing Lr Kamalapuram Fm in wells PF & PE

close of Cretaceous period exposed many submerged areas under erosional activity which generated active canyon system. The relief map close to top of Cretaceous (Fig-4) depicts more or less curvilinear Pattukottai – Mannargudi ridge and shows evenly distributed contours with gentle gradient of the basin due to continued erosion of the highs and deposition of sediments in the existing lows. This alongwith Easterly tilting during Campanian had resulted in shallowing of the Ramnad low (Fig 1 &4). The contour pattern depicted the canyon/ channel entry from Pattukottai-Mannargudi ridge though the overall contour value shows gentle gradient from 150-500 ms, closed spaced contour of 500-750 ms and again gentle slope downdip the basin shows building of relict shelf-slope system continued from earlier times.

The entire canyon network at the top of Cretaceous has been mapped (Fig-5) which will help in extending the P-E pay in Ramnad sub basin. The erosional as well as depositional activity has started from older time and subsequent cycles of this activity continued till Paleocene level with major erosional activity culminated on top of Cretaceous. Fig 5 and Fig 6 (3D image view over top of K/T) shows the several sub-aqueous drainage system emerged over top of Cretaceous . Contribution of sediments through transverse drainage is envisaged mainly from the western flank, however three prominent canyon systems originating from the Pattukottai-Mannargudi ridge are very conspicuous.

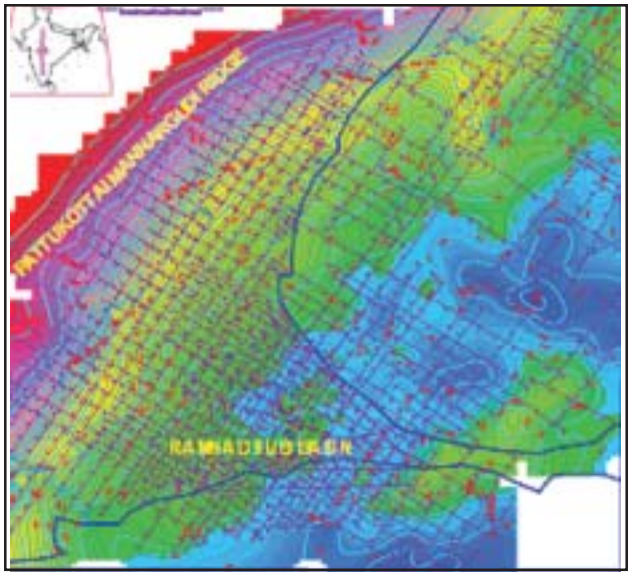

Fig. 4: Released map close to top of Creataceous

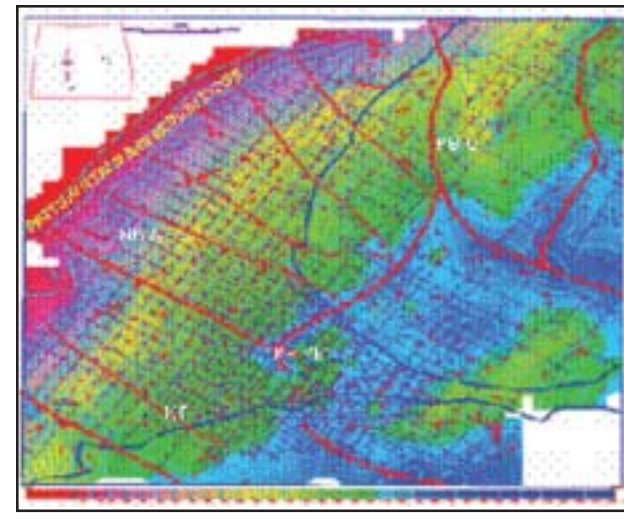

Fig.5 : network of canyon/channel system over top of Creataceous system

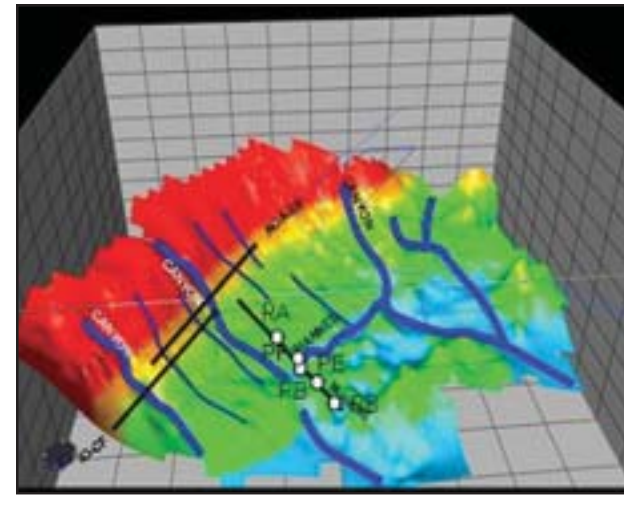

Fig. 6: Relief map at the top of K/T (3D Image view) showing network of canyon / channel.

The northern canyon starts from the Pattukottai-Mannargudi ridge traversing through west of PB-G structure & bifurcated into two, one arm enters into eastern Palk bay low and the other enters into western Palk bay low & ultimately terminating into present day Ramnad onland basin. This broad canyon on the ridge gradually changes to sub-aqueous channel down the dip (Fig-7). Channels are defined as relatively long lived erosional features associated with sediment transport pathway (Mutti and Normark,1991). As channel ceased to transport, they fill. Erosional channel fill is one of the main fill, where basal coarse grained sediments are overlain by fine grained channel abandonment deposits. The second 'V' shaped canyon system seen on seismic line AOA-DF (Fig-8) developed in the middle of Pattukottai-Mannargudi ridge west of well

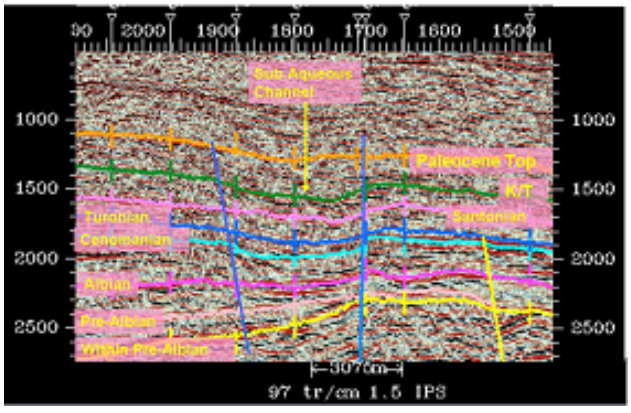

Fig. 7 Part of interpreted seismic section TP-I showing sub aqueous channel down dip the basin

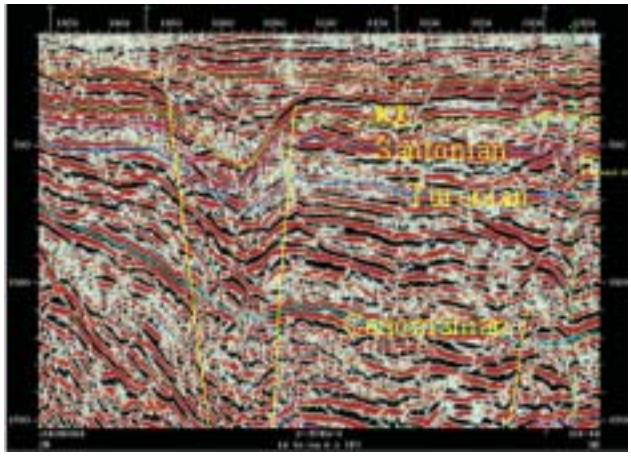

Fig. 8: Part of interpreted Seismic Section AOA-DF showing the "V shaped Canyon"

NK-A originated at much older time & has remained active upto the end of Cretaceous time and continued sediment dumping into Ramnad Sub basin. This canyon converts into channel down dip (Fig-9) and corresponds to anticipated ProtoVaigai (?) river. The third canyon origination from southwest part of Pattukottai-Mannargudi ridge along seismic line I0-CF (Fig-10) evolved during Turonian time & drastically enhanced the erosional activity during Cretaceous time. The erosional activity continued further & got ceased during Eocene. The seismic sections down the dip shows canyon/ channel activity & sediment load had been deposited in Gulf of Mannar.

The relief map close to top of Paleocene top (Fig 11) depicted the curvilinear nature of Pattukottai-Mannargudi ridge and basin architecture is almost same as that of K/T top but the gradient of basin became gentler as compared to Cretaceous that has been anticipated to be the cause of coarser clastics being deposited by gravity flow.

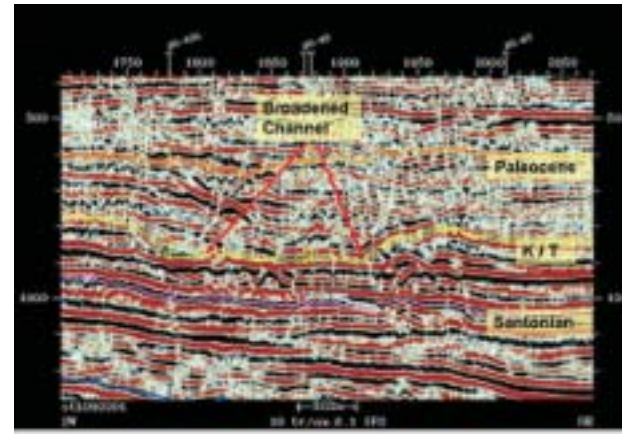

Fig.9. Part of interpreted seismic section 10-DO showing the nature of 2 canyon as broaddened channel towards basinal side

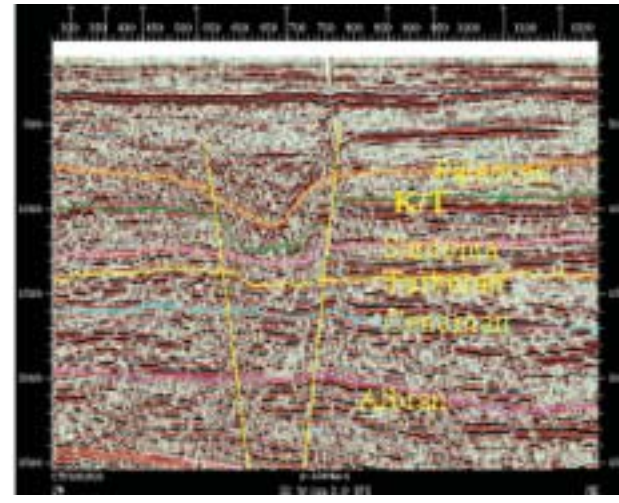

Fig.10: Part of interpreted seismic section I0-CF showing canyon activity on SW part of Pattukottai-Mannargudi ridge

Further easterly basin tilting during Paleocene has created multiple drainage pattern originating from Pattukottai-Mannargudi

The relief map close to top of Paleocene (Fig 9) depicted the curvilinear nature of Pattukottai-Mannargudi ridge and ridge which is reflected as wavy contour pattern and also shifing of depocentre to the East and narrowing down of the Ramnad low. The faults were observed to be active till the end of Paleocene time. The top of Paleocene being an erosional surface representing a hiatus of variable magnitude at Paleocene- Early Eocene boundary and cut & fill feature host the coarser clastics to accommodate potential reservoir termed as Upper Kamalapuram Formation. The relief map close to Paleocene also depicted channel network which is unexplored so far . Some of the salient observations are 1)Transverse drainage became prominent from

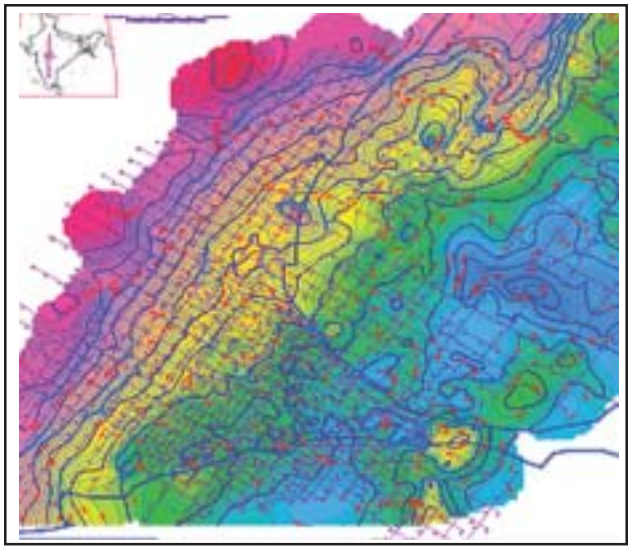

Fig 11: Relief map close to top of Paleocene

Pattukottai-Mannargudi ridge due to pronounced Easterly tilting during Paleocene. 2) A major drainage system is seen from Northern Palk bay offshore and thick pile of sediments had been deposited in the NW-SE alligned arm entering into Eastern Palk bay low (because of Eastern tilting) as well as in the Ramnad low area in NNE-SSW allignment.3)The northern canyon has further incised towards the ridge. 4) Several channels connecting Ramnad sub basin and Gulf of Mannar has been observed on the map 5) The canyon feeding to Gulf of Mannar in the southwestern part has diminished its gradient. 6) The low axis along the Proto-Vaigai(!) still continued.(Fig-12)

Source potential, Critical moment vis-à-vis Reservoir

There is fair source rock development within Andimadam Formation in the study area.The maturity modeling with EASY Ro programme reveals that Pre-Albian sediments (Lower Andimadam Formation) has attained onset of hydrocarbon generation (0.7%VRo) at around 3200m in Ramnad low Geochemical investigation has been carried out in numbers of wells in the area out of them effective source rock were encountered in only in four wells mainly in the rising flanks of the low (no well was drilled down to basement in the basinal low). The cutting samples of drilled wells indicate only Type-III and Type-IV kerogen, however finer clastics of undrilled section of the basinal low may contain Type –II kerogen. Geochemical studies and 1D genetic modeling on one synthetic well over Ramnad low was carried out by KDMIPE (Pahari,2005) estimated

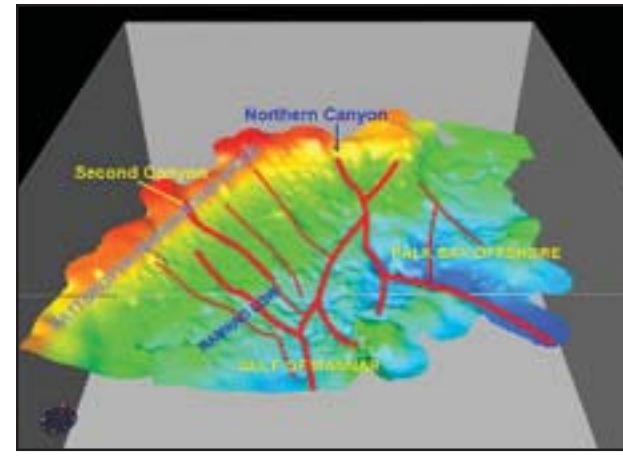

Fig.12: Relief map at the top of Paleocene (3D image view) showing network of Canyon / Channel

the critical moment for wet gas and condensate i.e VRo 1.3% is at 20 m.a (Early Miocene) for Pre-Albian sediments. This older Cretaceous source facies might charged the sands over channel/canyon cut through deep seated faults as well as unconformity surfaces and the overlying thick shale sequence provided the seal (Fig-13) .

Conclusions

Paleobathymetry data suggest the deposition of the Paleocene sediments have taken place under middle neritic to bathyal condition (Kalyansunder et.al,1991). Cretaceous top being an erosional unconformity, had led to the development of canyon and gradually transformed into sub-aqueous channel down the dip.The network of sub-aqueous canyon and channel over K/T surface has been brought out

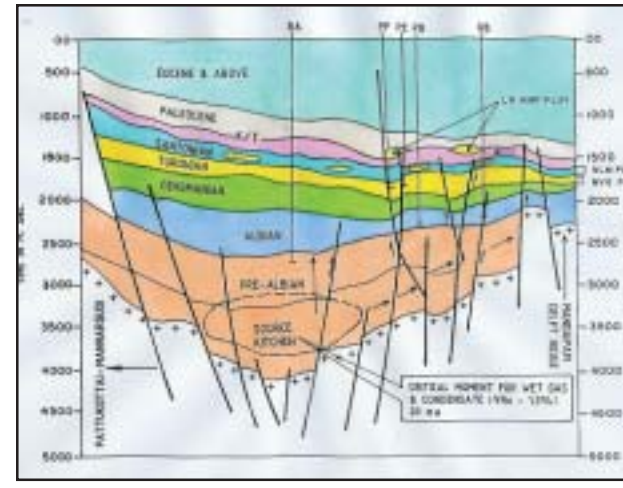

Fig.13: Geological cross-section along M-HE-DI showing possible source, migration and reservoir model.

which host the probable coarser clastics of Lower Kamalapuram Formation and had been charged through deep seated fault/unconformity surfaces from Older Cretaceous source facies. The top of Paleocene also being an erosional surface, the cut and fill feature might host the coarser clastics as Upper Kamalapuram reservoir which has not been proved so far. The detailing of geobody along the canyon / channel associated with structurization and its shoulder part, would lead to find out prospects.

Acknowledgement

The authors express their thanks to ONGC for providing infrastructure and giving permission to publish the paper. We sincerely thanks Director (E) and Head KDMIPE for assigning the work, providing the opportunity and the infrastructure, GGM(BSG),Basin Manager & Block Manager,Chennai for their encouragement and technical suggestions. Thanks are also due to Mr Saumitra Gupta, Chief Geologist along with the colleagues of KDMIPE and Cauvery basin, Chennai for the fruitful discussion. We also thank the authors of various reports referred during the study.

Views expressed in this paper are that of the author(s) only and may not necessarily be of ONGC.

References

B.M.Juyal, C.Chakrobarty, M.S.Rana & Sushil Chandra, 2005 : Re-Evaluation of Palk Bay, Gulf of Mannar and adjoining areas to assess the hydrocarbon potential of Kamalapuram, Nannilam, Bhuvanagiri & Andimadam Formations in light of recent drilled wells,. An unpublished ONGC report.

Gupta S., Chakrabarty C., Soren M. N., Bhradwaj B.M., Gideon N.D., 1999, Description of Paleocene-Eocene pay sands of Kamalapuram Field, Cauvery Basin. An unpublished ONGC report.

Gupta S., Chakrabarty C., Soren M. N., Bhradwaj B.M., Gideon N.D.,2004, Asset growth by Geological modeling and reservoir delineation of Paleocene- Eocene paysands of Kamalapuram field,Cauvery basin – An integrated approach. 2nd APG Conference, India.

Kalyansunder.R., Vijaylakshmi,K.G.,1991, Paleogeography of Cauvery Basin. - An unpublished ONGC report.

Kingston., J. Cauvery basin: Evaluation & Exploration Recommendation,1996. An unpublished ONGC report

Mohanty,S., Pravakar.S., Ramesh.P., Uppal.S.,Tirkkey.P.K., Singh.S.D., Begam.J., Sharma.D.C., Barua.P.,2005., Facies analysis, Paleogeographic reconstruction of Palk bay and clay typing for Cretaceous and Paleocene succession in Ramnad sub basin. - An unpublished ONGC report.

Mutti.E and W.R.Normark,1991, An integrated approach to study the turbitite system, in P.Weimer and M.H.Link eds, seismic facies and sedimentary process of submarine fans and turbidite system. New York.Springer-Verlag. P-75-106.

Samanta,U., Pandey,B.K., 1997, Evaluation and mapping of source rock of Ramnad sub basin, Cauvery Basin. - An unpublished ONGC report

S.G.K.Mohan., Gita Singh., S.P.Sharma., S.K.R.Moulick & J. Baral, 1999: Tectonic evolution & sequence stratigraphy of Cretaceous sediments in Ramnad sub basin, Cauvery basin.. An unpublished ONGC report.

S.Pahari, R.S.Bisht, A.Raina, A.K.Sinha & I.V.S.V. Prasad,2005, "Source rock evaluation of Ramnad,southern part of Palk bay and Gulf of Mannar area, an unpublished reports of ONGC

Thomas A Willams, Stephan A. Graham, Kurt N. Constenius,1998, Recognisation of a submarine canyon, Great Valley Group, Sacramento Basin, California: Implecation for Petroleum exploration and sequence stratigraphy of Deep Marine Strata. AAPG Bull,v-82,p.1575-1595.

Will M Satterfield and E.W.Behrens,1990, A late quaternary canyon/channel system, Northwest Gulf of Mexcico continental slope. Marine Geology,v-92 (1990) p 51-67.

Various Well completions, Sedimentological, Paleontological, Palynological, & Geochemical unpublished reports of ONGC.