

## **Paradigm shift in exploration strategy: Identification of prospective corridors in Ramnad- Palk Bay sub basin, Cauvery basin, India**

Chandan Chakraborty\*, D.K.Srivastava, M.S.Rana, V.M.Saxena and G.C.Sati

[chanchak2@yahoo.com](mailto:chanchak2@yahoo.com)  
BSD, KDMIPE, ONGC, DEHRADUN

### **Abstract**

The basin architecture of Ramnad sub basin of Cauvery basin in the Pre-Albian and Post-Albian set up have been evaluated for its tectono-sedimentation and prospectivity. The study identified two prospective corridors adjoining lesser explored West Palk Bay and East Palk Bay lows, which may establish more HC bearing structures in this sub basin for its substantial asset growth.

The morpho-tectonic elements of Cauvery basin are well defined by the deep-seated basement controlled fault systems with a series of sub-basins and ridges. The present study in Ramnad –Palk Bay sub basin, one out of six sub basins of Cauvery basin, identifies three basement related depocentres viz Ramnad low in the onshore part, West Palk Bay and East Palk Bay lows in the offshore part. The deepest Ramnad low, the principal kitchen area, is fairly explored and established five hydrocarbon bearing structures, believed to be mainly sourced from Pre-Albian sediments. The other two depocentres i.e. West Palk Bay low and East Palk Bay low in the off shore part holds sediments over 5000m at their respective deepest part, ranging in age from Lr.Cretaceous to Recent.

In Ramnad low, the lull period of tectonic activity coupled with high rate of sedimentation during Pre-Albian time shrunk its spread from its basement position. The renewed tectonic activity during Albian time helped in regaining the spread of Ramnad low and with passage of time, the basinal deep of Ramnad low started shifting towards east- northeast. The West Palk Bay low, separated from Ramnad low by a NW-SE high trend at basement level, obliterated during Pre-Albian time due to lesser tectonic activity coupled with high rate of sedimentation. Later some selective reactivation resulted in inversion bordering the low. This inversion related structuration with respect to its critical time demand merits for exploration. Whereas, the East Palk Bay low shows progressive spreading in space and time with continued tectonic activity along with lesser amount of sedimentation compare to other lows and being considered as another potential depocentre for commercial H.C generation and migration.

The abundant mature Valangian source sequence in recently drilled LK-H well in Ramnad area and also in QI-C well near East Palk Bay low led us to infer good amount of source sequence in Pre-Albian and Albian sediments in the basinal low. Hydrocarbon generation and maturity modeling based on drilled as well as synthetic locations in respective basinal deep reveals Pre-Albian sediments of West Palk Bay low and Albian & Pre-Albian sediments of East Palk Bay low entered hydrocarbon generation stage (0.7 VRo) at 59mybp and 58mybp respectively.

The structural analysis based on relief and chronopach of Pre-Albian, Albian and Post Albian sequences have brought out several high trending corridors among which the gentler flank of East Palk Bay low and N-S and NW-SE trending high corridors of respective western and southern part of West Palk Bay low would be the most

prospective targets and need paradigm shift in exploration strategy in Ramnad-Palk Bay sub basin.

### Introduction

Cauvery basin, a petroliferous basin forms the southwestern attenuated margin of Jurassic rift of the east coast of India. Taphrogenetic fragmentation of Archean basement as a result of rift-drift phenomena of Indian plate took place during late Jurassic-Early Cretaceous. The morphotectonic elements of the basin are defined by the deep-seated basement controlled fault systems with a series of depressions (sub-basins) and horst (ridges). Grabens forming sub-basins are Ariyalur-Pondichery sub basin, Tranquebar sub basin, Tanjore sub basin, Nagapattinam sub basin, Ramnad - Palk-Bay sub basin and Gulf of Mannar sub basin.

Ramnad and Palk Bay offshore areas constitute the southern part of Cauvery basin and is bounded by Pattukottai ridge to the west and Mandapam-Delft ridge towards the east (Fig. 1). The pace of exploration in the area has increased after the commercial gas discovery in well QF-A of Ramnad area, from the Late Cretaceous sands and so far established five hydrocarbon bearing structures. The sedimentary pile in the Ramnad sub basin is about 6 km and in Palk Bay sub-basin is more than 5 km ranging in age from Lower Cretaceous to Recent. The source rock facies are encountered in Andimadam Formation of Albian and Pre-Albian sediments. The hydrocarbon finds have been discovered in several reservoirs viz. Bhuvanagiri, Nannilam (main producing reservoir) and Kamalapuram formations. The thermal modeling of the basin indicate that the sediments within Andimadam Formation (main source rock) in Ramnad sub basin have achieved the end of oil generation maturation stage.

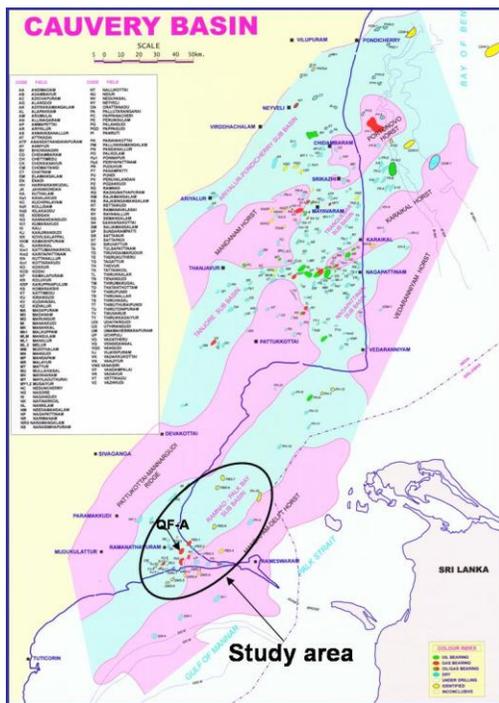


FIG. 1 : Location map showing study area

AGE		FORMATION	THICKNESS	
Recent to Mid. Miocene		Tittacheri Sandstone	300-500	
Lower Miocene	Madanam Limestone		600-1200	
	Vanjiyur Sandstone			
	Shiyali Claystone			
Oligocene	Kovilkalappal Fm.			
	Niravi Sandstone			
Eocene	Tirupundi Fm.		200-400	
Paleocene	Pandanallur Fm.		200-600	
	Karaikal Shale			
	Kamalapuram Fm.		200-800	
Cretaceous	Upper	Portonovo Shale	800-1700	
		Nannilam Fm.		
		Kudavasal Shale		
	Lower	Bhuvanagiri Fm.		800-1300
		Sattapadi Shale		
		Andimadam Fm.		
Archean	Basement			

Table. 1 : Stratigraphy of Ramnad Sub basin

The study has brought out the changing basin architecture during Pre-Albian - Post Albian time and its corresponding tectono-sedimentation and prospectivity of the sub basin.

### Methodology

Seismic sequence analysis based on chronostratigraphy validated by biostratigraphy and electrologs has been applied in this study. To decipher the depositional model during Pre-Albian - Albian, relief map as well corresponding iso chronopach maps have been prepared. Paleotectonic analysis was carried out to decipher the tectonic evolution of the sub-basin. In absence of deeper wells in basinal lows, synthetic wells were generated in respective depocentres. 1D hydrocarbon generation modeling was done in these locations to work out the hydrocarbon generation potential and the critical moment.

The generalized sub-surface stratigraphy of Cauvery basin is shown in Table 1

### Discussion

The relief and thickness maps generated at different chronostratigraphic levels depict the changing basin architecture with passage of time. The map on top of basement (Pre-Cambrian?, Fig-2,3 ) depicts the major basinal lows are aligned in the NE- SW direction with the basin broadening in the central and south central part and tapering towards the northern part of mapped area. The deepest basinal low is seen in the Ramnad Sub Basin. In main Palk Bay offshore two lows are seen – (a) an elongated, linear Eastern Palk Bay low bordering the western flank of Mandapam –Delft ridge and (b) the broader Western Palk Bay low with an elongated median ridge in between. The Western Palk Bay low again exhibits twin depocentre to the northern and southern side separated by intervening higher areas. Overall, these basinal lows progressively deepen from North to South.

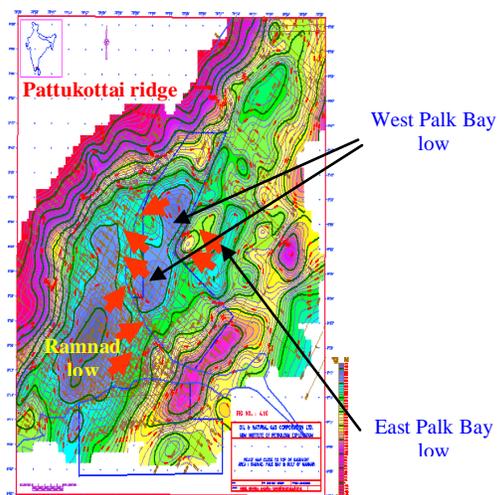


FIG. 2 : Relief map near top of basement

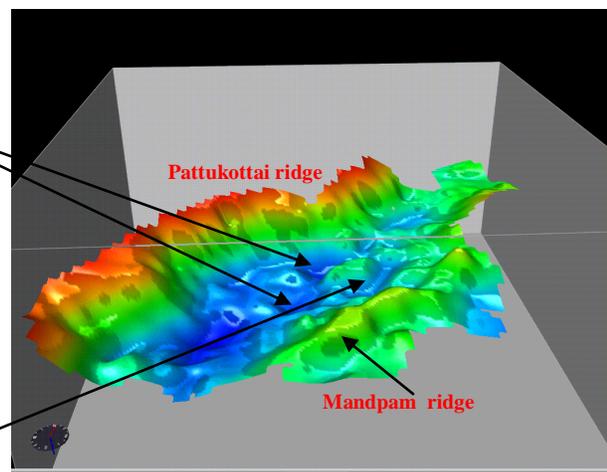
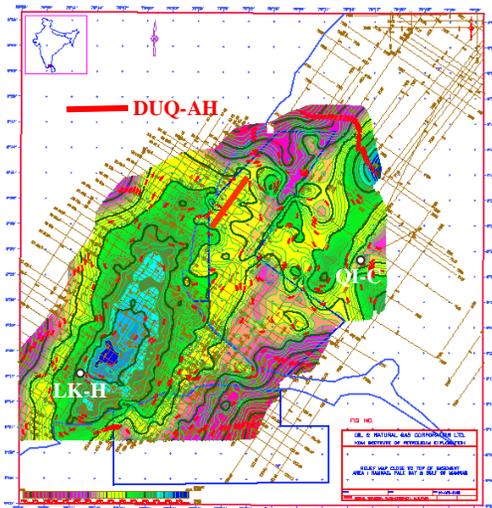
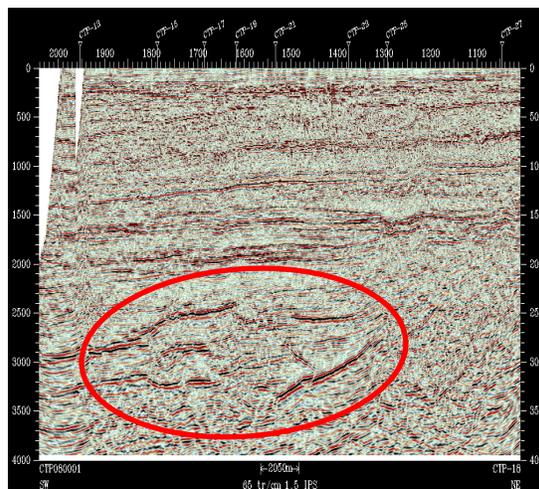


FIG. 3 : 3D view at basement level

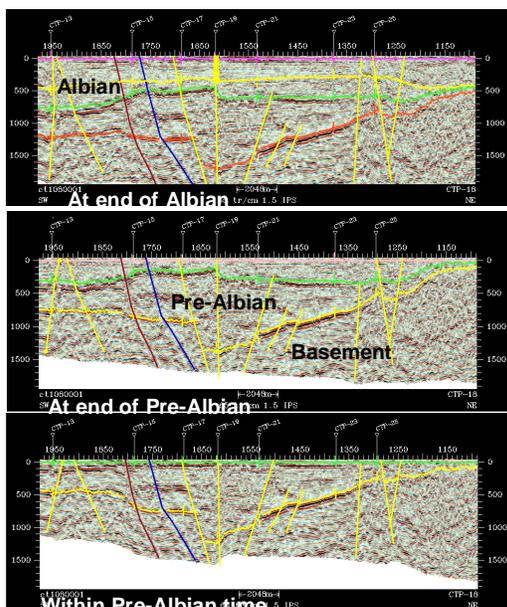
The map on a reflector within Pre-Albian, (Fig. 4 ), brings out major change from the basement level. The bigger Ramnad low, which covered an areal extent of around 550 sq.km during basin opening time, has shrunk to about 275 sq.km and the twin lows of Western Palk Bay offshore during basement level have been obliterated. The northern arm of Western Palk Bay low shows the thickest sediments. Denudation of Pattukottai Mannargudi ridge is more compared to Mandapam delft ridge indicating main sediment input from the former ridge while fragmented Mandapam delft ridge is the main provenance for Eastern Palk Bay low.



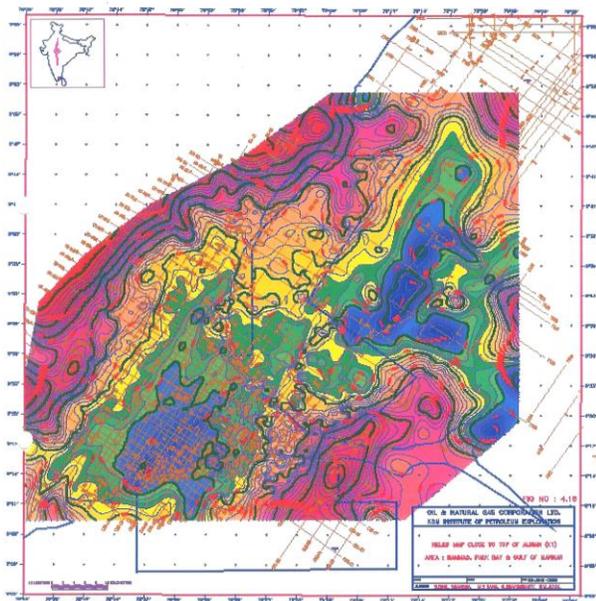
**FIG. 4 : Relief map on a reflector within Pre- Albian**



**FIG. 5 : Pre-Albian Inversion on line DUQ-AH**



**FIG. 6 : Paleo\_tectonic analysis on seismic line DUQ-AH**



**FIG. 7 : Relief map near top of Albian**

An inversion related structural feature was observed on the seismic line DUQ-AH within Pre-Albian level of Palk Bay offshore (fig-5). High rate of sedimentation from north-western side coupled with non activity of basin opening fault (sedimentation rate > accommodation space) has triggered the selective reactivation of basin opening normal faults resulting Pre-Albian inversion. The paleotectonic analysis (fig-6) also confirmed inversion exhibiting an inverted high trend.

The reactivation of older normal fault in to reverse direction has taken place all along the Eastern part of Ramnad sub basin in almost North – South direction and this inverted corridor encircles the main Ramnad low to the east and southeast, takes a swing in NW direction bordering the West Palk Bay low.

The shallow, linear Eastern Palk Bay low during basement level got its prominence during Albian time (fig-7). The continued tectonic activity has drowned the substantial areas of Eastern Palk Bay. The rapid subsidence along with slow rate of sedimentation compare to other lows is being considered to deposit potential source facies.

### **1D Hydrocarbon Generation Modeling of a Synthetic Well– “PBS-west & PBS-east**

1D modeling through three synthetic wells in basinal deep, one each in Western and Eastern Palk Bay offshore and another in Ramnad low were generated with stratigraphic boundaries were converted from time to depth using VSP data of nearby wells. Ideologies were generated with the help of nearby wells and conceptualized geological model model.

Following inferences can be drawn in the modeling-

#### **Synthetic well : “Ramnad\_low” (Ramnad sub basin)**

The critical moment for onset of hydrocarbon generation (0.7% VRO) is estimated around 82 ma for Pre-Albian sediments whereas critical moment for wet gas & condensate i.e. VRo 1.3 % is estimated at 20 m.a. for Pre-Albian sediments.

#### **Synthetic well : “PBS\_west” (Palk Bay offshore)**

The computed VRo & temperature at the bottom of sedimentary column worked out to be 1.1 % & 142°C. The Pre-Albian sediment entered adequate hydrocarbon generation maturity level (0.7% VRo) at the depth of ~4100m ( critical time-59 m.a.) and it is estimated 2.4 mg hydrocarbon/g rock (includes C6 & gas) has been expelled from the Pre-Albian sediments. About 62% of OM has been transformed in to hydrocarbons. However, no hydrocarbon expulsion is observed from Albian and post Albian sediments.

#### **Synthetic well : “PBS\_east” (Palk Bay offshore)**

The computed VRo & temperature at the bottom of sedimentary column to be 1.1 % & 142°C respectively. The Pre-Albian and Albian sediment entered in to hydrocarbon generation maturity (0.7% VRo) at the depth of ~4000m (critical time-58m.a) and it is estimated 5.8 mg hydrocarbon/g rock (includes C6 & gas)has been expelled from the Pre-Albian sediments.About 59% of OM has been transformed in to hydrocarbon.

The abundant mature Valangian source sequence in recently drilled LK-H well and also in wells OL-A, LP-A, SW-A & D in Ramnad area led us to infer the presence of Pre-Albian source component in West Palk Bay low also. Thus the Western Palk Bay low are bordered by inverted structures which would be the first locale to receive the expelled hydrocarbons.

Again the source facies within Albian sediments in QI-C well near East Palk Bay low surmise the presence of good amount of source rock in Pre-Albian and Albian sediments in Eastern Palk Bay low. Tracking down the analogy of hydrocarbon occurrence of different sub basins of Cauvery basin, the gentler slope to the west of Eastern Palk Bay low have merits for exploration (fig-2).

### **Conclusion**

The integrated Basement map has brought out the total basin configuration. The depocenters at the time of Basement, Pre-Albian and Albian time have revealed the distribution of source rock facies i.e Pre-Albian to Albian source for Eastern Palk Bay derived from Mandapam –Delft ridge and Pre-Albian source for West Palk Bay low derived from Pattukottai Mannargudi ridge. The N – S main hydrocarbon fairway in the Ramnad sub basin swings towards NW in to Western Palk Bay offshore which also experienced Pre-Albian inversion. This inverted corridor adjoining West Palk Bay low as well the gentle flank of Eastern Palk Bay low may establish more HC bearing structures in this sub basin.

### **Acknowledgment**

The authors express their sincere thanks to Sh. P.K.Bhowmick, E.D –HOI, KDMIPE for his encouragement to carry out the study. The authors also express their sincere thanks to Dr. Anil Bhandari GGM & Head BRG and Mrs Shipra Bhagawani, G.M (Geology) for their constant guidance and technical suggestions. We sincerely thank the authors of various reports referred during this study.

### **References**

1. Chandan Chakraborty, S.Chandra,M.S.Rana, B.M.Jewel &N.D.Gideon:2006 Submarine canyon and channel filled Kamalapuram formation: a new play in Ramnad subbasin, cauvery basin, SPG,Kolkata.
2. Juyal.B.M, C.Chakraborty, M.S.Rana & Sushil Chandra : Re-Evaluation of Palk Bay, Gulf of Mannar and adjoining areas to assess the hydrocarbon potential of KMP, NLM, BVG & AND. Formations in light of recent drilled wells, 2005. An unpublished ONGC report.
3. Lowell.,J.D. Mechanics of basin inversion from worldwide examples. P-39-57 Geol. Society special publication no-88 edited by James.G. Buchman and Peter.G.Buchman. 1995 Kalyansunder.R., Vijaylakshmi,K.G., Paleogeography of Cauvery Basin. - An unpublished ONGC report.
4. Kingston., J. Cauvery basin: Evaluation & Exploration Recommendation,1996. An unpublished ONGC report
5. Mahesh Chandra, Pateria,M.L. , Jaya Kumar, I., Srinivas.D., Awasthi,A.K., 1989, Integrated Geological and Geophysical studies for reassessment of prospects of Palk Bay area in Cauvery Basin. - An unpublished ONGC report.
6. PS CUBE report OF Cauvery Basin,2007 - An unpublished ONGC report.
7. Samanta,U., Pandey,B.K., 1997, Evaluation and mapping of source rock of Ramnad sub basin, Cauvery Basin. - An unpublished ONGC report
8. S.G.K.Mohan., Gita Singh., S.P.Sharma., S.K.R.Moulick & J. Baral : Tectonic evolution & sequence stratigraphy of Cretaceous sediments in Ramnad sub basin, Cauvery basin.1999. An unpublished ONGC report.
9. Sibson, R.H., Selective fault reactivation during basin inversion: potential for fluid redistribution through fault- valve action. P-3-19, Geol. Society special publication no-88 edited by James.G. Buchman and Peter.G.Buchman. 1995

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