

# **Paradigm Shift in Exploration Strategy: Identification of Prospective Corridors in Ramnad- Palk Bay Sub Basin, Cauvery Basin, India\***

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## **Abstract**

The basin architecture of Ramnad sub basin of Cauvery basin in the Pre-Albian and Post-Albian set up has 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 hydrocarbon-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 5,000 m at their respective deepest part, ranging in age from Lower 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

structurisation 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 hydrocarbon 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 and Pre-Albian sediments of East Palk Bay low entered hydrocarbon generation stage (0.7 VRo) at 59 mybp and 58 mybp 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 the Jurassic rift of the east coast of India. Taphrogenetic fragmentation of Archean basement because 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 horsts (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 are bounded by Pattukottai ridge to the west and Mandapam-Delft ridge towards the east ([Figure 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 the 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 indicates that the sediments within Andimadam Formation (main source rock) in Ramnad sub basin have achieved the end of oil generation maturation stage.

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 isochronopach 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?, [Figure 2](#) and [Figure 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.

The map on a reflector within Pre-Albian, ([Figure 4](#)), brings out major change from the basement level. The bigger Ramnad low, which covered an areal extent of around 550 km<sup>2</sup> during basin opening time, has shrunk to about 275 km<sup>2</sup> 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.

An inversion related structural feature was observed on the seismic line DUQ-AH within Pre-Albian level of Palk Bay offshore (Figure 5). High rate of sedimentation from northwestern 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 (Figure 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 (Figure 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.

#### 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 and condensate i.e. VRO 1.3 % is estimated at 20 ma 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 % and 142°C. The Pre-Albian sediment entered adequate hydrocarbon generation maturity level (0.7% VRO) at the depth of ~4,100 m (critical time-59 ma) and it is estimated 2.4 mg hydrocarbon/g rock (includes C6 and 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 and temperature at the bottom of sedimentary column is 1.1 % and 142°C respectively. The Pre-Albian and Albian sediment entered in to hydrocarbon generation maturity (0.7% VRo) at the depth of ~4,000 m (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 in wells OL-A, LP-A, SW-A and D in Ramnad area led us to infer the presence of Pre-Albian source component in West Palk Bay low also. Thus, the Western Polk Bay low is 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 ([Figure 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.

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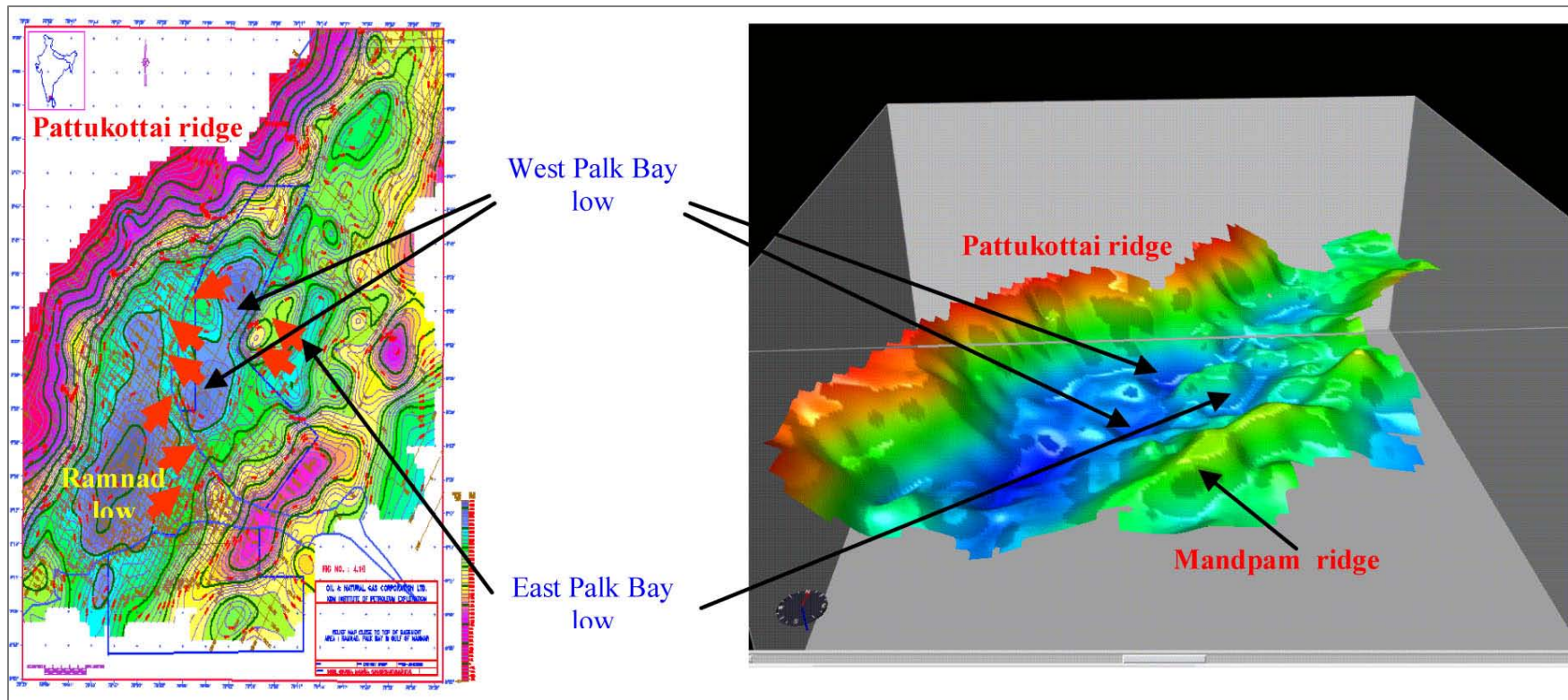


Figure 2. Relief map near top of basement.

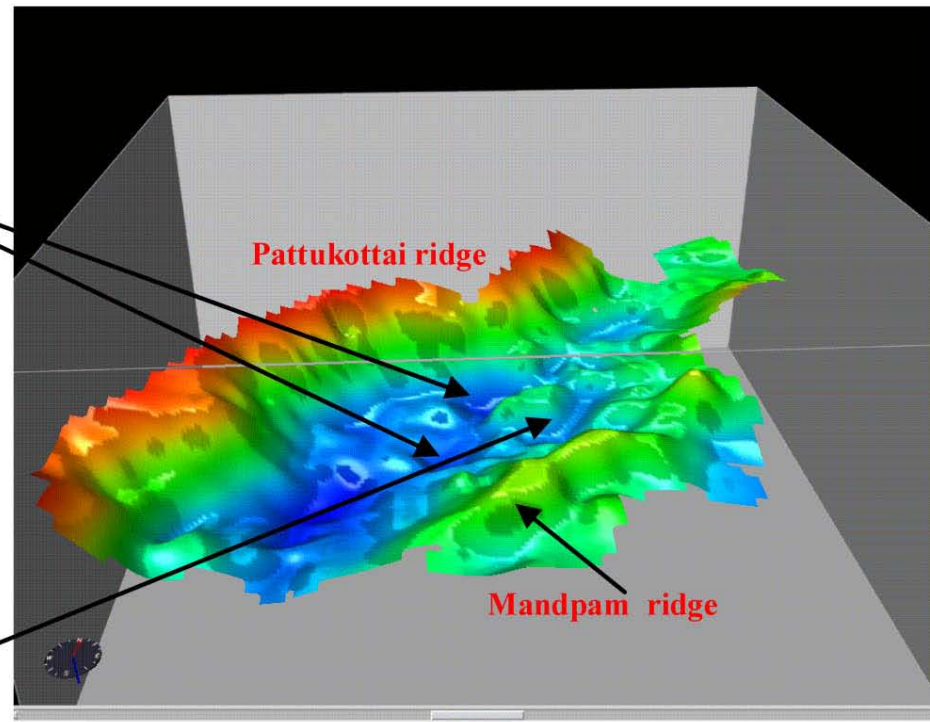


Figure 3. 3D view at basement level.

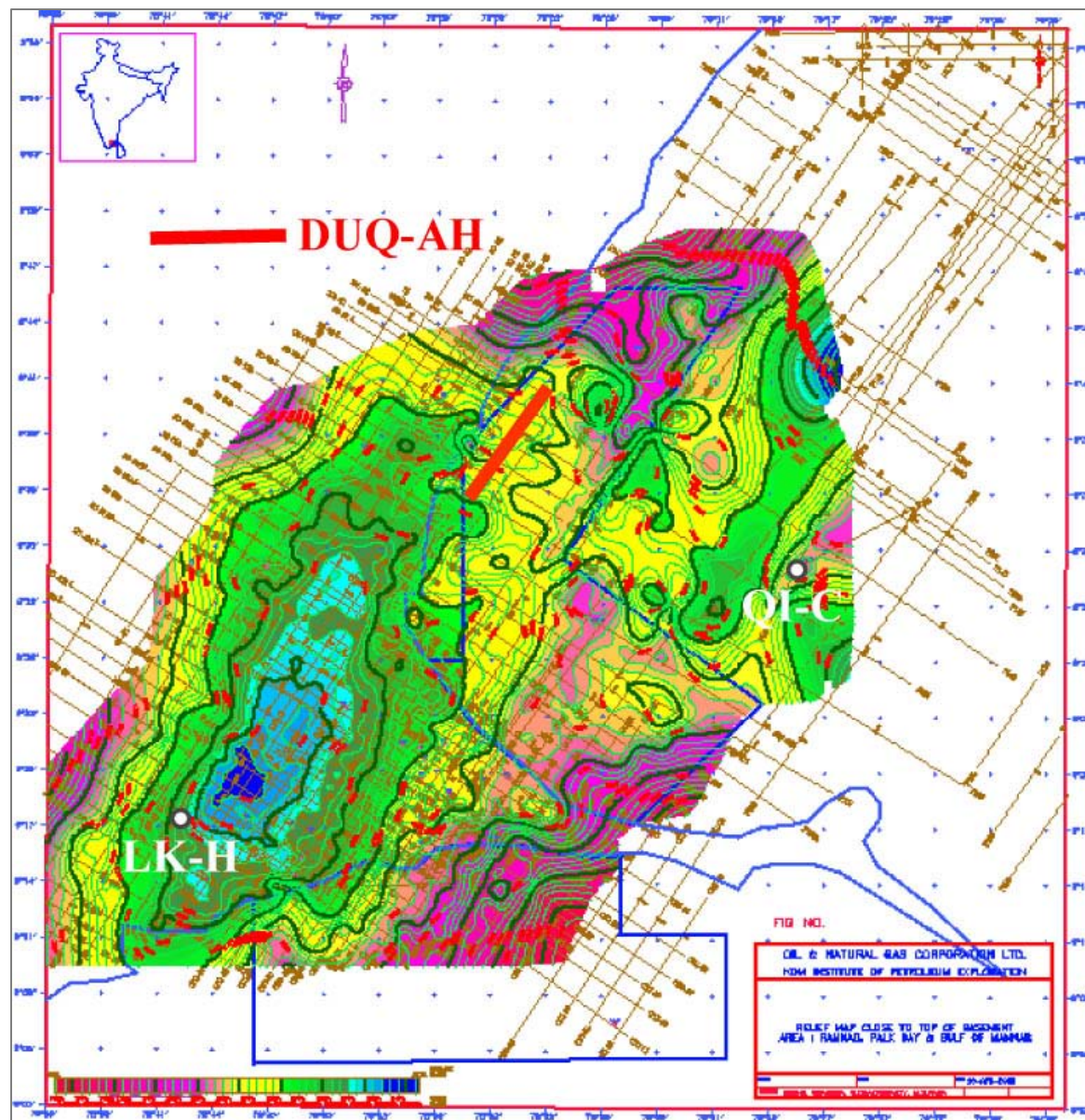


Figure 4. Relief map on a reflector within Pre-Albian.

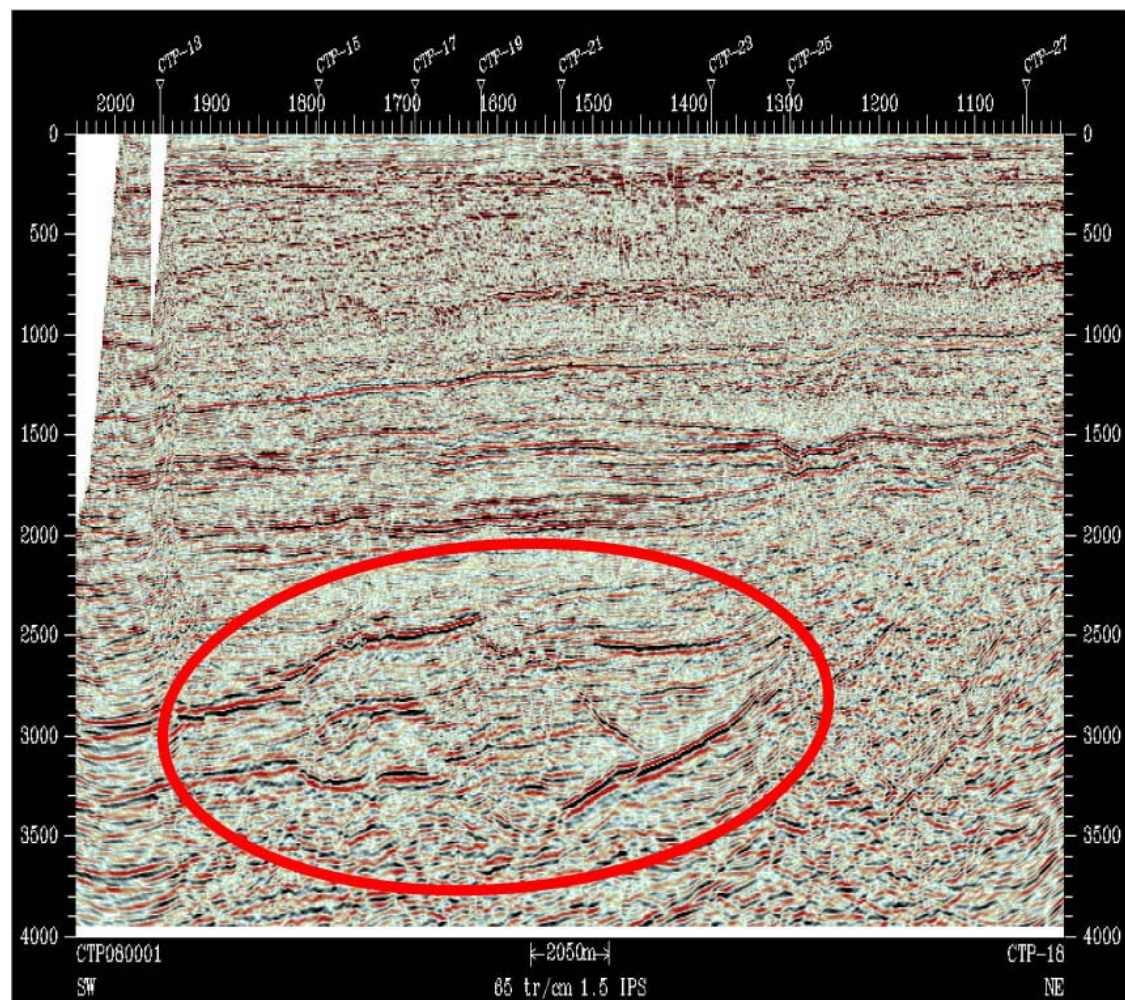


Figure 5. Pre-Albian Inversion on line DUQ-AH.

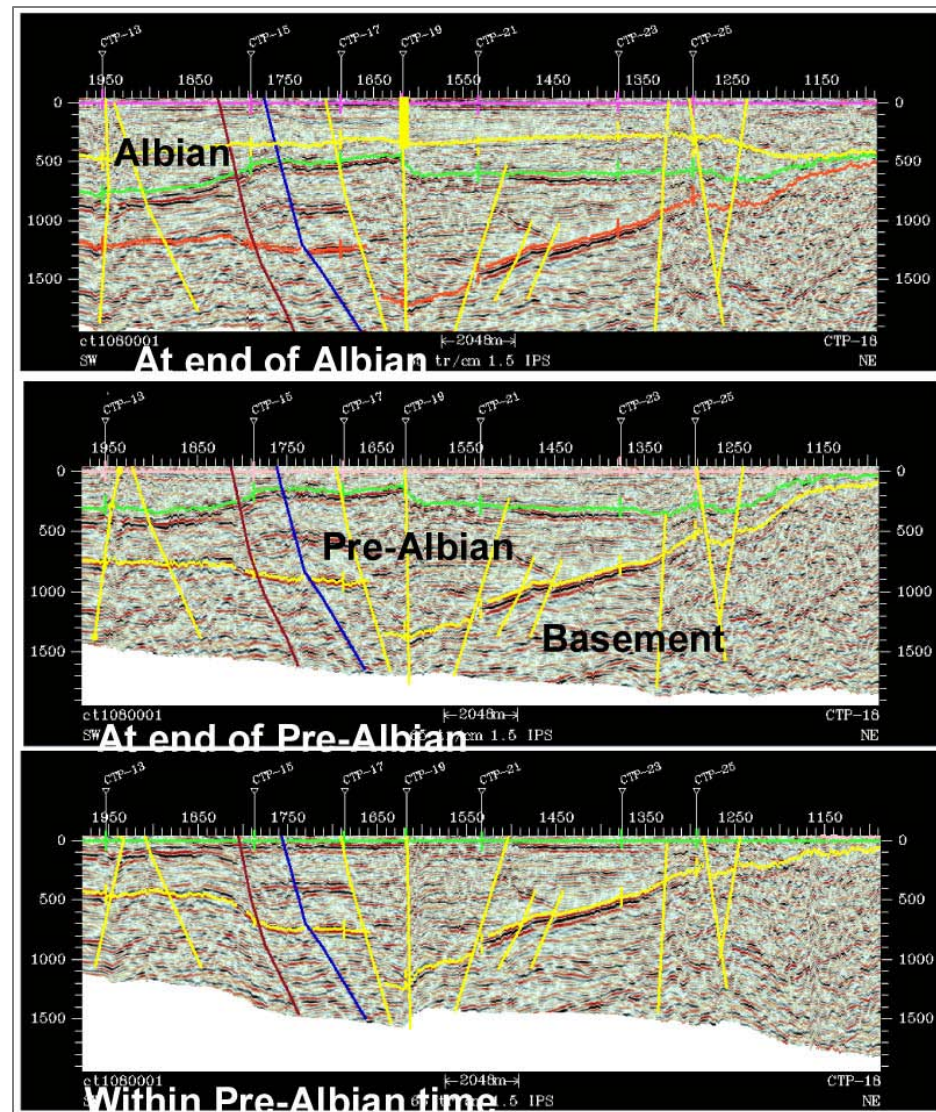


Figure 6. Paleo-tectonic analysis on seismic line DUQ-AH.

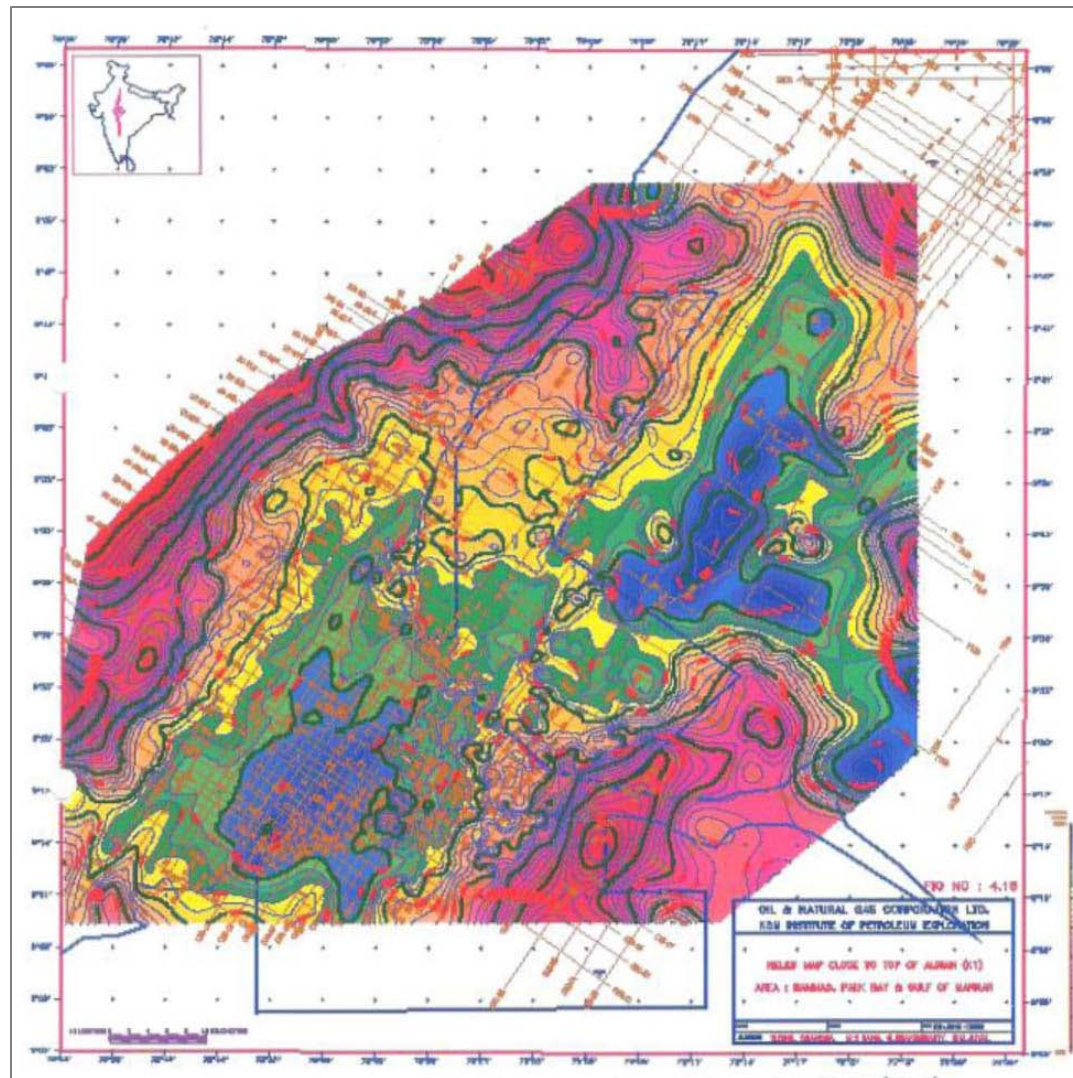


Figure 7. Relief map near top of Albion.

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		Tiruppundi Fm.	200-400
Paleocene		Pandanallur Fm.	200-600
		Karaikal Shale	
		Kamalapuram Fm.	200-800
Cretaceous	Upper	Portonovo Shale	800-1700
		Nannilam Fm.	
		Kudavasal Shale	
		Bhuvanagiri Fm.	
	Lower	Sattapadi Shale	800-1300
		Andimadam Fm.	
Archean		Basement	

Table 1. Stratigraphy of Ramnad Sub basin.