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# Paleogeographic Reconstruction from Oxfordian to Albian of Cauvery Basin, India

*H. S. Aswal* and A. Poovendan*
Regional Geoscience Laboratories, Cauvery Basin
Oil and Natural Gas Corporation Limited, Chennai, India
Email Id: aswalhs@gmail.com

**Keywords**
Paleogeography, Ariyalur-Pondicherry (A-P), Organic Matter (OM)

**Summary**

The Cauvery Basin is a pericratonic rift basin situated along the south eastern part of Indian peninsula. With exploration shifting focus to synrift sediments, there is a greater need to understand the reservoir depocentres and source facies distribution. The present study was taken up with the objective of reconstructing the stage wise paleogeographic maps of the synrift sediments from Oxfordian to Albian. The study is based on depositional environments inferred from palynofloral associations, corroborated with lithological attributes and electro log motifs.

The paleogeographic maps suggest during early period of rifting through Oxfordian, five main depocentres corresponding to Ariyalur-Pondicherry (A-P), Tranquebar, Nagapattinam, Tanjore and Ramnad sub basins were present as localized lows. The A-P and Ramnad sub basins were under the marine influence in shallow marine setup. The Tranquebar and Nagapattinam were localized lakes while the Tanjore was an isolated inland basin. The sedimentation initially was controlled by progradation and aggradation processes under low stand normal regressive setup. From Kimmeridgian the low stand normal regressive setup paved the way for the sedimentary processes represented by retrogradation and aggradation in an overall transgressive setup resulting in deposition of more than 2000m of thick sediments during the synrift phase ending in Albian. Tranquebar and Nagapattinam depocenters merged during the transgressive phase in Kimmeridgian. The A-P, Tranquebar, Nagapattinam and Tanjore sub basins came together and merged in Valanginian, while Ramnad sub basin fused with the other sub basins during Hauterivian period. The rising sea level resulted in establishing open marine conditions by Albian.

From the exploration perspective study suggest Oxfordian-Kimmeridgian sediments in Tranquebar, Nagapattinam and Tanjore subbasins are deposited under lacustrine setup, where highly carbonaceous shales may prove to be good source rocks.

## Introduction

The paleogeographic and paleobathymetric maps provide effective tools to explorationists to identify sediment provenance, depocentres of source and reservoir facies. They also present insights into the temporal and spatial juxtaposition of the various play elements within a basin and the dynamics responsible, and predictions of extension of play elements beyond areas of available data (Quallington, 2011)

The key paradigm that underpins the mapping of these paleogeographic reconstructions is that of contemporary base level; depositional areas within which paleoenvironment and lithology's are mapped; and terrains above base level where erosion has taken place (clastic source areas).

## Objectives

The objective of the study is reconstruction of stage wise Paleogeographic maps from Oxfordian to Albian.

## Approach

The study started with selection of representative wells of entire Synrift sediments and construction of profiles with collection of available Palynological data and basement structure map. Generation of new data and interpretation of depositional environments and corroboration of interpreted depositional environment with electro log and Sedimentological data to be carried out. Transfer of interpreted depositional environment on structure map at the top of basement and establishing the relationship of changing rift phases with the depositional environment. Sedimentary processes and process sedimentology is understood through the basic principles of sequence stratigraphy. Finally the identification of sediment source and depocenters in Cauvery Basin with respect to deposition of source and reservoir facies has been attempted.

## Present Work

For the present study five strike profiles and thirteen dip profiles have been have been constructed (Fig. 1).

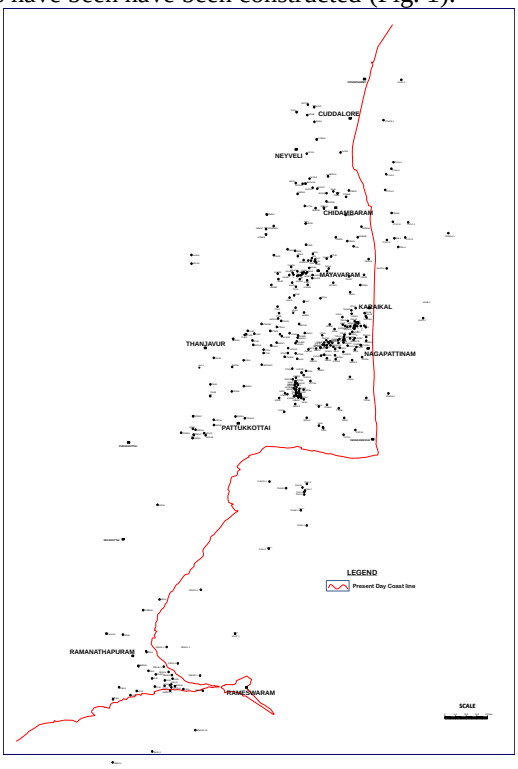


*Fig. 1 Location map of studied wells*

**Oxfordian (163.5 -157.34 Ma):**

The Paleogeographic map suggests presence of five independent depocentres during Oxfordian. These five depocentres corresponds to the five sub basins i.e. Ariyalur-Pondicherry (A-P), Tranquebar, Nagapattinam, Tanjore and Ramnad sub basins. The Oxfordian sediments are represented by shales and sandstone deposited under fluvio-lacustrine to shallow marine conditions. The palynofloral association suggest that the A-P and Ramnad depocenters were under marine influence suggested by Palynofossil assemblage showing dominance of chorate dinoflagellate cysts indicative of marginal marine high energy conditions. These marine sediments have been recorded from BVG-AA, AB, KMR-A, VL-A, KJ-H, and PE-H wells. The deposition took place under low stand normal regressive setup (LST-NR).

The Tranquebar and Nagapattinam depocentres were inland lakes. The lithological attributes comprised lacustrine shales and silty sands, fine to coarse grained sediments with lithic fragments. The Tanjore depocentre was an independent inland sub basin where the sediments sourced from the surrounding highs in a continental/lacustrine setup. The OM is mainly represented by algal mats. The sediments are highly carbonaceous shales with plant impressions, at places coaly. The paleo shore line restricted to A-P and Ramnad areas as brought out in Fig. 2.

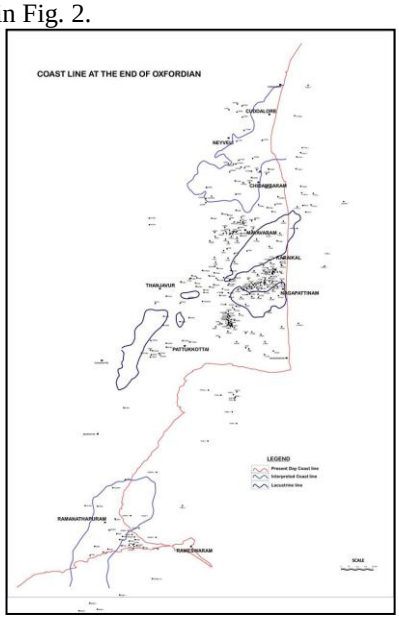


*Fig. 2 Paleogeographic reconstruction at the top of Oxfordian*

**Kimmeridgian (157.3-152.1 Ma):**

The paleogeographic map (Fig. 3) suggests that the LST-NR setup of Oxfordian shifted to overall transgressive (TST) mode during Late Oxfordian-Kimmeridgian. The depositional processes were controlled by retrogradation and aggradation. The sea level rise resulted in submergence of more areas in A-P and Ramnad sub basins. The palynofloral assemblage suggests increased marine influence.

The sea level rise resulted in convergence of Tranquebar and Nagapattinam depocentres. Tranquebar subbasin came under tidal influence and slowly turned to lagoonal setup. The lithological attributes comprised of highly carbonaceous lacustrine shale and silty sands along with lithic fragments. Tanjore remained as an independent inland depression with increased water level, deposition continued in continental / lacustrine setup. The OM mainly represented by algal filaments/mats. The retrograding Paleo shore line restricted to A-P and Ramnad Sub basin as represented in Fig. 8. In A-P and Ramnad subbasins, the deposition took place under the shallow marine setup mainly in back shore, fore shore and shore face environment.

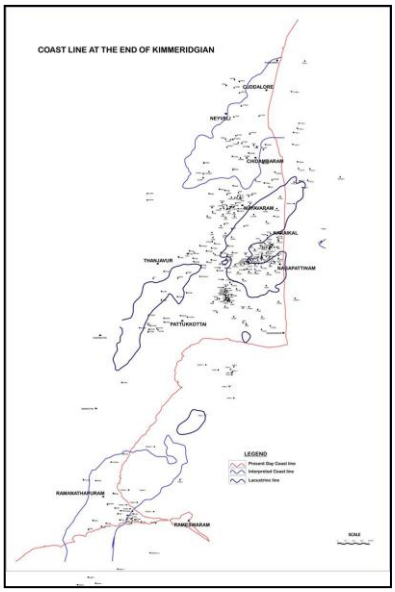


*Fig. 3 Paleogeographic reconstruction at the top of Kimmeridgian*

**Tithonian (152.1- 145.0Ma):**

The Paleogeographic map at the top of Tithonian (Fig. 4) suggests that the overall transgressive setup continued in Tithonian. Further rise in sea level resulted in submergence of more areas in A-P and Ramnad subbasins as suggested by Palynofloral assemblage.

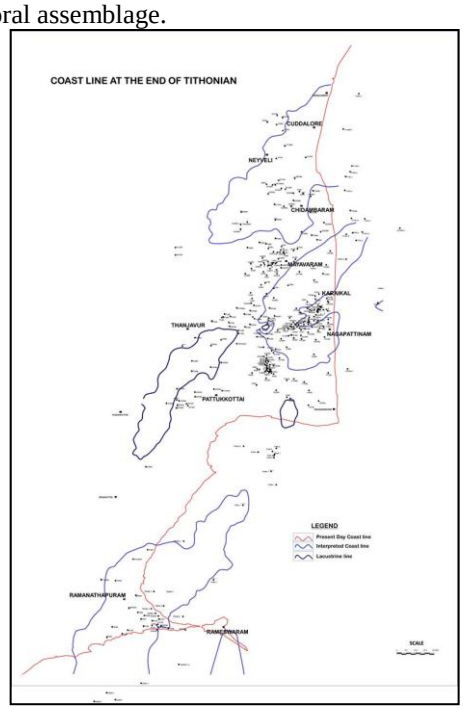


*Fig.4 Paleogeographic reconstruction at the top of Tithonian*

The expanding coast line submerged more areas in Karaikal and Madnam highs. Tranquebar-Nagapattinam

subbasins remained as inland lakes with brackish water influence i.e. a lagoonal type set up. Tranquebar depression got connected with the oceanic realm from E and NE. Lithological attributes comprised of lacustrine shale and silty sands in deeper settings while in marginal marine areas are coarser clastics. During Tithonian Tanjore depocentre remained an inland basin.

The palynoflora also suggest that the paleoshore line during Tithonian still restricted to Ariyalur-Pondicherry and Ramnad Sub basin as represented in the Fig. 4, moved inland submerging more area and deposition took place under shore face, fore shore and back shore environment.

**Berriasian (145.0-139.8 ± 3.0 Ma):**

The paleogeographic map (Fig. 5) suggests main five independent depocentres remained as the main centres for deposition. The overall transgressive phase continued in late Tithonian - Berriasian and resulted in submergence of more areas in A-P, Tranquebar, Nagapattinam and Ramnad sub basins. Sedimentary processes continued to be controlled by overall transgression of shore line. High marine influence indicated by palynofloral assemblage.

In Tranquebar and Nagapattinam depocentres the increasing water level covered more areas in Karaikal and Madanam highs towards east and also to the west towards Pattukottai - Mannargudi ridge and Pandanallur high, but still remained in lagoon setup. The lithological attributes are suggestive of finer clastics comprised of lacustrine shale and silty sands along with coarser clastics.

Tanjore depocentre remained an inland basin. The water level rose towards the west, east, NE and south. The sea level rise in evidenced by the increasing number of proximate and cavate dinoflagellate. The basin received sediments from the surrounding uplands in a continental/lacustrine setup represented by both arenaceous and argillaceous facies.

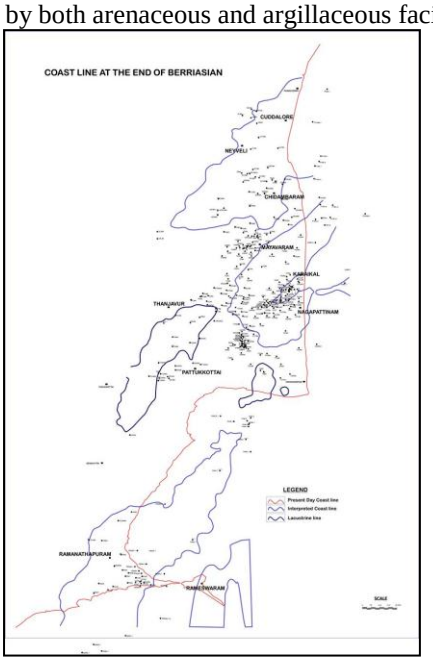


*Fig. 5 Paleogeographic reconstruction at the top of Berriasian*

The palynoflora also suggest that the paleoshore line moved inland covering A-P, Tranquebar, Nagapattinam and Ramnad sub basin areas as depicted in the Fig. 5. New areas in Ramnad sub basin like Rameswaram, Ramanathapuram areas, and Pattukotai area in Pattukotai - Mannargudi high also came under marine influence. In Tranquebar-Nagapattinam sub basins the transgression is most visible as after the convergence of these two inland lakes the coast line reached up to Kuthalam in the N, Adichapuram and Kottur in the S.

The overall depositional setup continued to be shallow marine to continental. The sediments were mainly deposited in shore face, fore shore and back shore areas. In Tanjore sub basins the sediments were mainly deposited under fluvio-lacustrine setup.

**Valanginian (139.8-132.9 Ma):**

The paleogeographic map (Fig. 6) suggests the continued transgression resulted in submergence of more areas in A-P, Tranquebar-Nagapattinam, and Ramnad subbasins. The sedimentary processes are controlled by retrogradation and aggradation resulting in overall transgression of shore line. The Valanginian transgression resulted in the connecting four depocentres viz A-P, Tranquebar, Nagapattinam, Tanjore subbasins. Due to merging of Tanjore subbasin with A-P, Tranquebar and Nagapattinam, the Tanjore subbasin started receiving the marine inputs through Nidur, Nidamangalam-Nannilam gate way along with the terrestrial input.

In the geological evolution of the Cauvery Basin these four depocentres merged for the first time. The lithological attributes comprised of both arenaceous and argillaceous facies. In A-P subbasin the coast line reached to Alinagaram in W and in S merged with Tranquebar, Nagapattinam and Tanjore subbasin. In S coast line reached to the N of Tiruturaipundi and Kattimedu area. The impact of this marine transgression in Tanjore sub basin is recorded in many wells of Vadatheru, Vadakukottai, Vettikadu and Ammapetai. In Ramnad subbasin the retrograding coast line moved inland and towards N and NE almost covered the Tulsapatnam area.

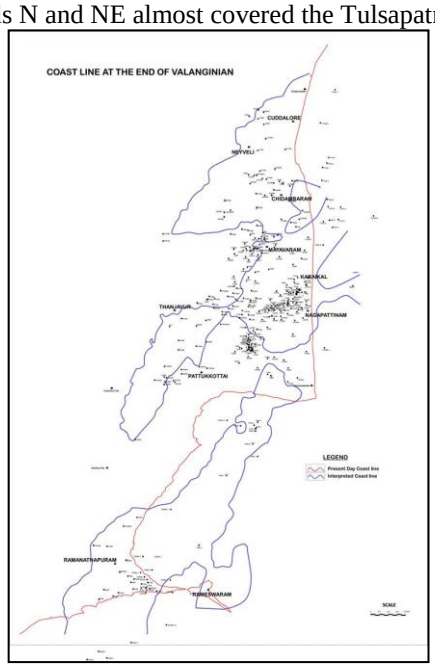


*Fig. 6 Paleogeographic reconstruction top of Valanginian*

The overall impact of this transgression is manifested by overall serrated gamma ray log signatures indicative of the fluctuations in the mean sea level. The areas under considerable water depth produced high gamma shales and in areas beyond the fore shore in lower back shore and back

shore areas have produced thick pile of coarser clastic sediments represent by blocky nature.

**Hauterivian (132.9 - 129.4 Ma):**

The map (Fig. 7) suggests Hauterivian transgression has resulted in submergence of more areas with the retrogradation and aggradation resulting in overall transgression. This Hauterivian transgression brought unification of all the five depocentres in the geological history of the Cauvery basin and turning basin into an open marine set up. The Ramnad subbasin merged with Nagapattinam sub basin through a narrow corridor. A wide spread marine influence is marked by dominance of marine phytoplanktons.

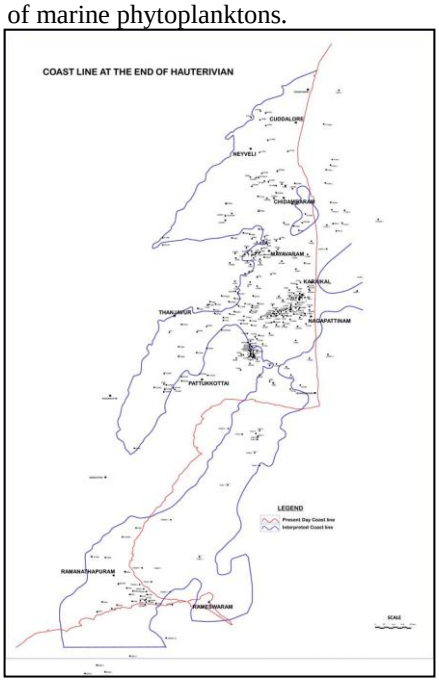


*Fig. 7 Paleogeographic reconstruction of Hauterivian*

The palynofloral assemblage suggest high energy conditions in the near shore areas while in the deeper section of the basin the calm and quieter conditions prevailing resulting in deposition of argillaceous facies. The lithological attributes are suggestive of deposition of both arenaceous and argillaceous facies and arenaceous facies. Palynoflora also suggest more inland movement of paleoshore line and submergence of more elevated area as represented in the Fig. 7. The coastline has crossed Alinagaram and Ariyalur areas in A-P, Kuthalam, Kuduvasal area in Tranquebar and Ammapetai, Jaikundam areas in Tanjore sub basin with the coastline reaching W of Neduvasal, Ennadi, and Arumulai. In Nagapattinam subbasin the coastline was along North Kovilkalappal. Nagapattinam subbasin also got connected directly with the sea. On the Karaikal high to the E of well KKL#B, E and AA narrow low saddle got submerged, while the entire high remained a positive area. Similarly the Madnam high was exposed and appeared as an island. In Ramnad sub basin more areas on Vedaranyam high came under marine influence. The dominant sedimentary processes are retrogradation and aggradation controlled by rise in base level. The overall setup remained as transgressive system tract the paleogeographic map also suggests that this rise in sea level has resulted in formation of tidal channel type setup in North Kovilkallapal and Kali-Kuthalam areas.

**Barremian (129.4-125.0 Ma):**

The paleogeographic map at the top of Barremian (Fig. 8) suggests that the main five depocentres remained as the main centres for deposition. The transgression submerged fresh areas and basin was under oceanic realm. The exposed highs are positive areas. The fluctuations of the sea level with in overall transgressive phase (within trend system tract) resulted in creation of typical serrated log signatures of Andimadam Formation. A wide spread marine influence in the basins is marked by dominance of marine phytoplanktons assemblages. The lithological attributes suggest the presence of both arenaceous and argillaceous facies. The arenaceous facies plays a major role in marginal areas whereas the argillaceous facies is dominant in deeper section.

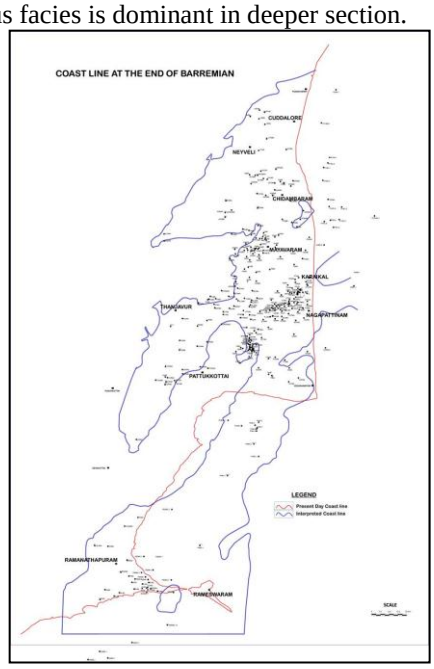


*Fig.8 Paleogeographic reconstruction of Barremian*

The paleogeographic map also suggest that the continued transgression which resulted in formation of tidal channel like setup in North Kovilkallapal and Kali-Kuthalam areas during Hauterivian prevailed during Barremian also, while the low created during Hauterivian across the Karaikal High no more exists during Barremian. The overall sedimentation controlled by the sedimentary processes representing sea level rise, sediment aggradation and retrogradation. The sediment supply to the depocentres slowed down, thick arenaceous sequence got deposited in upper fore shore to back shore areas. The Madnam high which was exposed till Hauterivian time as an Island completely submerged during Barremian.

The paleogeographic map also suggests overall marine regime prevailed. The rift and drift phase in the Cauvery Basin culminated by Hauterivian and Barremian onwards the Cauvery Basin entered in to the Sag phase where the sea level rise was controlled by sagging in the basin areas (Reeves, 2008). A recent analysis of litho- and tectono-stratigraphy in the Ariyalur outcrop of the Cauvery Basin suggests that the onset of rift-related subsidence occurred during the Barremian-Aptian and that rift related extension ceased in the Cenomanian or Turonian (Watkinson et al., 2007).

**Aptian (125.0-113 Ma):**

The paleogeographic map (Fig. 9) suggests entire basin acted as the depocentre in open marine set up, while the rise in MSL continued unabated. The sea level rise and the sagging in the basin contributed to overall transgression. The sedimentary processes are controlled by retrogradation and aggradation.

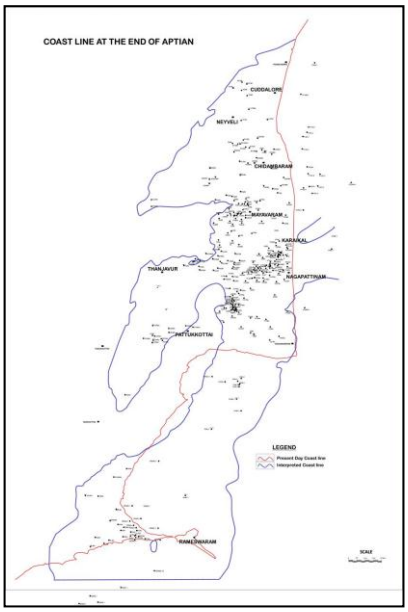


*Fig. 9 Paleogeographic reconstruction of Aptian*

The palynofloral assemblage is represented by Chorate, Proximate and Cavate cysts along with the spore-pollen assemblages. This indicates that the basin was under low to high energy conditions from deeper marine setup to the shallow marine setup. In A-P, Tranquebar and Nagapattinam subbasins the entire Pandanallur and Kuthalam field submerged. The tidal channel which was present during Hauterivian-Barremian in Kovilkalappal area also submerged and coast line in the Nagapattinam sub basin moved further west on Pattukotai-Mannargudi ridge. In A-P sub basin to the west the coast line moved beyond Alinagaram and Ariyalur. In Tanjore subbasin the coast line rose to the Pattukotai-Mannargudi ridge towards E and almost reached. Towards N the Pundi area was almost covered by the rising sea level. The area S of Vedaranyam high and Mandapam Delft ridge area submerged in the rising sea level towards Ramnad subbasin.

The paleogeographic map suggests that the Aptian transgression has a much wider impact, where more areas becoming low energy marine setup and the deeper part of the basin may be starved of sediments, as observed in the wells of Bhuvanagiri and adjoining areas. Similar conditions prevailed in other sub basins, while in the marginal areas there is an increase in the thickness of coarser clastics.

During Aptian globally a regressive phase prevailed but in Cauvery Basin due to the basin in sag phase overall transgressive phase prevailed.

**Albian (113.0-100.5 Ma):**

The paleogeographic map at the top of Albian (Fig. 10) suggests that the entire Cauvery Basin was a unified depocentre covering the outcrop areas.

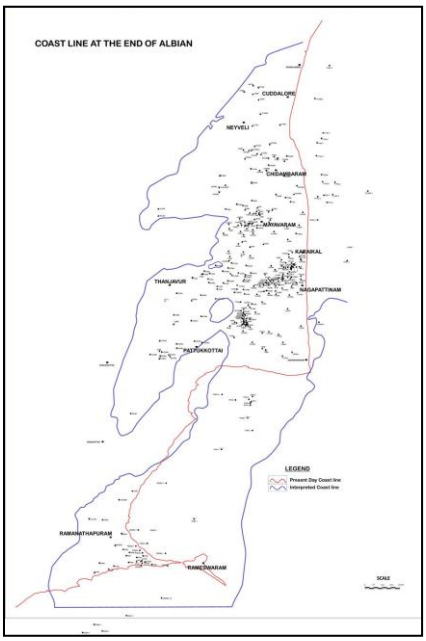


*Fig. 10 Paleogeographic reconstruction at the top of Albian*

The Albian transgression resulted in submergence of entire basin with the retrogradation of coast line and aggradation of sediments. The extent of the transgression was so extensive that the transgression covered the outcrop areas of the basin resulted in the deposition of upper part of Terani beds, Dalmiapuram Formation, Grey shale and lower part of Karai Shale.

The presence of Chorate, Proximate and Cavate cysts indicate that basin was under low to high energy conditions. The spore-pollen assemblages are also indicative of presence of fluvial / continental environment beyond marine realm.

The Albian transgression brought entire basin in open marine environment. Very few highs / positive areas remain exposed in the vicinity of Cauvery Basin. The transgression is marked by dominance of marine phytoplanktons assemblages. The palynofloral assemblage suggest high energy conditions in the near shore areas while in the deeper section of the basin the calm and quitter conditions were prevailing resulting in deposition of argillaceous facies basin wide.

The overall transgressive phase which commenced in the basin with the Oxfordian sea encroaching the basin from north in A-P subbasin and from south in Ramnad subbasin with the sedimentary processes represented by progradation and aggradation of sediments in LST-NR set up, changed to the transgressive phase (TST) reached to its maxima in Albian with overall flooding in the basin represented by MFS of Albian-Cenomanian age (Sattapadi shale). This MFS is followed by basin wide regression under high stand normal regressive (HST-NR) setup resulting in deposition of Bhuvanagiri Formation, which is mainly a coarser clastic unit of Cenomanian-Turonian age followed by Late Turonian Forced Regressive (FR) phase indicated by the basin wide Turonian unconformity.

**Conclusions**

The paleogeographic reconstruction of Cauvery Basin (synrift phase) has been brought out. Nine biostratigraphic stage wise paleogeographic maps from Oxfordian to Albian have been constructed. Paleogeographic map of Oxfordian

suggests presence of five main depocentres corresponding to present five sub basins. The Ramnad sub basin was connected with sea from south while the Ariyalur- Pondicherry sub basin was connected with the sea from east. The Tranquebar and Nagapattinam sub basin were inland lakes while Tanjore was a separate inland basin. The sedimentation in the basin was started with sedimentary processes controlled by progradation and aggradation in an overall low stand normal regressive setup. Since Kimmeridgian the low strand normal regressive setup paved the way for overall sedimentary processes controlled by aggradation and retrogradation in an overall transgressive setup. The Tranquebar and Nagapattinam lows merged with the rising sea level during Kimmeridgian and during Tithonian the Tranquebar sub basin also started getting marine influence and was connected with sea from east to north east. The Ariyalur- Pondicherry sub basin got fused with Tranquebar and Tanjore sub basin joined Nagapattinam and Tranquebar during Valanginian period with the rising sea level. The Ramnad Sub basin joined with rest of the basins in Hauterivian. Since Hauterivian the ever rising sea level, in an overall transgressive phase continued till Albian-Cenomanian and culminated with the basin wide transgression represented by Sattapadi shale, the maximum flooding surface. It is also inferred that the sediments overlying the Sattapadi Shale represented by Bhuvanagiri Formation is deposited under high stand normal regressive set up followed by forced regressive phase marked by basin wide Turonian unconformity.

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The views expressed are those of authors only.

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