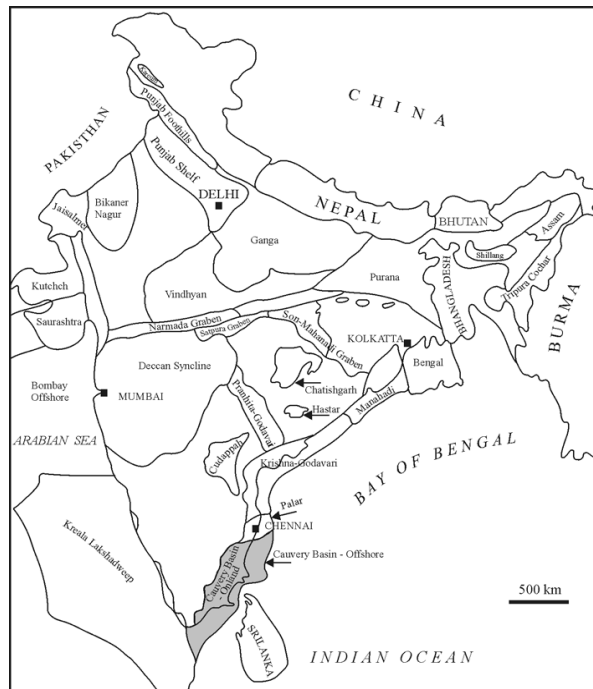


## PETROLEUM SOURCE ROCK EVALUATION OF ARGILLACEOUS SEDIMENTS IN A PART OF THE CAUVERY BASIN

### 1. INTRODUCTION

The Cauvery Basin extends along the East Coast of India, bounded by - latitudes  $8^{\circ} 30'$  and  $12^{\circ} 30'N$  and longitudes  $78^{\circ} 30'E$  and  $80^{\circ} 20'E$ . It covers an area of 1.5 lakh sq.km comprising on land (25,000 sq.km) and shallow offshore areas (30,000 sq km). In addition, there is about 95,000 sq km of deep-water offshore areas in the Cauvery Basin.



**Figure 1 Location of Cauvery basin (After Berner Z., Stuben D., Rajkumar M 2004)**

The Cauvery basin was formed during Late Jurassic time by sagging of a part of the Indian shield, mainly along the dominant northeast-southwest basement trends. The basin consists of several depressions separated from each other by subsurface basement ridges aligned parallel or sub parallel with the dominant basement trends. The sedimentation in the respective depressions was controlled by movements

along these trends since late Jurassic. The depocenters, which were mainly open toward the west during Upper Gondwana deposition, shifted toward the east as a result of general basinal tilt at the beginning of the Tertiary. These movements were responsible for repeated transgressions and regressions, as is evidenced by lithofacies, biofacies, and thickness variations, as well as by sedimentation breaks. (Berner Z., Stuben D., Rajkumar M. 2004)

This is an intracratonic basin, characterized by the following observations:

1. The basin has a linear geometry with a large length (400 km) to breadth (170 km) ratio.
2. Both the margins of the basin area bounded by basin margin faults.
3. The basin forms a high angle with the east coast margin of India and is underlain by continental crust.
4. The basement faults are generally of the gravity type with a listric character.
5. The basin has Narimanam oil field in Tertiary sediment (Oligocene age) in the Karaikal Horst. The present study is aimed to identify the possible petroleum kitchen from where the oil migrated to four parts in this field.

From the cutting and cored well data set geochemical analysis of the argillaceous sediments of Cauvery Basin by ONGC an effort has been made to evaluate argillaceous sediments of various stratigraphic units for their source to generate petroleum hydrocarbon in commercial quantity in part of Cauvery basin with the following observations

1. Evaluation of abundance of organic matter (for potential to generate commercial quantity of hydrocarbon).
2. Evaluation of quantity of organic matter to assure their parameters for generation of hydrocarbon.
3. Evaluation of thermal maturation stage of organic matter.
4. Identification of petroleum kitchen in these areas of study in space and time.

## 2 Basin Age & Sediment Thickness

- This basin is result of Gondwanaland fragmentation during drifting of India- Srilanka landmass system away from Antarctica/ Australia plate in Late Jurassic/ Early Cretaceous.
- Endowed with five to six kilometres of sediments ranging in age from Late Jurassic to Recent (mainly thick shale, sandstone & minor limestone).

### 2.1 Stratigraphy from Evolution, Sedimentation History and Depositional Environment

**Evolution of the Cauvery Basin is understood to have taken place through the following three distinct stages-**

#### A) Late Jurassic-Early Cretaceous Rift Stage, is characterized by following

- Initiations of rifting have begun during the Late Jurassic/Early Cretaceous.
- Rift stage sediments (Shivganga and Therani formations) of Upper Gondwana affinity are known from exposures.
- Deposition of sediments in fluvial environments.
- The Kallakudi Limestone, younger to the Shivganga Formation, may represent an episode of basinal deepening and paucity of clastic supply.
- In the subsurface, the Andimadam Formation, overlain by the Sattapadi Shale, appears to mark the peak of this transgressive episode during Cenomanian.

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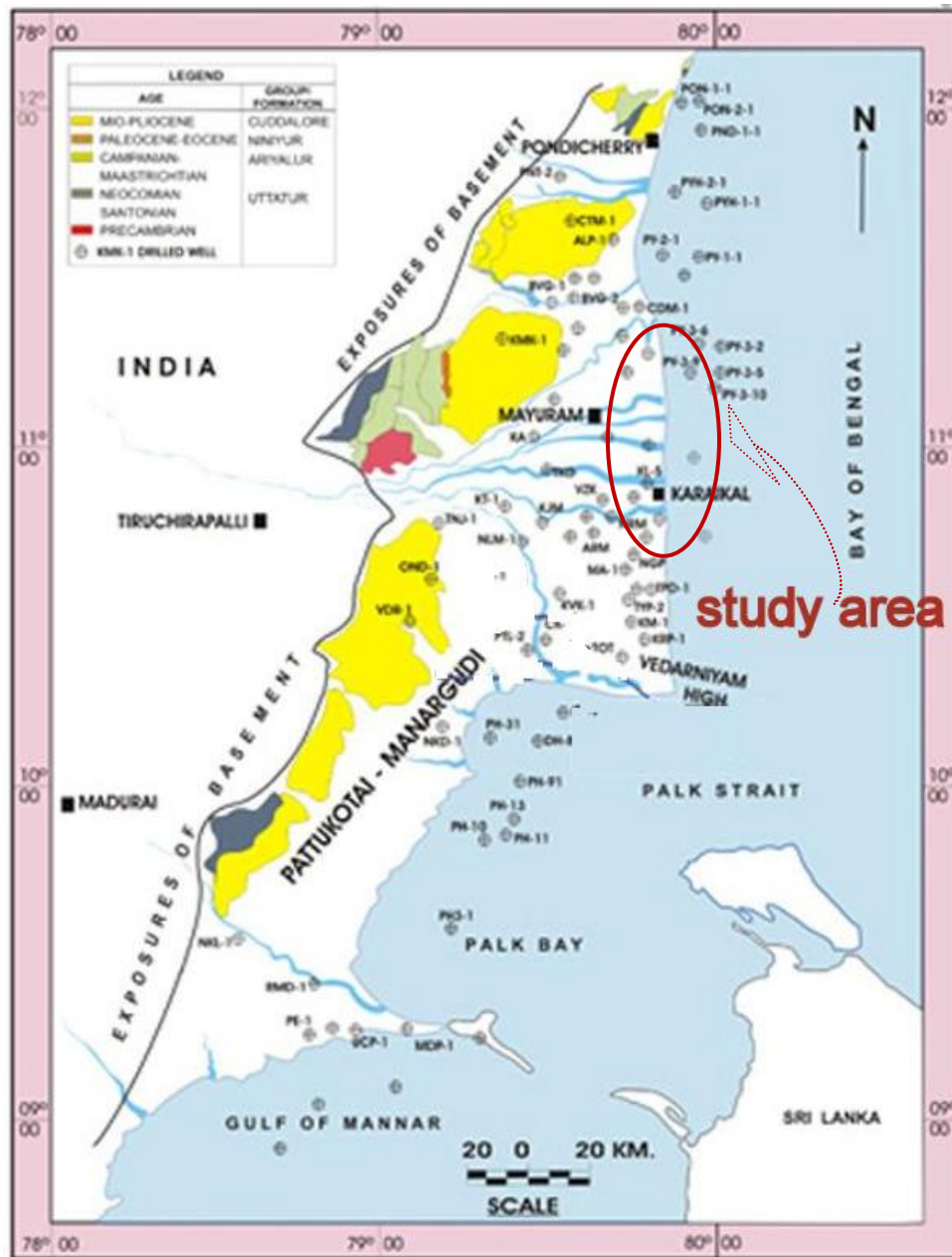


Figure 2: Geological map of Cauvery basin (After DGH 2009)

### C) Post Cretaceous

- Towards the end of the Cretaceous, the basin experienced a phase of upliftment and erosion and a gradual basin ward tilt of the shelf.
- The Tertiary sequence was deposited in a general prograding environment with gradual subsidence of the shelf.

- This sequence can be subdivided into two groups, the Nagore and Narimanam. The Nagore Group is well developed in the south, whereas the Narimanam Group attains its full development north of Karaikal High.
- The Kallakudi Limestone, younger to the Shivganga Formation, may represent an episode of basinal deepening and paucity of clastic supply.
- – By this time, Tertiary deltaic environment appears to have considerably progressed eastwards.

## 2.2 Tectonic History:-

The Cauvery Basin is an intra-cratonic rift basin, divided into a number of sub-parallel horsts and grabens, trending in a general NE-SW direction. The basin came into being as a result of fragmentation of the Gondwana land during drifting of India-SriLanka landmass system away from Antarctica/Australia continental plate in Late Jurassic / Early Cretaceous. The initial rifting caused the formation of NE-SW horst-graben features. Subsequent drifting and rotation caused the development of NW-SE cross fault.

### **The Cauvery Basin contains the following major tectonic elements**

- Ariyalur-Pondicherry Depression
- Kumbhkonam-Madnam-Portonovo High
- Tranquebar Depression
- Karaikal High
- Nagapattinam Depression
- Vedarniyam High
- Thanjavur Depression
- Pattukuttai-Manargudi Ridge
- Mandapam Ridge
- Mannar Depression
- Vedarniyam – Tiruchirapally Fault

## RESULTS AND DISCUSSION

### 3.1 Quantity of Organic Matter

Organic matter abundance has been found using the TOC values for the Cretaceous and Eocene sediments in the study area. The main characteristics are as follows:

1. The TOC values are more than the threshold value of 0.5 % in both Cretaceous and Eocene sediments.

2. TOC is rated “fair” to “good” in the Eocene sediments and “good” to “rich” in the Cretaceous sediments.
3. TOC is “fair” to “rich” in the Nagapattinam depression, the central western sub basin, North western sub basin and the Tranquebar depression.

### 3.2 Type of Organic Matter

Quality of Organic Matter has been found using the rock eval. parameters – those of HI. The main characteristics are as follows:

1. The organic matter in the Cretaceous and Eocene sediments is of the mixed type (Type III & IV) with HI value mostly below 300 in any of the basin.
2. In the Oligocene sediments, the hydrogen content of the organic matter is poor with HI values below 100 i.e. Type IV.

### 3.3 Maturity of Organic Matter

The maturity of the organic matter has been assessed using parameters of VRo %, TAI, and  $T_{max}^0$  °C. The main characteristics are as follows:

1. Oligocene and Eocene sediments are immature due to the low  $T_{max}^0$  °C (<435), VRo % (<0.6) and TAI (<2.5).
2. The organic matter in the Upper Cretaceous sediments are immature to marginally mature in the entire area as indicated by VRo % which varies between (0.45-0.60) and TAI varies between (2.25-2.7).
3. The Lower Cretaceous sediments are moderately mature to mature in Nagapattinam depression and moderately mature in the Central Western sub basin. Maturity is marginal-moderate in the North Western sub basin. In the Tranquebar depression, maturity is moderately mature to mature.
4. Thus, the Lower Cretaceous sediments (Sattapadi & Andimadam Formations) are effective source rocks and adequately mature to generate petroleum hydrocarbons.

### Petroleum Kitchens

A petroleum kitchen is designated to that geologic locale which has got organic matter optimally cooked to generate petroleum hydrocarbons of commercial value.

In the present study, the boundary conditions of TOC > 1.0 %, VRo > 0.65 and HI > 150 has been taken to locate petroleum kitchens in the study area.

Of the four petroleum kitchens in the Andimadam Formation located in Nagapattinum depression, North Western sub basin, central Western sub basin and the Traquebar depression, the one at the Nagapattinum depression is the dominant.

The number of kitchens has decreased to three in the Sattapadi formation. The north western sub basin moving out of the foray and the Nagapattinum depression being the most dominant in this formation too.

### **Proven / Expected Play Types**

- Structural and combination traps in Early Cretaceous to Paleocene sequences.
- Stratigraphic traps such as pinch-outs / wedge-outs and lenticular sand bodies in Early to Late Cretaceous sequences.

**Table 1 Expected play types in a part of Cauvery Basin**

Source	Sattapadi shale within Cretaceous– main source Kudavasal Shale within Cretaceous Basal part of Kamalapuram Fm (Paleocene).
Reservoir	Andimadam, Bhuvanagiri & Nannilam Formations within Cretaceous Kamalapuram and Niravi Formations within Paleocene Precambrian Fractured Basement.
Cap Rock	Sattapadi shale within Cretaceous Post unconformity shales like Kudavasal and Kamalapuram.
Entrapment	Structural/ Stratigraphic, Combination traps.

### **Source Rock Evaluation**

#### **Andimadam Formation (Pre-Albian to early Albian)**

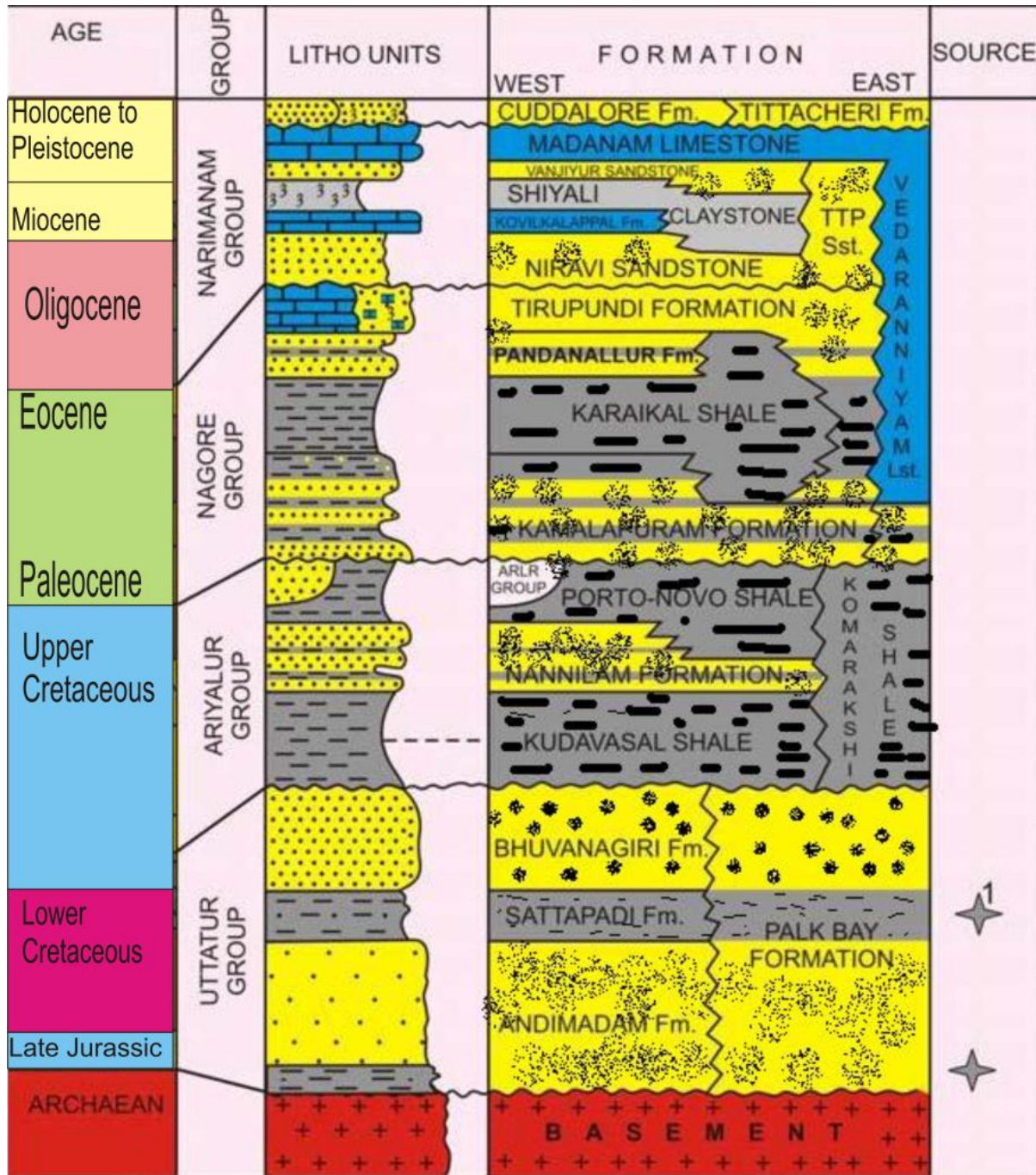
This oldest Cretaceous unit found in various depression, has been analysed for its source rock features as given below:

Good source rock characteristics are indicated in the Nagapattinum Depression with TOC values ranging in 1.9-2.4 %. TOC ranges from 1.5-2.0 % in the Central Western Basin and decreases towards southwest

of this sub basin. The TOC in North Western Sub basin ranges from 1.5-2.0 % and decreases towards west and in Tranquebar Depression where the TOC is 1.5%.

An average HI value of 200 units is found only in the Nagapattinum Depression and nearby areas. In the Central Western sub basin HI values ranges between 100-150 units and the quality of organic matter deteriorates towards the south western part of this sub basin. In the North Western sub basin and the Tranquebar Depression HI values are around 100 units and decreases towards the west of the North Western sub basin. Inferences are drawn on this basis that good source rock characteristics are indicated in the Nagapattinum Depression, central Western sub basin, North Western and Tranquebar Depression.





**Figure 3 Petroleum System and Generalized Stratigraphy (source DGH)**

The argillaceous sediments of the Andimadam formation are moderately mature to mature. To generate petroleum hydrocarbon in Nagapattinum Depression VRo % is about(0.75-0.85 %) and TAI is about (2.7-2.85), Central western sub Basin VRo % is about(0.70-0.75 %) and TAI is about (2.7-2.75), North Western Sub Basin VRo % is about(0.65-0.75 %) and TAI is about (2.65-2.75). In Tranquebar

Depression the VRo % is about 0.85% and TAI is about 2.85. So the maturity decreases towards North Western sub basin.

### **Sattapadi Formation (Albian to Cenomanian)**

The TOC ranges of (0.6-6.1 %), these sediments can be rated as fair to good. In the Nagapattinam Depression and Central Western Sub Basin, TOC is on an average of about 2.0 %, which indicates good source rock characteristics. Rich potential is indicated in the western part of the North Western Sub Basin with TOC around 3 %.

Average HI values in Nagapattinam Depression and Central Western Sub Basin are about 100-125 units. Richness of hydrocarbon in organic matter decreases towards south of Central Western Sub Basin, in the North Western Sub Basin and the Tranquebar Depression. It is inferred that the Sattapadi Formation in Nagapattinam Depression, Central Western Sub Basin and North Western Sub Basin has good source rock potential.

Vitrinite Reflectance ranges from 0.7-0.74 % in the Nagapattinam Depression indicating moderate maturation level. In the Central Western Basin, the VRo of 0.61-0.68 % indicates early to moderate maturity of the organic matter. The sediments in and North Western Sub Basin are just matured (VRo - 0.55 %). However the sediments are moderately mature (VRo - 0.715) in the Tranquebar depression. It is therefore inferred that the shales of Sattapadi formation are matured to generate oil/gas and form petroleum kitchen around Karaikal Horst at Nagapattinam Depression in the south, Tranquebar Depression in the North and Central Western sub basins in the west.

### **Bhuvanagiri Formation (Turonian to Coniacian)**

The Bhuvanagiri Formation is good for TOC %(1-2%) content but it has no potential to generate hydrocarbon which is immature in terms of VRo %(<0.65) and TAI value(2.25-2.7). The HI value ranges between (10-195) units. Thus it may form thus form small petroleum kitchen in patches.

### **Kudavasal Formation (Santonian to Campanian)**

The majority areas of all the basins are found to be below average value 100 units of HI which indicates the whole formation have little potential to generate hydrocarbon. The highest value found to be 162 units from Nagapattinam depression. The content in the Nagapattinam Depression and adjacent area to the north is Moderate to good. Thus it indicates good rock characteristics in which TOC range from 0.8-1.4 %. So the Kudavasal formation is immature in terms of Vitrinite reflectance(0.45-0.5%) and TAI (2.25).

Petroleum kitchen areas are not expected in the regions in the view of thermal immaturity of organic matter in this formation.

### **Kamalapuram and Tiruppundi Formation (Eocene)**

The argillaceous sediments of the Eocene sequence have sufficient organic matter (TOC range 1.0-5.5 %). The maximum concentration of organic matter is found in central western sub basin and adjacent flanks of Karikal horst(3-4 %). In Nagapattinum Depression it varies from 2-3 %.

Towards Tranquebar depression and North Western sub-basin, TOC concentration decreases, but is more than 0.5 % (threshold ) everywhere. The HI values range from 29-156 units. HI values of 100-150 units are found only in Central Western part whereas in other parts of the study area HI decreases.  $T_{max}^0c$  (375-525)  $^0c$  TAI<2.25 and VRo% (<0.55) indicate that the organic matter in the shales of Eocene is also immature to generate petroleum hydrocarbons commercially and no kitchen is indicated.

### **Niravi Formation (Oligocene)**

The maximum concentration of organic matter is found in North Western Sub basin and Karikal horst. (TOC values range from 2-3 %). So it is good. The highest value of HI is 71 units near Karaikal Horst and other areas have lower value than this unit. So technically the whole area has no potential to generate hydrocarbon in this formation.  $T_{max}^0c$  ranges from 325-425 $^0c$ , i.e. less than 430 $^0c$  , TAI <2.25, VRo <0.4 % thus indicating immaturity of organic matter in all sub basins. No kitchen in this formation in any sub basin is found.

## **4. Conclusions of the Source Rock Evaluation**

The organic matter in the Upper Cretaceous sediments is immature to marginally mature in the entire area. The Lower Cretaceous sediments are moderately mature to mature in the Nagapattinum Depression and marginally to moderately mature in Central Western sub basin. The maturity in North western sub basin is marginal. In the Tranquebar Depression, the organic matter is moderately mature. Thus, Lower Cretaceous sediments (Sattapadi and Andimadam Formations) have been identified as effective source rocks and are adequately matures to generate petroleum hydrocarbons.

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