

# **Palynostratigraphy and Depositional Environment of Cambay and Olpad Formations in Nawagam - Asmali Area, Cambay Basin, India\***

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## **Abstract**

The area of present study covers Nawagam, Naika, Mahelaj, Dholka and Asmali Fields in the Ahmedabad Block of Cambay Basin. A number of hydrocarbon discoveries in this block hold promise for exploration of pay sands of Olpad and Cambay Formations. The wells have been drilled to explore the hydrocarbon prospects of Deccan Trap, Olpad, and Cambay Formations.

Palynological studies were carried out on the subsurface samples to bring out the palynostratigraphy and paleodepositional environments. The detailed studies enabled mapping of the variations in palynofloral content and demarcating the age boundary between Paleocene/Early Eocene. The palynofloral assemblage is dominated by angiospermous pollen, pteridophytic spores, and marine phytoplankton. The palynofloral yield in general is moderate to rich. The stratigraphic ranges, appearance, and disappearance levels of various marker taxa have been used for dating and correlation of the sediments in different wells.

Two palynozones have been recognized in all the studied wells. Palynozone-I corresponds to Paleocene age while Palynozone-II to Early Eocene age. The palynofloral assemblages recorded belong to eight floral ecological complexes, namely, inland, freshwater, fern, fungal, palm, low salinity water plant complex, mangrove, and marine phytoplankton. The subsurface sedimentary sequence has been studied in detail and paleoenvironment at micro level has been deciphered.

Recognition of paleoenvironments in the subsurface sequence is a pre-requisite for understanding the depositional set up of any given basin for hydrocarbon exploration. At the same time correlation of equivalent units with age relationship is also important in a sequence stratigraphic framework using zonations based on microfossils. Palynological studies have been carried out on the subsurface samples to bring out the variation in palynofloral content as well as precisely mark the age boundaries between Middle Eocene/Early Eocene and Early Eocene/Paleocene. In order to achieve these objectives five wells viz., Nawagam#A, Naika#B, Dholka#C,

Mahelaj#D, and Asmali#E (Figure 1) were taken up for study.

The material used for this study consists of 300 samples of cores and cuttings were collected and studied in detail. The samples show various lithologies, such as claystone, siltstone, clay, shale, and sandstone. These samples were processed by using standard processing techniques adopted by various laboratories in ONGC.

### Palynostratigraphy

The palynofloral assemblage recorded from the subsurface samples of the wells under study consist of diverse spores-pollen and dinoflagellate cysts. The assemblage is dominated by angiospermous pollen, pteridophytic spores, and marine phytoplankton. The palynofloral yield is moderate. The stratigraphic ranges of various marker taxa have been used for dating and correlation of the sediments in different wells (Figure 2). The top of Paleocene and Early Eocene has been marked on the basis of first down hole appearance of the index marker taxa.

### Palynozone - I:

**Definition:** This zone is characterized by the restricted occurrence of *Rhombipollis geniculatus*, *Peninsulapollis gillii*, and *Yeguapollis prolatus*. This zone has been mainly recognized in all the studied wells.

**Top:** The upper limit of the this zone is marked by the first down hole appearance of *Rhombipollis geniculatus*, *Peninsulapollis gillii*, *Yeguapollis prolatus*, *Spinizonocolpites adamanteus*, *Milfordia homeopunctata*, *Polycolporopollenites calvus*, *Nuxpollenites* sp., *Mulleripollis bolpurensis*, *Echitriporites* sp., *Kapurdipollenites* sp., *Cricotriporites vimalii*, *Plicatopollis* sp. *Apectodinium homomorphum*, and *A. parvum*.

**Bottom:** The lower limit of this zone has been taken as the top of the Deccan Trap. **Associated taxa:** includes *Palmaepollenites kutchensis*, *P. nadhamunii*, *Florschuetzia* sp., *Zonocostites ramonae*, *Proxapertites operculatus*, *Proxapertites cursus*, *Lycopodiumsporites* sp., *Lygodiumsporites* sp., *Cyathidites* sp., *Couperipollis rarispinosus*, *Longapertites vaneedenburgi*, *Margocolporites tsukadai*, *Marginipollis concinnus*, *Adnatosphaeridium* sp., *Exochosphaeridium* sp., and *Apectodinium* spp.

**Reference section:** Mahelaj#D: 2100m-3200m

**Suggested Age:** The palynofloral assemblage is suggestive of a Paleocene age.

**Remarks:** This zone corresponds to the Olpad Formation. Majority of the wells are terminated in this formation.

### **Palynozone - II:**

**Definition:** This zone is characterized by restricted occurrence of *Pellicieiroipollis langenheimii*, *Triangulorites bellus*, and *Striacolporites striatus*.

**Top:** The top of this zone is characterized by the first down hole occurrence of *Pellicieiroipollis langenheimii*, *Triangulorites bellus*, and *Striacolporites striatus*.

**Bottom:** The bottom of this zone is characterized of the first down hole appearance of characteristic Paleocene marker palynotaxa, namely *Rhombipollis geniculatus*, *Peninsulapollis gillii*, *Yeguapollis prolatus*, *Spinizonocolpites adamanteus*, *Milfordia homeopunctata*, *Polycolporopollenites calvus*, and *Nuxpollenites* sp.,

**Associated palynotaxa:** include *Polybrevicolporites cephalus*, *Ctenolophonidites* sp., *Meliapollis* sp. *Lakiapollis ovatus* and *Triorites communis*.

**Reference section:** Mahelaj#D: 1580m-2100m.

**Suggested Age:** The palynofloral assemblage is suggestive of Early Eocene age.

**Remarks:** This zone corresponds to the Cambay Formation. This zone has been demarcated in all the studied wells.

### **Depositional Environment**

The palynofloral assemblage recorded from different wells, has been grouped into eight floral ecological complexes. These complexes are inland, freshwater, fern, fungal, palm, low salinity water plant complex, mangrove, and marine phytoplankton.

The palynofloral assemblage recorded from the lower part of Olpad Formation, in the well Nawagam#A, is dominated by inland complex, fresh water complex, fern complex, low salinity water complex, marine phytoplankton along with very low frequency of mangrove complex. The fair occurrence of marine phytoplankton along with very low frequency of mangrove pollen in the palynofloral assemblage suggests that the sediments were deposited under subtidal environment. In the middle part of Olpad Formation similar complexes continue to occur excepting marine phytoplankton, which is attributable to intertidal conditions,

during Middle to Late Paleocene period. As the deposition continued, subtidal conditions again prevailed in the upper part of Olpad Formation towards the end of Paleocene age. Subtidal followed by intertidal conditions continued during the deposition of lower part of Cambay Formation in Early Eocene times. The sediments of the upper part of Cambay Formation show dominance of marine phytoplankton, suggesting, inner shelf environment towards the end of Early Eocene period.

The well Naika#B was terminated in the upper part of Olpad Formation. The subsurface section has yielded dominantly inland complex, fern complex, palm complex, low salinity water complex, along with moderate frequency of marine phytoplankton and sporadic occurrence of mangrove pollen. The palynofloral association is suggestive of an intertidal environment. Similar conditions prevailed almost during the deposition of Cambay Formation. The sediments of the upper part of Cambay Formation show dominance of marine phytoplankton, suggesting an inner shelf environment towards the end of Early Eocene period.

The well Dholka#C was also terminated on reaching the Olpad Formation. The Olpad sediments have yielded dominantly inland complex, fern complex, palm complex, low salinity water complex, along with moderate frequency of marine phytoplankton and rare occurrence of mangrove pollen. The palynofloral assemblage is suggestive of an intertidal environment. Increase in phytoplankton percentage indicates rise in the relative sea level during the deposition of lower part of Cambay Formation. The associated palynofloral assemblage include, mangrove complex, fern complex, palm complex, low salinity water complex. The low frequency of mangrove palynotaxa and dominance of marine phytoplankton is suggestive of inner shelf environment. During the deposition of middle part of Cambay Formation due to the relative fall in the sea level, low frequency of marine phytoplankton are recorded, besides, very low frequency of mangrove pollen in the palynofloral assemblage, suggesting that the sediments were deposited under subtidal environment. Towards the end of Early Eocene, the upper part of Cambay Formation was deposited under inner shelf conditions.

The well Mahelaj#D (Figure 3) was drilled still deeper into the Olpad Formation. The palynofloral assemblage include inland complex, fern complex, palm complex, and 10% low salinity water complex, mangrove complex and marine phytoplankton. The sediments of the Olpad formation were deposited under intertidal conditions. Towards the end of Early Eocene times, the palynofloral assemblage is dominated by marine phytoplankton complex along with fair occurrence of mangrove complex in the upper part of Cambay Formation. The low frequency of mangrove palynotaxa and dominance of marine phytoplankton is suggestive of inner shelf environment.

In the well Asmali#E the depositional environment of Olpad Formation oscillates between intertidal to supratidal. During the deposition of Cambay Formation subtidal to inner shelf conditions prevailed.

Schematic representation of paleoenvironment in Nawagam – Asmali area shows various depositional environments existed during

Paleocene and Eocene when the Olpad and Cambay Formations were deposited (Figure 4).

### **Olpad Formation :**

Mainly subtidal environment prevailed during the deposition of Olpad Formation. Asmali area experienced supratidal environments whereas in Mahelaj and Nawagam areas intertidal environment prevailed during early part of Paleocene.

### **Cambay Formation :**

During Early Eocene times the areas such as Asmali, Mahelaj, Naika, Nawagam mainly experienced subtidal environment whereas Dholka area was under inner shelf conditions. At the end of Eocene, supratidal environment was followed by inner shelf environment in Mahelaj area, while Nawagam and Dholka areas experienced inner shelf environment during this time. This condition was followed by subtidal environment in Asmali area.

### **Conclusions**

Two correlatable palynozones have been recognized in the studied wells, viz., Nawagam#A, Naika#B, Dholka#C, Mahelaj#D, and Asmali#E. Palynozone-I has been dated as Paleocene while Palynozone-II as Early Eocene in age. Palynozone-I corresponds to the Olpad Formation, while Palynozone-II corresponds to Cambay Formation.

Paleocene/Early Eocene and Early Eocene/Middle Eocene boundaries have been precisely marked in these studied wells. The palynofloral association suggests that the Olpad Formation was deposited mainly under intertidal environment, while Cambay Formation was deposited under subtidal to inner shelf conditions.

The studies have not only brought out age and correlatable stratigraphic units but also helped to conceptualize the model of paleoenvironments in space and time for future exploration leads. The wells have been drilled to explore the hydrocarbon prospects of Deccan Trap, Olpad and Eocene pays of Cambay Formation. The longitudinal and transverse fault blocks at these levels and the pinch out termination of Eocene sands are the probable locales of hydrocarbon entrapment where the depositional environments in the present study are interpreted as subtidal to inner shelf.

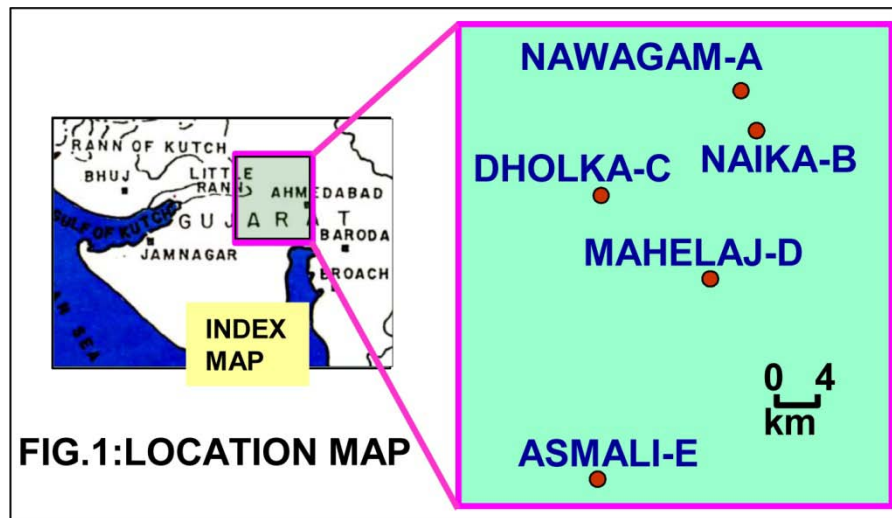


FIG.1:LOCATION MAP

Figure 1. Location Map.

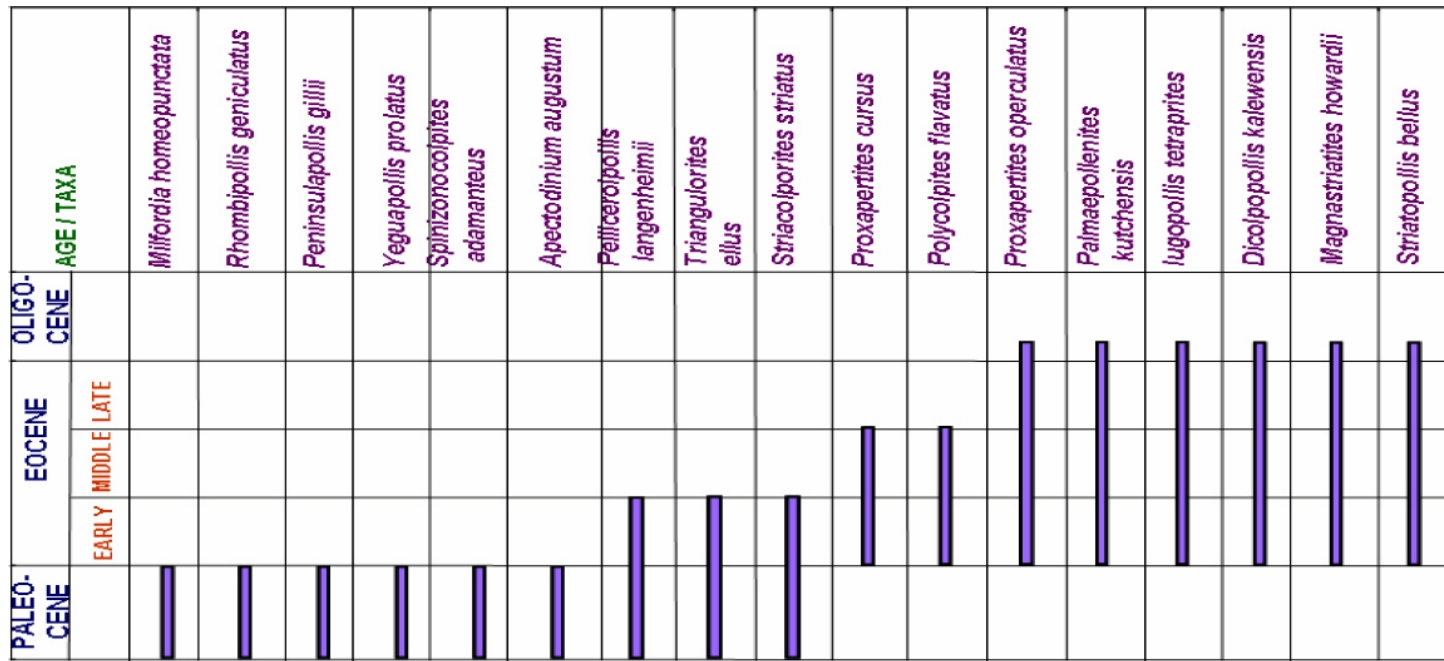


Figure 2. Stratigraphic ranges of age marker taxa in Cambay Basin.

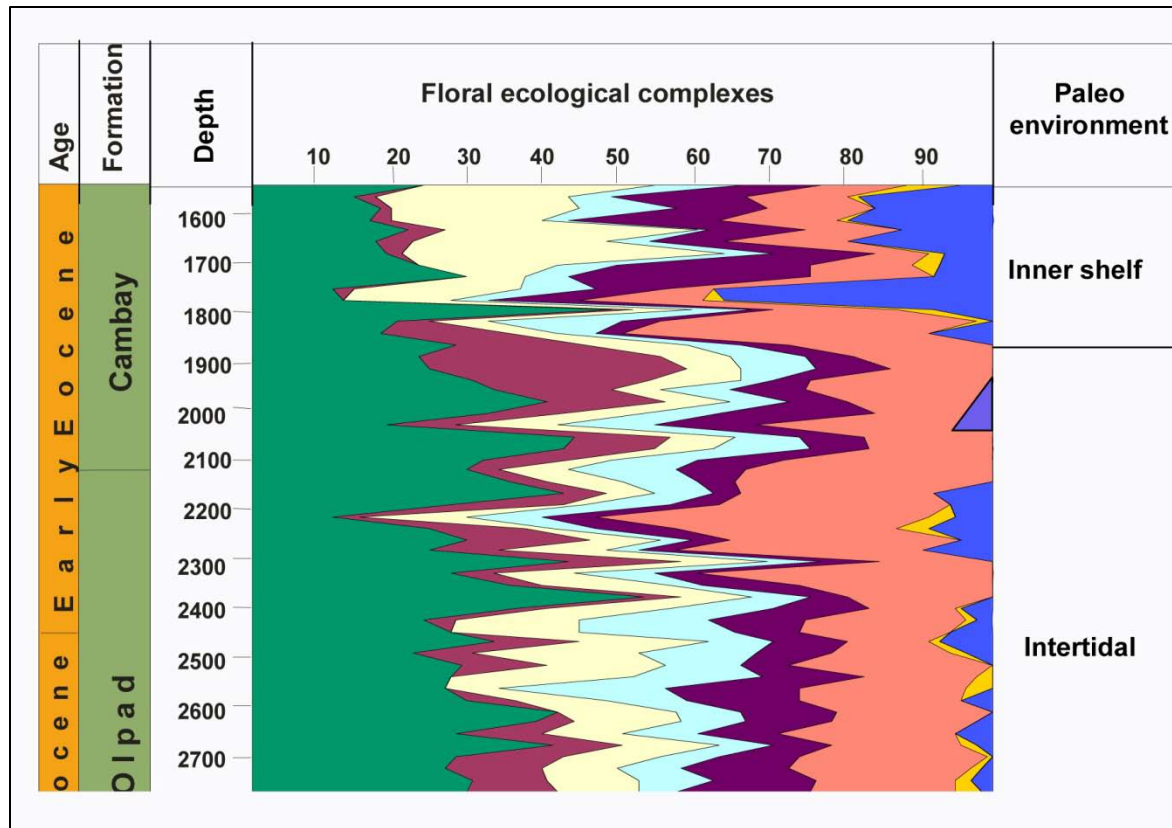


Figure 3. Paleoenvironment of Mahelaj#D.



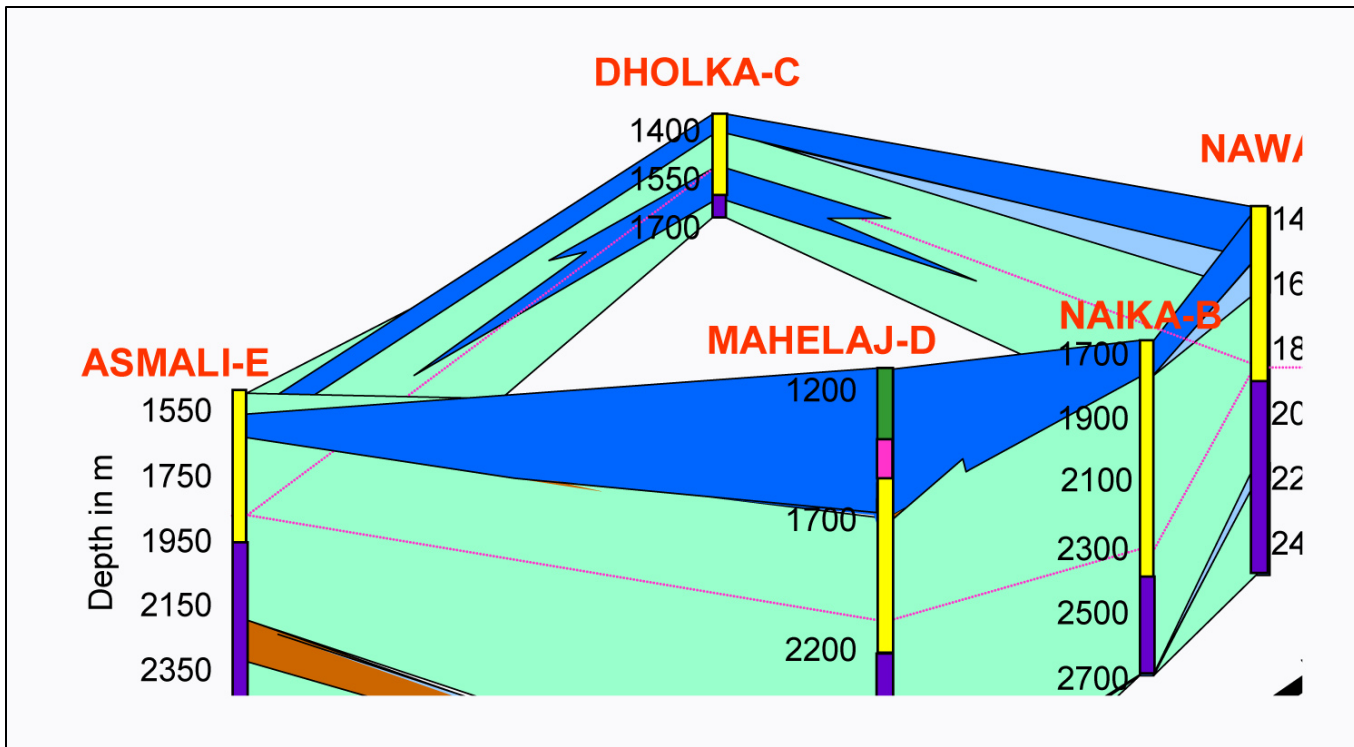


Figure 4. Schematic Representation of Paleoenvironment in Nawagam-Asmali area.

<b>PALYNOZONE / AGE</b>	<b>NAWAGAM # A</b>	<b>NAIKA # B</b>	<b>DHOLKA # C</b>	<b>MAHELAJ # D</b>	<b>ASMALI # E</b>
STUDIED INTERVALS	1400-2500m	1700-2700m	1400-1700m	1580-3200m	1550-2500m
PALYNOZONE-II (Early Eocene)	1440-2000m	1700-2440m	1400-1670m	1580-2440m	1550-2020m
PALYNOZONE-I (Paleocene)	2000-2500m	2440-2700m	1670-1700m	2110-3200m	2020-2500m

Table I. Age Boundaries of the wells in Nawagam – Asmali areas.