# Palynological investigation of the Arabian Sea bottom surface sediments along the western coast of India

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Pollen analyses of surface sediments from continental shelf and slope of the Arabian Sea along the western coast of India (12°47' - 15° 55' N and 72°20' - 74°52' E) have revealed a good assemblage of pollen taxa representing littoral, mangrove and tropical upland vegetation. The pollen are distributed up to 123 km offshore. With the increase in offshore distance, the quantity and quality of pollen decrease proportionately. Pollen spectra show that amongst the mangroves, rhizophoraceous pollen are overrepresented as compared to their presence on the corresponding coasts. The tropical plants, viz., *Terminalia*, Sapotaceae, *Caryota*, Anacardiaceae and *Acacia*, etc. are fairly well represented. Overall dominance of non-arboreals over the arboreals is recorded in the pollen spectra.

**Key-words**—Palynology, Bottom surface sediments, Arabian Sea, India.

## INTRODUCTION

POLLEN distribution in marine sediments is influenced by differential pollen production of the neighbouring vegetation. Yet, pollen buoyancy and its dispersal by atmospheric and marine processes are amongst the important factors which determine the pollen spore frequency in the marine sediments. An understanding of the processes controlling pollen distribution and deposition in surface sediments is the prerequisite to interpret the chronological pollen assemblages in marine cores in terms of changes of the vegetation, climate, palynofacies and ancient shore lines. The present study is in sequel to the earlier work of Ratan and Chandra (1983, 1984) to work out the pollen/spore distribution and the relationship between palyno-assemblage and corresponding vegetation on the adjacent coast.

The investigation is based on fifty two grab samples collected during the cruise 17 and 18 of R.V. Gaveshani (Anonymous, 1977a, b) from the continental shelf and slope off Maharashtra, Goa and Karnataka (12°47' - 15°55' N and 72° 20' - 74° 52' E). The details of the samples and their position are shown in Table 1 and Text-figure. 1. The lithology of the sediments is clayey silt, silty clay, silty sand, and sand. The water depth of the sampling sites ranges from 18 m to 1330 m. The distance of the stations, nearest and farthest off the coast is approximately 6 km and 123 km, respectively. Samples belonging to XVII Oceanographic Cruise and sample nos. 18/33, 18/47, 18/79, 18/109, 18/126 belonging to XVIII Oceanographic Cruise are from the inner continental shelf while sample nos. 18/56, 18/57, 18/70, 18/86, 18/119 of XVIII Ocenographic Cruise are from the upper continental slope. The remaining samples are from the outer continental shelf.

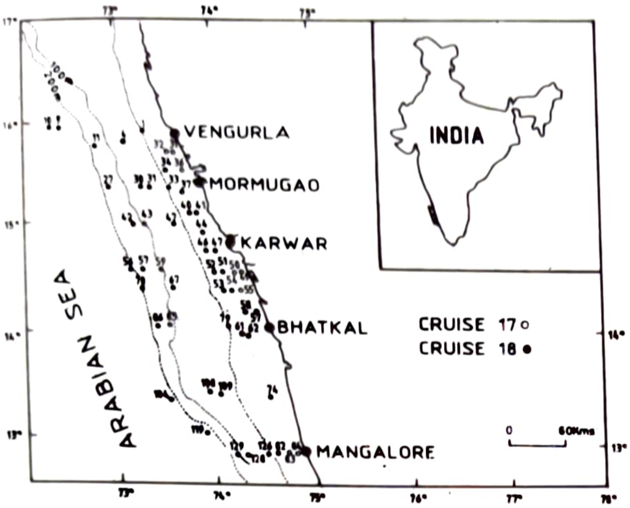
## VEGETATION

The coastal vegetation of India has been studied by Champion and Seth (1968), Rao and Sastry (1974), Blasco (1975, 1977) and Pascal (1986). The coasts of Maharashtra, Goa and Karnataka are infested with different types of vegetation from sea to inland.

The littoral forest occurs all along the coast and colonizes sandy beaches and sandy bars on the sea face. *Borassus flabellifer* and *Cocos nucifera* are common on the western coast of India. The common soil binders are *Canavalia maritima*, *Ipomoea pes-caprae* and *Launea sarmentosa*. The succulents and bulbous plants (*Hydrophyllax maritima* and *Crinum latifolium*) are also common. The transition from open dunes to sand bars near the shore is colonized by shrubs like *Scaevola frutiscens*, *Pandanus fasicularis*, *Calophyllum inophyl-*

**Table 1. Details of samples from the Arabian Sea**

| Sl. no. | Station number (Sample no.) | Latitude | Longitude | Water depth (m) | Lithology | Approximate distance from the coast (km) |
|---|---|---|---|---|---|---|
| 1. | 17/31 | 15° 40"N | 73° 32"E | 34 | Clayey-silt | 9 |
| 2. | 17/32 | 15° 40"N | 73° 26"E | 45 | Clayey-silt | 16.5 |
| 3. | 17/34 | 15° 30"N | 73° 35"E | 36 | Clayey-silt | 27 |
| 4. | 17/36 | 15° 17"N | 73° 45"E | 28 | Silty-clay | 9 |
| 5. | 17/37 | 15° 17"N | 73° 50"E | 18 | Clayey-silt | 24 |
| 6. | 17/40 | 15° 6"N | 73° 46"N | 34 | Clayey-silt | 20 |
| 7. | 17/41 | 15° 5"N | 73° 53"E | 18 | Clayey-silt | 12 |
| 8. | 17/44 | 15° 54"N | 73° 46"E | 50 | Silty-sand | 18 |
| 9. | 17/46 | 14° 43"N | 73° 58"E | 39 | Silty-sand | 24 |
| 10. | 17/47 | 14° 43"N | 73° 4"E | 26.5 | Clayey-silt | 15 |
| 11. | 17/49 | 14° 32"N | 74° 10"E | 31 | Clayey-silt | 6 |
| 12. | 17/50 | 14° 32"N | 74° 4"E | 41 | Clayey-silt | 15 |
| 13. | 17/51 | 14° 32"N | 73° 58"E | 50 | Silty-sand | 20 |
| 14. | 17/52 | 14° 21"N | 74° 4"E | 45.5 | Sand | 36 |
| 15. | 17/53 | 14° 21"N | 74° 10"E | 40 | Silty-sand | 36 |
| 16. | 17/54 | 14° 21"N | 74° 15"E | 30 | Silty-sand | 25 |
| 17. | 17/55 | 14° 21"N | 74° 20"E | 19 | Clayey-silt | 15 |
| 18. | 17/57 | 14° 10"N | 74° 18"E | 32 | Clayey-silt | 6 |
| 19. | 17/58 | 14° 10"N | 74° 13"E | 44 | Clayey-silt | 20 |
| 20. | 17/61 | 13° 56"N | 74° 15"E | 30 | Silty-sand | 36 |
| 21. | 17/62 | 13° 57"N | 74° 21"E | 35 | Clayey-silt | 22 |
| 22. | 17/74 | 13° 24"N | 74° 25"E | 42 | Clayey-silt | 21 |
| 23. | 17/82 | 12° 47"N | 74° 41"E | 35 | Clayey-silt | 30 |
| 24. | 17/83 | 12° 47"N | 74° 46"E | 21 | Clayey-silt | 16 |
| 25. | 17/84 | 12° 36"N | 74° 52"E | 46 | Clayey-silt | 6 |
| 26. | 18/1 | 15° 54"N | 73° 16"E | 54 | Clayey-silt | 30 |
| 27. | 18/4 | 15° 47"N | 73° 7"E | 88 | Silty-sand | 60 |
| 28. | 18/9 | 15° 55"N | 72° 31"E | 990 | Clayey-silt | 114 |
| 29. | 18/10 | 15° 55"N | 72° 25"E | 1050 | Silty-clay | 123 |
| 30. | 18/11 | 15° 55"N | 72° 20"E | 1330 | Silty-clay | 90 |
| 31. | 18/27 | 15° 20"N | 72° 56"E | 186 | sand | 90 |
| 32. | 18/30 | 15° 20"N | 73° 15"E | 80 | Silty-sand | 60 |
| 33. | 18/31 | 15° 20"N | 73° 21"E | 65 | Sand | 45 |
| 34. | 18/33 | 15° 20"N | 73° 34"E | 51 | Silty-sand | 30 |
| 35. | 18/42 | 14° 58"N | 73° 10"E | 112 | Silty-sand | 81 |
| 36. | 18/43 | 14° 58"N | 73° 17"E | 99 | Silty sand | 75 |
| 37. | 18/47 | 14° 57.9"N | 73° 35.9"E | 54 | Silty-sand | 45 |
| 38. | 18/56 | 14° 33"N | 73° 8.5"E | 210 | Silty-sand | 124 |
| 39. | 18/57 | 14° 33"N | 73° 14.5"E | 140 | Silty-sand | 112.5 |
| 40. | 18/59 | 14° 33"N | 73° 27"E | 96 | Silty-sand | 90 |
| 41. | 18/67 | 14° 22"N | 73° 34"E | 94 | Silty-sand | 87 |
| 42. | 18/70 | 14° 22"N | 73° 15"E | 218 | Sand-silt-clay | 123 |
| 43. | 18/79 | 14° 00"N | 74° 06"E | 52 | Sand | 42 |
| 44. | 18/85 | 14° 00"N | 73° 30"E | 117 | Silty-sand | 102 |
| 45. | 18/86 | 14° 00"N | 73° 24"E | 176 | Silty-sand | 118 |
| 46. | 18/104 | 13° 19"N | 73° 30"E | 172 | Silty-sand | 129 |
| 47. | 18/108 | 13° 24"N | 73° 52"E | 63 | Sand | 84 |
| 48. | 18/109 | 13° 22.4"N | 74° 01"E | 51 | Sand | 73 |
| 49. | 18/119 | 13° 00"N | 73° 50"E | 390 | Sand | 99 |
| 50. | 18/126 | 12° 47"N | 74° 28"E | 55 | Sand | 39 |
| 51. | 18/128 | 12° 47"N | 74° 16"E | 84 | Silty-sand | 61.5 |
| 52. | 18/129 | 12° 47"N | 74° 10"E | 114 | Silty-sand | 72 |




**Text-figure 1.** Location of samples (after Anonymous, 1977a, b).

*lum*, etc. *Casuarina equisetifolia* has been recently planted all along the Indian coastline for checking the fast erosion of soil. It has so quickly naturalized that it often forms pure fringes on the sandy beaches and sand dunes along the sea.

The mangrove vegetation is not very rich but at places, patches consisting of *Rhizophora mucronata, R. apiculata, Ceriops tagal, Bruguiera cylindrica* and *B. parviflora* are found. *Sonneratia caseolaris, Avicennia alba, A. officinalis, Excoecaria agallocha, Acanthus ilicifolius* and grasses are inhabitants of back water.

Tropical moist deciduous forest is distributed in Maharashtra, Karnataka and Kerala. The top canopy is characterized by *Tectona grandis, Bombax ceiba* and *Lagerstroemia* sp. *Adina cordifolia* is found on drier platforms. The second storey trees include *Schleichera* sp. and *Careya* sp. Shrubby vegetation is represented by *Ziziphus, Casearia* sp., *Helicteres* sp. and *Desmodium* sp.

Tropical semi-evergreen forest occurring in strings within moist deciduous forest is comprised *Terminalia paniculata, Diospyros* sp., *Lagerstroemia lanceolata, Holigarna arnottiana, Lophopetalum wightianum, Persea macrantha, Cinnamomum* sp., *Hopea parviflora* and *Artocarpus hirsuta*. Main associates of the second canopy are *Elaeocarpus sp., Mallotus* sp., *Diospyros assimilis* and *Ixora malabarica*.

In tropical evergreen forest the top canopy is characterized by *Dipterocarpus indicus, Calophyllum indicum, C. apetalum, Hopea* spp., *Holigarna* sp., *Olea* sp., *Lophopetalum* sp., *Polyalthia* sp., *Persea* sp., *Mangifera* sp. and *Chrysophyllum* sp. The second canopy is composed of *Aglaia* sp., *Euphorbia longana, Aporosa lindleyana, Nothopegia* sp., *Colebrookiana* sp., *Litsea* sp. The dominant shrubs are *Strobilanthes* sp. and *Psychotria* sp.

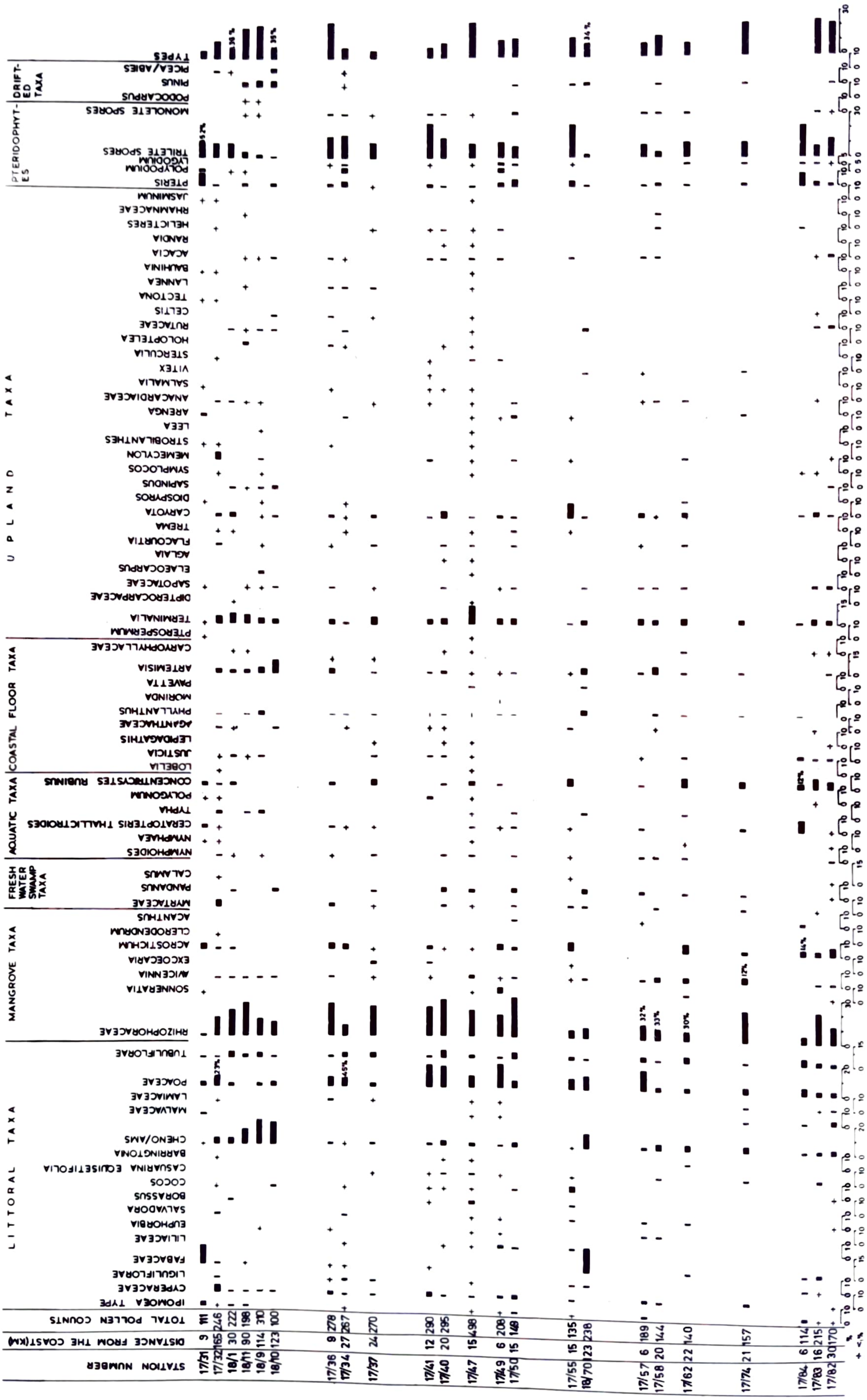
## METHOD

For pollen analysis the samples were processed employing Erdtman (1943) and Faegri and Iversen (1964) techniques. Out of fifty two samples macerated for pollen analyses only 23 were found to be rich in pollen/spores. The pollen taxa, in most cases, are ascertained only up to generic and family level. Rhizophoraceae members such as *Rhizophora mucronata, R. apiculata, Bruguiera* and *Ceriops* have been clubbed together for all practical purposes owing to their similar ecological requirements and tolerances. Pollen of Chenopodiaceae and Amaranthaceae have been counted as Cheno/Ams type. Pollen of *Avicennia alba* and *A. officinalis* which are not distinguishable under LM are grouped together as *Avicennia* pollen. Some of the pteridophytic spores which could not be identified to generic level are listed as trilete or monolete spores. Pollen grains of uncertain affinities are put under types in order to record their presence and also for relative frequency calculation. Total pollen and spores included in the pollen sum range from 100 to 400.

## POLLEN SPECTRA AND THEIR COMPOSITION

For convenient of interpretation, pollen taxa have been arranged in the pollen spectra (Text-fig. 2) according to their ecological distribution. In the pollen spectra littoral elements are represented by *Cocos* (0.5-4%), *Ipomoea* (0.5-3%), *Borassus* and *Casuarina equisetifolia* (0.5-2% each) *Salvadora* and *Barringtonia* (0.5-1% each), Fabaceae, Cheno/Ams (0.5-17% each), Poaceae (2-23%), Tubuliflorae (1-5%), Malvaceae (0.5-3%), Cyperaceae (90.5-5%), Liliaceae (0.5- 2%), Liguliflorae, *Euphorbia* and Lamiaceae (0.5-1% each) inhabit diverse ecological habitats on the coastal floor. Values of all pollen taxa are inversely proportionate to the offshore distance except for Cheno/Ams. Chenopods grow in dry halophilous soils all over the coastal floor and exhibit the ubiquitous nature of distribution. Due to their relatively smaller size with greater resistance to physico-chemical environs, they remain intact and drift for longer distance before being deposited in the sediments. High values of Fabaceae pollen in samples 17/31 (13%) and 17/70 (17%) is due to their drifting from varied ecozones, viz., littoral, tidal and hinterland.

Rhizophoraceae, a core mangrove forest element, depicts overall dominance except for sample no. 17/31. Poor occurrence of plants of Rhizophoraceae in the present mangrove vegetation of the western coast of India and considerably high frequency of pollen of Rhizophoraceae in the modern surface sediments is, however, an anomaly. The overall representation of Rhizophoraceae pollen in offshore sediments is largely accounted as due to its high pollen production and their proximity to shore. Nevertheless, high representation of



**Text-figure 2.** Pollen spectra showing the relative percentage of taxa recovered.

Rhizophoraceae has also been recorded by Muller (1959) in the Orinoco delta, Caratini *et al.* (1973) in Pichavaram, Tamil Nadu, and Gupta (1981) in Bengal Basin. Pollen concentration of Rhizophoraceae increases up to 90 km in samples 17/31, 17/31, 18/1, 18/11 off Vengurla coast and then decreases in samples 18/9 and 18/10, 114 and 123 km off shore, respectively. The decline in values of Rhizophoraceae is dotted by a corresponding spurt in values of Cheno/Ams and *Artemisia* pollen. Water depth of sample 18/11 is higher than that of samples 18/10 and 18/9. The lithology of samples 18/11 and 18/10 is silty clay while sample 18/9 is clayey silt. The values of Rhizophoraceae also decrease in sample 17/34 off Mormugao with an increase in values of Poaceae. The lithology of sample 17/36 is silty clay and that of 17/34 clayey silt suggesting that there has been a change from low energy to high energy depositional environment. Concentration of Rhizophoraceae pollen and fine grained sediments with increase in off shore distance does not hold true for samples 17/84, 17/83, 17/82. Lithology of all these samples is clayey silt. Decrease in the values of Rhizophoraceae in sample 17/82 with increase in offshore distance may have been caused by turbulence. *Avicennia* is the dominant constituent in the modern mangrove vegetation of the western coast of India. Palynologically, it is under represented in most of the samples. Caratini *et al.* (1973) have also found that *Avicennia* is under represented in mangrove sediments at Pichavaram. *Sonneratia* (0.5-4%) pollen are sporadic. Common occurrence of *S. caseolaris* along the Karwar coast is reflected by higher values of its pollen in sample 17/49. *Excoecaria* and *Acanthus* (0.5-2% each) and *Clerodendrum* (1%) are sporadic. *Acrostichum aureum*, primarily a fresh water taxon also adapted to grow on saline soils (Rao *et al.*, 1973), is very common.

Fresh water swamp taxa, represented by pollen of Myrtaceae (0.5-5%) and *Pandanus* (0.5-3%), are well represented. *Pandanus fasicularis* grows luxuriantly in the open dunes and sandy beaches. *Calamus*, a common element of swamp, is sporadic and under represented.

The marshy and aquatic elements, viz., *Nymphoides* (0.5-1%), *Polygonum serrulatum*, *Typha angustifolia* (0.5-2% each) and *Nymphaea* (1%) are sporadically represented. *Ceratopteris thallictroides*, which grows in ponding environs, is common (0.5-8%) in near coast samples. *Concentricystes rubinus* is high (1-11%) in sample 17/84. It is considered to be fluvial in origin and its high values together with *C. thallictroides* off Mangalore indicate high fluvial discharge in the sea.

Amongst the herbaceous elements of coastal floor vegetation, *Artemisia* (0.5-10%), *Justicia* (0.5-2%), Acanthaceae and Caryophyllaceae (0.5-1% each) are consistently present but in low values. *Lobelia*, *Morinda* and *Pavetta* (1% each) are sporadic. Pollen of ground vegetation are usually transported by rivers and streams as their dispersion by wind is restricted to small distances. Due to the hydrodynamic features, large sized pollen are deposited in the near shore sediments, whereas smaller ones transported to farther distances by water currents. Pollen grains of *Artemisia* which are comparatively smaller in size show an increase in their representation with increase in offshore distance.

Pollen of trees and shrubs are poorly represented in marine sediments. Amongst these, *Terminalia* (0.5-13%) and *Caryota* are the dominant elements. Other arboreal elements are *Memecylon* (0.5-5%), Sapotaceae, *Elaeocarpus, Sapindus, Arenga, Holoptelea*, Rutaceae and *Acacia* (0.5-2% each), *Flacourtia, Trema, Diospyros*, Anacardiaceae, *Vitex, Sterculia, Celtis, Lannea* and *Helicteres* (0.5-1% each), *Pterospurmum, Dipterocarpus, Aglaia, Symplocos, Strobilanthes, Leea, Salmalia, Tectona, Bauhinia, Randia* and *Jasminum* (1% each) are sporadic in occurrence. These pollen might have been derived mostly from the tropical forest of the corresponding coast. Poor representation of arboreal pollen in marine sediments could be due to entomophily in most of the tropical forest elements.

Pteridophytic spores show a marked decreasing trend with increase in offshore distance.

Conifer taxa, not growing on the coast are also represented by their pollen. These drifted taxa include *Pinus* (0.5-4%), *Picea/Abies* (0.5-3%) and *Podocarpus* (1%). The *Podocarups* could be derived from the Tirunelvely hills, Tamilnadu, and hills of Kerala whereas *Pinus*, *Picea/Abies* pollen from the Himalayan region.

## DISCUSSION

Pollen vegetation relationship shows that the pollen composition is not fully analogous to the vegetation of the corresponding area. The stands of Rhizophoraceae, which are scarce and scattered in the mangroves in Karnataka coast, have high pollen values. *Avicennia* is under represented in the pollen composition as compared to its occurrence along the coastline. The other littoral forest constituents are poorly represented. The most convincing reason for this anomaly could be due to predominant entomophily amongst these taxa. The pollen spectra in general show the dominance of non-arboreal over the aboreals. Predominance of pteridophytes and other herbaceous taxa, especially in near coast sediments exemplifies the influence of fluvial influx in the sea. Selective increase in the values of Rhizophoraceae, Cheno/Ams and *Artemisia* in fine–grained sediments with the increase in offshore distance is suggestive of their sedimentation in low energy environment. Extra regional pollen taxa of *Pinus* and *Picea/Abies* in offshore sediments are brought by wind currents from the Himalayan region.

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