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PALYNOLOGICAL INVESTIGATION OF THE ARABIAN SEA: POLLEN/SPORES FROM THE RECENT SEDIMENTS OF THE CONTINENTAL SHELF OFF BOMBAY, INDIA

RAM RATAN & ANIL CHANDRA

Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India

ABSTRACT

The palynological analysis of 22 bottom sediments from the continental shelf off Bombay shows mixed pollen spectra which is the reflection of the adjoining mangroves, tropical evergreens and the mixed deciduous type of vegetation. Herbaceous pollen and pteridophytic spores dominate over the trees in all the samples. It has been observed that the palynomorphs in the sediments from station numbers 22 to 28 are derived from the vegetation of the Saurashtra coast, while in other samples from station numbers 1 to 4, 5 to 15 and 20, the pollen appear to have been derived from the Bombay coast vegetation. The quantitative analysis of the assemblage shows comparatively higher frequency of pollen/spores in the samples collected from near the coast. Corroded grains have been found in all the samples and their percentage is higher in the samples collected from near the coast between Bombay and Marmugao.

Key-words — Palynology, Mangroves, Continental shelf, Arabian Sea (India).

सारांश

अरब सागर का परागाणविक अन्वेषण : भारत में मुम्बई के महाद्वीपीय अपतट के वर्तमान अवसादों से प्राप्त परागकण / बीजाणु – राम रतन एवं अनिल चन्द्रा

मुम्बई के महाद्वीपीय अपतट से प्राप्त 22 तलीय अवसादों के परागाणविक विश्लेषण से मिश्रित परागकण स्पेक्ट्रम प्रदर्शित होते हैं जो कि आस-पास में उगने वाले दलदली पौधों, उष्णकटिबंधीय सदाहरित एवं मिश्रित पर्णपाती वनस्पति का प्रतिस्वरूप है। सभी नमूनों में वृक्षों की अपेक्षा शाकीय परागकणों एवं टेरिडोफ़ाइटी बीजाणुओं का बाहुल्य है। यह प्रेक्षित किया गया है कि प्रेक्षण स्थल संख्या 22 से 28 तक के अवसादों में परागाणविकरूपक सौराष्ट्र तट की वनस्पति से व्युत्पादित हैं जबकि प्रेक्षण स्थल संख्या 1 से 4, 5 से 15 तथा 20 से प्राप्त नमूनों में परागकण मुम्बई तट की वनस्पति से व्युत्पादित प्रतीत होते हैं। तट के समीप से एकत्रित नमूनों में समुच्चय का परिमाणात्मक विश्लेषण तुलनात्मक दृष्टि से परागकण/बीजाणुओं की उच्चतर बारम्बारता व्यक्त करता है। क्षीण कण सभी नमूनों में मिलते हैं तथा इनकी बारम्बारता मुम्बई तथा मारमुगाव के बीच में तट के समीप से एकत्रित नमूनों की अपेक्षाकृत उच्चतर है।

INTRODUCTION

TERRESTRIAL microfossils were first described from the marine cores and the coastal water sediments by Erdtman (1921) and Halden (1922). Since then significant contributions to the marine palynology have been made by various workers (Koreneva, 1957, 1964a, b, 1966, 1968, 1971, 1980; Muller, 1959; Ingram *et al.*, 1969; Rossignol, 1961; Livingstone, 1964; Panov *et al.*, 1964; Cross & Shaefer, 1955; Stanley, 1965, 1966a, b, c, d, 1967, 1969; Groot, 1966; Groot & Groot, 1966; Cross *et al.*, 1966; Traverse & Ginsburg, 1966; Horowitz, 1966; Boulouard & Delange, 1966; Zagwijn & Veenstra, 1966; Aoutin, 1967; Assemien, 1969; Davey, 1971; Florer, 1973; Heusser & Florer, 1973; Heusser & Balsam, 1977; Maljasowa, 1980; Vronsky, 1980 etc.). In India, palynological studies of the mangrove sediments have been carried out by Das, 1961; Mukherjee, 1969, 1972; Vishnu-Mittre and

Gupta, 1972; Vishnu-Mittre and Guzder, 1975; Blasco and Caratini, 1973; Caratini *et al.*, 1973; Gupta, 1981 and many others.

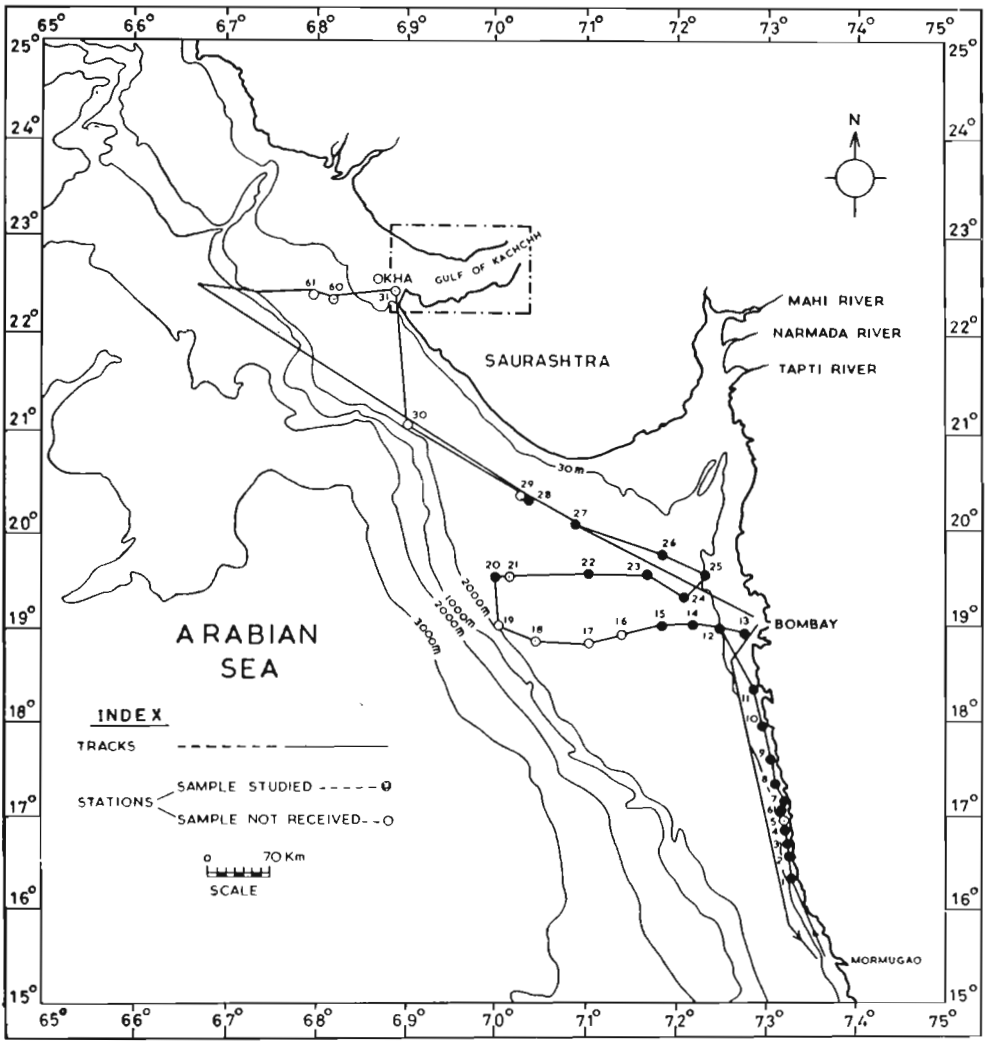
The present contribution on the palynology of the oceanic sediments deals with the study of 22 bottom surface (grab) samples from the continental shelf off Bombay. These samples were collected along the western coast of India (between 16° 17.8′N: 73°19.3′ E a·d 20°19.5′N: 70°20.5′ E) by R. V. Gaveshani of the National Institute of Oceanography, Goa under its second Oceanographic Cruise. The objectives of the present study are to investigate the distribution and source of the palynomorphs and their relationship with the major sediment types in the continental shelf off Bombay and also to observe the relationship of the pollen spectra with the surrounding continental vegetation.

MATERIAL AND METHOD

All the 22 grab samples (bottom sediments) were collected from the continental shelf off Bombay by the R. V. Gaveshani (Second Oceanographic Cruise, 1976). These samples were received from the National Institute of Oceanography, Goa for palynological investigations. The lithology of the sediments is clay, sandy clay, silty clay, sandy silt and silty sand. The water depth of the stations is from 10.5 to 88.5 metres. The distance of stations nearest and farthest off the coast is approximately 7 km and 154 km. Samples from station numbers 1 to 4, 13 and 22 to 26 are from the inner shelf while those from station numbers 14, 15, 27, 28 are from the outer shelf. The depth, latitude, longitude and lithology of these sediments are shown in Table 1 and the location of these samples is shown in Text-fig. 1. The samples have been macerated by the standard procedure of Erdtman (1943). Pollen grains have been assigned to their respective families and those which could not be identified have been categorized as ' unknown ' pollen. The distribution of maximum concentrated pollen/spore taxa have been shown in Contour maps (Text-figs 3-15). The source area of the pollen grains except that of Poaceae, Cyperaceae, Asteraceae, Cheno/Ams which are ubiquitous, have been shown by shade.

TABLE 1 — SHOWING THE STATION LOCATION AND OTHER DATA OF THE CRUISE II — R. V. GAVESHANI

No.	Station No. (Sample No.)	Position		Depth in Meters	Lithology of the Sediments
		Latitude	Longitude		
1	1	16°17.8′N	73°19.3′E	26.5	Silty clay
2	2	16°33.4′N	73°17.0′E	18.5	Clay
3	3	16°41.1′N	73°15.3′E	20.5	Clay
4	4	16°51.9′N	73°14.4′E	20.5	Clay
5	6	17°03.0′N	73°13.5′E	18.5	Silty clay
6	7	17°06.0′N	73°14.5′E	16.5	Silty clay
7	8	17°18.0′N	73°08.1′E	22.5	Silty clay
8	9	17°34.1′N	73°06.1′E	12.0	Clay
9	10	17°57.6′N	72°59.2′E	10.5	Clay
10	11	18°18.5′N	72° 5.8′E	10.5	Clay
11	12	18°58.1′N	72°30.0′E	33.5	Clay
12	13	18°53.1′N	72°42.3′E	15.0	Clay
13	14	19°00.0′N	72°11.0′E	62.5	Sandy silt
14	15	18°58.0′N	71°50.0′E	70.0	Sandy silt
15	20	19°30.0′N	70°00.0′E	88.5	Silty sand
16	22	19°31.5′N	71°01.5′E	48.0	Sandy silt
17	23	19°30.5′N	71°44.8′E	47.0	Clay
18	24	19°16.0′N	72°03.0′E	48.0	Clay
19	25	19°30.5′N	72°20.5′E	24.0	Clay
20	26	19°43.5′N	71°51.0′E	31.0	Clay
21	27	20°03.0′N	71°00.0′E	68.0	Clay
22	28	20°19.5′N	70°20.5′E	78.0	Sandy clay



TEXT-FIG. 1 — Map showing the location of samples (from the Report of Second Oceanographic Cruise, R. V. Gaveshani).

DESCRIPTION, BATHYMETRY AND GEOLOGY OF THE AREA

The area under study lies between 16°15′: 22°30′N and 67°45′: 73°30′E. According to Nair (1975) the shelf width off Bombay is about 300 km, of which the outer 225 km between depths of 65 and 100 m is composed of pinnacles (commonly 1-2 m in height) with or without adjacent troughs (usually 1-2 m deep). There are a number of large (C. 2000 to 4000 m in width) mound-shaped protuberances with a relief of 6 to 8 m on the outer shelf at depths of 80 to 85 m. Off Ratnagiri the shelf narrows down to about 100 km and the shelf break takes place at 130 m. Pinnacles and troughs, restricted to depths between 95 and 100 m are poorly developed as compared to those off Bombay. Progressive narrowing of the shelf is reflected in 60 km wide shelf off Goa, the shelf break occurring at a depth of 130 m. Pinnacles with relatively gentle depression occur on a sloping shelf between the sea floor depths of 62 and 84 m. Unlike off Ratnagiri, the shelf slopes smoothly to the upper continental slope.

According to Hashimi *et al.* (1978) the continental shelf off Bombay is floored with three types of sediments: (i) the nearshore sand zone which extends from shore to water depth of 5-10 m, (ii) the muds (silt and clay) which extend to a water depth of 60-70 m, and (iii) the calcareous sediments (seaward of the mud zone and extending to shelf edge) composed of shells of various organisms, oolite and algae. The sediments of the inner shelf (0-60 m) are geologically recent. They represent the contribution made by the present day rivers of the west coast. According to Nair and Hashimi (1980), the modern sands of the shore zone occur within a few kilometers of the coast and extend to about 10 m water depth. These are derived as a result of the wave erosion of cliffs and promontories of the west coast. Beyond 10 to 20 m the modern muds are found. The source of these muds are the rivers which drain the western Ghats and the coastal plain at their foot.

The coastal geology is varied. On the west coast along Kachchh shore recent deposits of newer alluvium are met with. Over the western shore of the Saurashtra too the newer alluvium are found with small pockets of a foraminiferal limestone known as meliolite, and of rocks which have been correlated with the Gaj Series (of Sind) of the Lower Miocene age. The Deccan Traps dominate the Maharashtra coast. Further south along the Karnataka and Kerala shores, up to Kanyakumari the most important formation is recent alluvium, though Pleistocene alluvium, Archaean genissic complex, laterites and Miocene sandstones (Warkali beds) are also encountered.

Drainage — The entire Maharashtra is drained by three principal river systems, the Tapti, the Godavari and the Krishna. Except Tapti basin which is drained to Arabian Sea, the rest of the region is drained to the Bay of Bengal. The radial drainage pattern of Kathiawar is guided by two hill masses of Rajkot (383 m) and Gir range (728 m) which are linked by tortuous narrow neck of high land. The North flowing streams unite with the Gulf of Kachchh and little Rann, while the south flowing streams merge in the Arabian Sea. Carving out their valleys in the Surat sea coast, the Bhadar and Ojat rivers together with other west flowing streams terminate in the Arabian Sea, whereas the eastward drainage discharges its waters in the Gulf of Cambay (Singh, 1971).

Coastal Environment — The west coast line of India is long and more or less straight from Cape Comorin in the south to the 20° parallel north and includes two peninsula-Saurashtra and Karnataka and is spread into the states of Gujarat, Maharashtra, Karnataka and Kerala. These two major inshore ecosystems, strand and estuary lie between the coastline and the adjacent plains. The climate along the coast line is relatively uniform over extensive areas and on the basis of humidity it has been classified into five climatic groups, viz., prehumid, humid, subhumid, semiarid and arid as already recognized by Thorrthwaite (1948). In the extreme north of west coast in the vicinity of Kachchh and Okha-Dwaraka shores, the climate is arid. Further down and along the south western shores stretching into the states of south Gujarat, Maharashtra, Karnataka and Kerala the humid climate exists.

The influence of marine climate on upland part of the coastal biosphere is affected by the combined action of precipitation and local topography and all the prevailing influence of sea is felt only in low lying coastal areas. The nature of vegetation is greatly influenced by the upland sandy relief which alters the influence of climate and the properties of soils due to variations in environmental factors. On the contrary, the effect of land climate is not appreciable in the low lying coastal areas. Here they are chiefly influenced by tides, waves, sea winds, saline water and nature of substratum.

Water Currents — The general surface circulation in the Arabian Sea is counter clockwise during north-east monsoon. By February, this system is gradually reversed into a clockwise circulation which intensifies during south-west monsoon. Currents in the continental shelf are a combination of tidal currents, density currents, wind induced currents, currents due to surface and internal waves and those due to the land drainage. The tidal currents are strong farther from the shore.

The tidal currents off Mangalore are of rotary type. The rotary nature of the

currents, however, is not very regular which may be due to the effect of winds and waves, etc. The tidal influence on the currents decreases in the off shore direction and ultimately becomes negligible. The seasonal currents show an increase in the speed in the off-shore direction. The currents are weakest (about 5 cm per second) in December. During May to October they are strong and the maximum speed is about 50 cm per second or even more. The currents are southerly from April to October and northerly from November to February and show the tendency to change from north to south during the transition months of February and March. The currents are governed by the tides during the non-monsoon seasons (Varma & Gopinathan, 1977; Gouvenia & Varadachari, 1979).

Vegetation — The coastal vegetation is influenced by the marine environment. The vegetation, in the transition zone of sea and land, and upland vegetation are discussed separately. The coastal vegetation of India has been extensively studied by Champion and Seth (1968), Rao and Sastry (1974) and Blasco (1975, 1977).

The littoral forest occurs all along the coast where the sandy beach, sandy bars on the sea face and river deltas are found. *Hyphaene indica* is common on the sandy beaches of Saurashtra only while *Borassus flabellifer* and *Cocos nucifera* are common on the entire western coast of India. *Casuarina equisetifolia* often forms almost along pure fringe on the sandy beaches and dunes along the sea face. There are scattered evergreen smaller trees with fewer deciduous trees and these form the dominant canopy in absence of *Casuarina*. The common sand binders are *Canavalia maritima*, *Ipomoea pescaprae* and *Launea sarmentosa*. The succulents and bulbous plants (*Hydrophyllax maritima* and *Crinum latifolium*) are also common. The transition from open dunes to sandy near shore is made by shrubs like *Scaevola frutescens*, *Pandanus fasicularis*, *Calophyllum inophyllum*, etc.

The best conserved halophytic population is found near Ratnagiri, in Bombay and Salsette islands. The large areas of halophytes are on the point of extinction, particularly in Kolaba area. On the whole, only a few dense but bushy stands of *Avicennia alba* Bl. are seen out of the original littoral formations and the swamps are completely covered by *Acanthus ilicifolius* here and there. The other mangrove species, particularly members of Rhizophoraceae, still survive in some places. They are very few in number and generally scattered. In some places these along with some other species, have been completely destroyed in the recent past. In these regions where the mangroves are preserved three zones can be recognized. These are: (i) "the Rhizophoraceae zone" (*Rhizophora mucronata*, *R. apiculata*, *Ceriops tagal*, *Bruguiera cylindrica* and *B. parviflora*) — towards the sea, (ii) a zone of *Avicennia alba* (and *A. officinalis*) — a little retreated, and (iii) a zone of a sort of grasses. These grasses with the dominance of *Aleuropus agallocha* are found in the continental regions of the back mangrove.

On the Saurashtra coast the mangrove vegetation is very poor. The most common formations have a physiognomy of lowly cropped thickets (less than 2 m) which are very open but continuous in some places. The members of Rhizophoraceae are very rare. *Avicennia* forms gregarious populations. Some avicennias attain 7-8 m height and stand out distinctly from the rest of the vegetation to form a zone of *Avicennia* (*Avicennia marina* var. *acutissima*). The back mangrove behind this zone is composed of *Salicornia brachiata* and grass *Urochondra setulosa*. On the sandy clayey sites with salinity, *Suaeda fruticosa* and *Atriplex stocksii* may be locally abundant.

The tropical moist deciduous forest is distributed in Maharashtra, Karnataka and Kerala. The top canopy is characterized by *Tectona grandis*, *Terminalia* spp., *Pterocarpus* sp., *Salmalia malabarica* and *Lagerstroemia* sp. *Adina* is found in drier condition. The common second storey trees are *Schleichera* and *Careya*. The important constituents of the top canopy in non-teak bearing forest are *Pterocarpus marsupium*, *Salmalia malabarica*, *Terminalia* spp., *Anogeissus latifolia*, *Dalbergia latifolia*, *Lannea coromandelica* and *Madhuca indica*. The second canopy is characterized by *Miliusa*, *Gravia*, *Diospyros*, *Flacourtia* and *Polyalthia*. The main shrubs are represented by *Zizyphus*, *Casuarina*, *Helicteres* and *Desmodium*.

Tropical semi-evergreen forest occurring in strips between moist deciduous forest

TABLE 2 — DISTRIBUTION OF MAIN HALOPHYTES IN BOMBAY REGION

FAMILY	GENERA AND SPECIES	MANGROVE	BACK MANGROVE	OLD MANGROVE	SALINE SAND	GEOGRAPHICAL DISTRIBUTION
Acanthaceae	*Acanthus ilicifolius* L.	+	⊕	⊕		Tropical Asia + Australia
Aizoaceae	*Sesuvium portulacastrum* L.		+	⊕		Pantropical
Avicenniaceae	*Avicennia alba*	⊕	⊕	⊕		Asia, Australia
	A. officinalis L.	⊕	⊕			Tropical Pacific
Chenopodiaceae	*Arthrocnemum indicum* Moq.		+	⊕	+	India, Africa, Indonesia
	Salicornia brachiata Roxb.		⊕	⊕		India
	Salsola foetida Delile			+	⊕	India + Pakistan + Africa
	S. kali L.			+	⊕	Pantropical + Europe
	Suaeda fruticosa Forsk.		+	+		± Cosmopolitan
	S. maritima (L.) Dum		⊕ ⊕	+		± Cosmopolitan
	S. monoica Forsk.			+		India + Africa Moy. Orient.
Combretaceae	*Lumnitzera littorea* (Mack) Voigt.	⊕	+			Palaeotropical
Euphorbiaceae	*Excoecaria agallocha* L.	+	⊕	⊕		Asia Tropical + Pacific
Gramineae	*Aleuropus lagopoides* (L.) Trin.		⊕	⊕		Asia + Mediterranean + N. Africa
Myrsinaceae	*Aegiceras corniculatum* (L.) Bl.	⊕	+			Palaeotropical
Papillionaceae	*Derris trifoliata* Lour.	⊕	+			Palaeotropical
Potamogetonaceae	*Zannichellia palustris* L.			⊕		± Cosmopolitan
Rhizophoraceae	*Bruguiera cylindrica* W. et A.	⊕	+			Palaeotropical
	B. parviflora W. et A.	⊕				Tropical Asia + Australia
	Ceriops tagal (Perr.) Rob.	⊕	+			Pantropical
	Rhizophora apiculata Bl.	⊕				Asia Tropical
	R. mucronata L.	⊕				Palaeotropical
Salvadoraceae	*Salvadora persica* L.			⊕	+	India + Africa
Sonneratiaceae	*Sonneratia apetala* Buch. Ham.	⊕	+			India + Ceylon + Burma
	S. caseolaria (L.) Engl.	⊕	⊕			Asia + Australia tropical
Verbenaceae	*Clerodendrum inerme* Gaertn.		+	⊕	+	Palaeotropical (or Pantropical)

⊕, Formation where it is more frequent.
+, Formation where it is occasionally found (from Blasco, 1975).

is characterized by *Terminalia paniculata* with *Diospyros* sp., *Lagerstroemia lanceolata*, *Holigrana arnottiana*, *Lophopetalum wightianum*, *Machilus macrantha*, *Cinnamomum* sp., *Hopea parviflora* and *Artocarpus hirsuta*. The main associates of the second canopy are *Elaeocarpus* sp., *Mallotus*, *Diospyros assimilis* and *Ixora arborea*. The shrubs are characterized by *Strobilanthes* spp., *Webera* and *Ixora malabarica*.

The tropical dry deciduous forest occurs throughout the Indian Peninsula and it

merges with tropical thorn forest lee-ward of the Ghats. *Tectona grandis* is the characteristic constituent of the teak bearing forests and its typical associates are *Anogeissus latifolia* and *Terminalia* which are dominant in the non-teak-bearing forests and are accompanied by *Diospyros*, *Boswelia* and *Sterculia*.

The tropical thorn forest is distributed in Maharashtra, Mysore, Saurashtra and Kachchh. *Acacia* with a number of species and other allied genera are the characteristics of the southern thorn forest while fleshy euphorbias and *Capparis* are the important constituents. In the thorny forest of Kachchh and Saurashtra *Acacia* is widespread and *Capparis decidua* is the important tree. The fleshy *Suaeda* and *Salsola* are common on the saline soils while *Calligonum polygonoides* is common on the sandy soils.

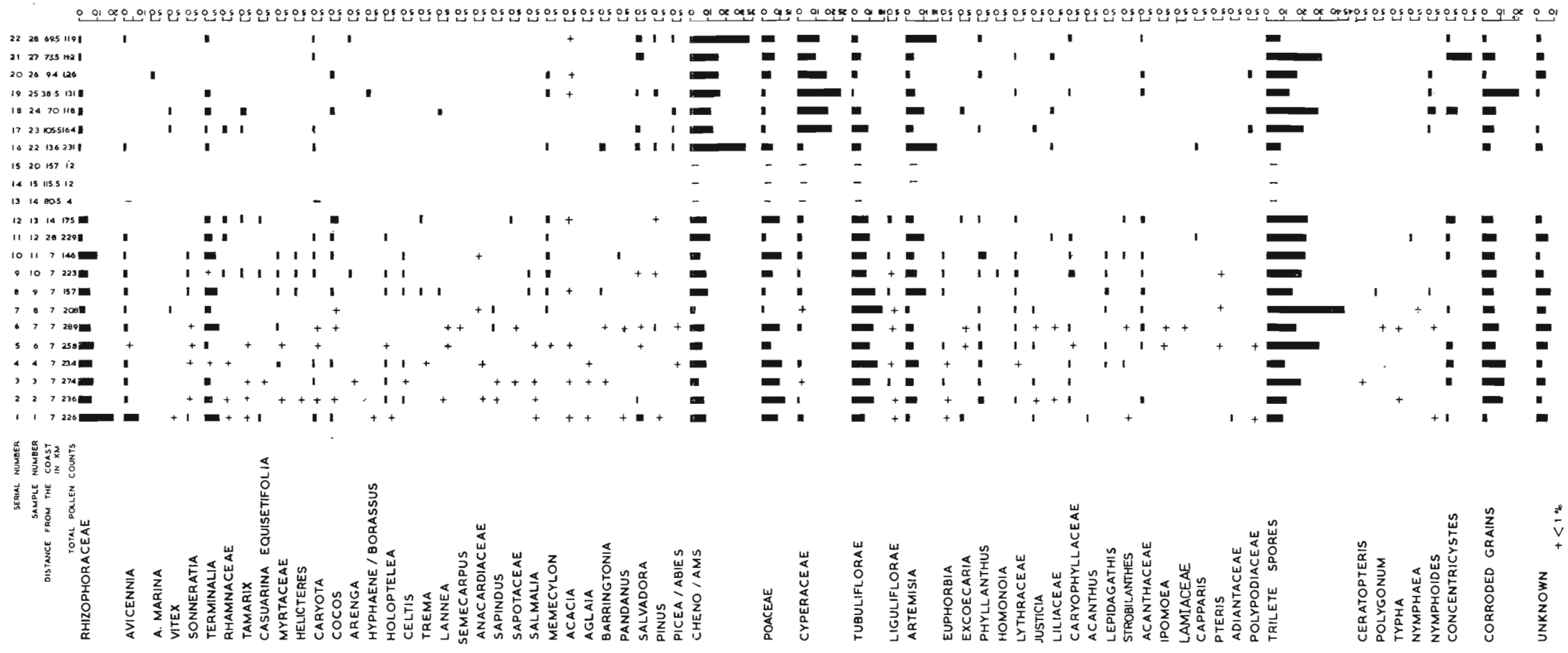
RESULTS AND DISCUSSION

All the 22 grab samples (except sample nos. 14, 15 & 20) have yielded a rich assemblage of pollen/spores. Pollen of mangrove vegetation trees and herbs and the pteridophytic spores have been identified while remaining ones have been kept as 'unknown' (Text-fig. 2). Corroded grains, which could not be identified, have also been counted.

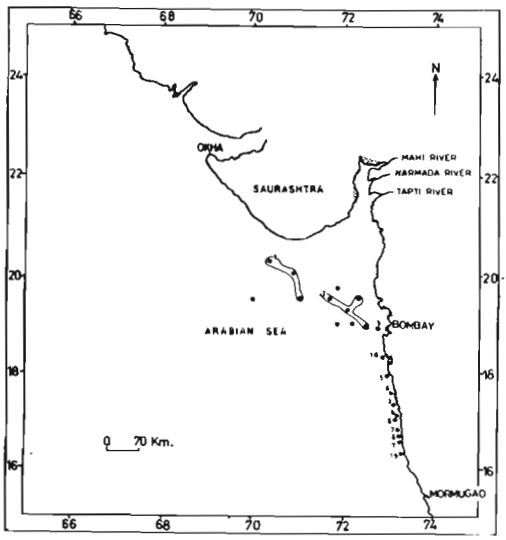
Distribution of Mangrove Pollen — The pollen of Rhizophoraceae are present (1-19 per cent) in most of the samples (Text-fig. 3) but are rich in sample nos. 1 to 4 and 6 to 13 from the shelf off Bombay. As these samples are from along the margin (off the coast) the variation in pollen frequencies is directly controlled by the population of the Rhizophoraceae in the mangroves. The sample nos. 22 to 28 from the shelf off Saurashtra have poor representation of Rhizophoraceae and this may be the reflection of poor occurrence of the Rhizophoraceae members in the salt swamps. The pollen of *Avicennia* are common (0.5-4 per cent) in the samples from the shelf off Bombay (Text-fig. 4). The percentage of the pollen of Rhizophoraceae and *Avicennia* in sample no. 1 is higher in comparison to all others. This may be due to some local effect or because of very healthy growth of mangroves in the area resulting in the high influx of pollen grains. The pollen of *Avicennia marina* have been found in sample no. 26 only. The pollen of *Sonneratia* have been found up to one per cent in the sample nos. 1, 9, 10 11 and are also present in sample nos. 2, 4, 6, 7 off Bombay (Text-fig. 5). *Salvadora persica* and *S. oleoides* which grow in salt swamps and mangroves are represented up to 4 per cent. Herbaceous species of mangroves, i.e. *Excoecaria* (1-2 per cent in sample nos. 1, 13, 14; present in sample nos. 6 and 7) and *Acanthus* (1 per cent in sample no. 1) have been recorded in a few samples from the continental shelf off Bombay. Pteridophytic spore resembling to that of *Acrostichum* (Adiantaceae), which is a typical mangrove plant, has been recorded in sample no. 1 only (less than 1 per cent). The pollen of Cheno/Ams (3-33 per cent) are found in all the samples and their percentage in the samples (nos. 22 to 28) from the shelf off Saurashtra is higher than in those off Bombay (Text-fig. 6).

Distribution of Arboreal Pollen Grains — The arboreal pollen of tropical forest are present in the samples off Bombay. The pollen of *Terminalia* range from 0.5 to 8 per cent and are higher in the sediments off Bombay (Text-fig. 7). The tropical forest taxa are represented by the pollen of *Salmalia* (0.5-1 per cent, Text-fig. 8), Sapotaceae (0.5-1 per cent), *Acacia* (0.5 per cent), Myrtaceae (0.5-1 per cent), *Helicteres* (0.5-1 per cent), *Sapindus* (0.5-1 per cent), *Memecylon* (0.5-2 per cent, Text-fig. 10), *Arenga* (0.5-1 per cent), *Caryota* (0.5-1 per cent, Text-fig. 9) *Acacia* 0.5-1 per cent), *Holoptelea* (0.5-1 per cent), *Trema* (0.5-1 per cent), *Celtis* (0.5-1 per cent) and Rhamnaceae (0.5-2 per cent).

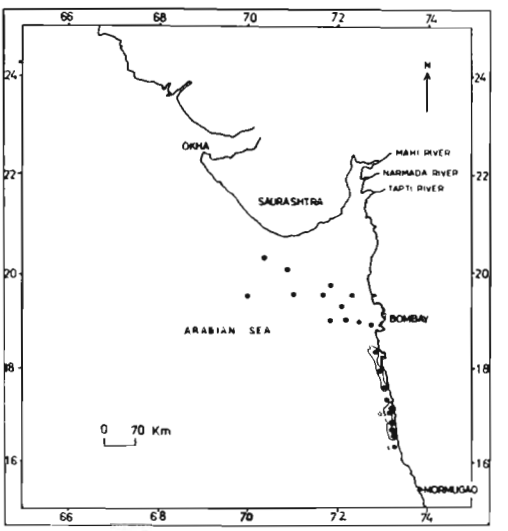
The beach forest taxa are represented by the pollen of *Cocos*, *Hyphaene* and *Borassus* (sample nos. 1, 2, 4, 7-9 & 11-13). The pollen grains of *Borassus* and *Hyphaene* are morphologically similar though each of them has a different phytogeographical distribution. *Borassus* is cultivated along the western coast of India while *Hyphaene indica* is cultivated in Saurashtra. The pollen representation of these plants is poor in our samples and from the phytogeographic point of view the pollen grains in the samples off Bombay may be regarded as of *Borassus* and those found in the samples off Saurashtra may be taken as of *Hyphaene*. The pollen grains of *Pandanus*



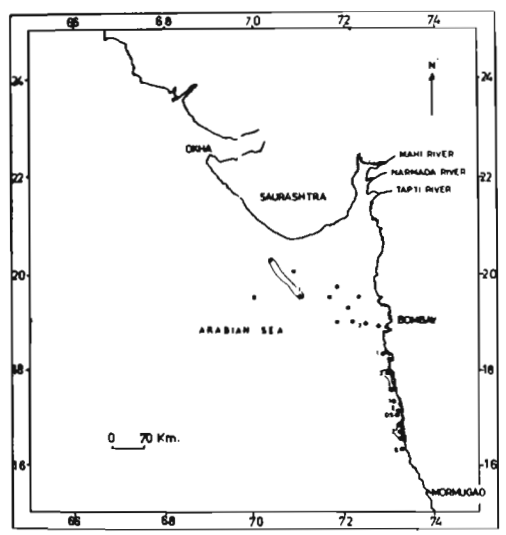
TEXT-FIG. 2 — Histogram showing the percentage frequency of pollen/spores in various samples.



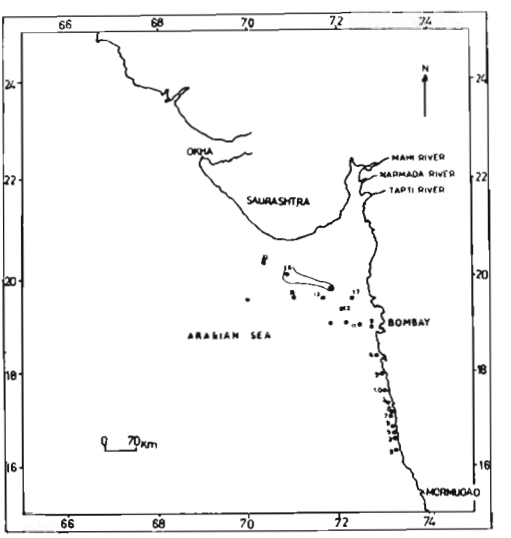
TEXT-FIG. 3 — Percentage distribution of Rhizophoraceae pollen.



TEXT-FIG. 5 — Percentage distribution of *Sonneratia* pollen.



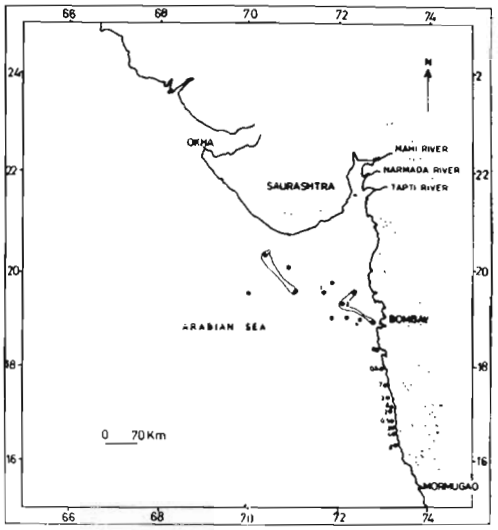
TEXT-FIG. 4 — Percentage distribution of *Avicennia* pollen.



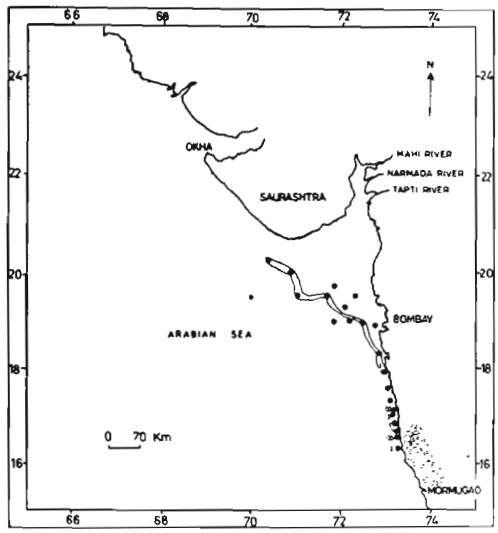
TEXT-FIG. 6 — Percentage distribution of Cheno/Ams pollen.

(0.5-1 per cent) is poorly represented in the near shore sediments off Bombay. *Casuarina equisetifolia* (0.5-1 per cent) is poorly represented in the samples off Bombay. The pollen grains of *Barringtonia* have poor representation in our samples. The *Tamarix* pollen (0.5-3 per cent) has the maximum concentration in sample no. 24, collected from 70 km off the coast.

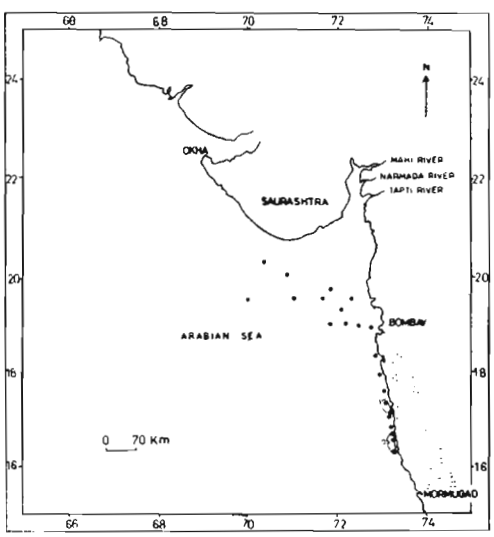
The pollen grains of *Pinus*, *Picea*/*Abies*, growing in Himalayas, are represented up to two per cent. The long distance transport of Pine pollen is due to wind transport. The Pine pollen equipped with air sacs are



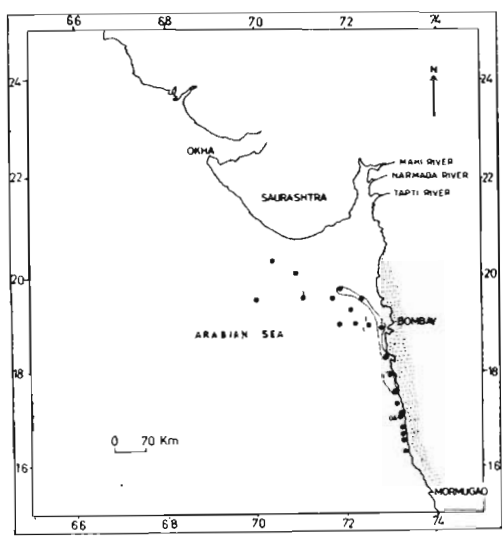
TEXT-FIG. 7 — Percentage distribution of *Terminalia* pollen.



TEXT-FIG. 9 — Percentage distribution of *Caryota* pollen.



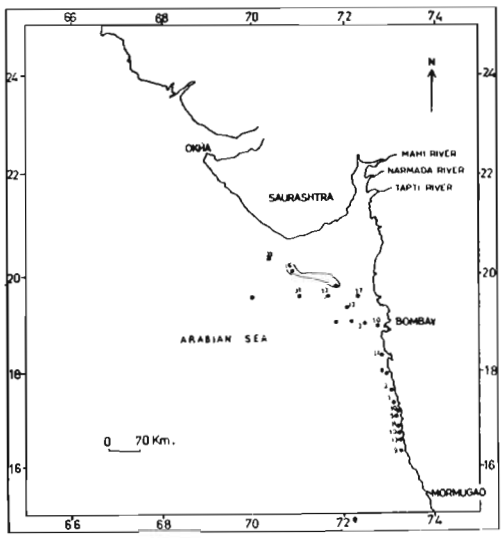
TEXT-FIG. 8 — Percentage distribution of *Salmalia* pollen.



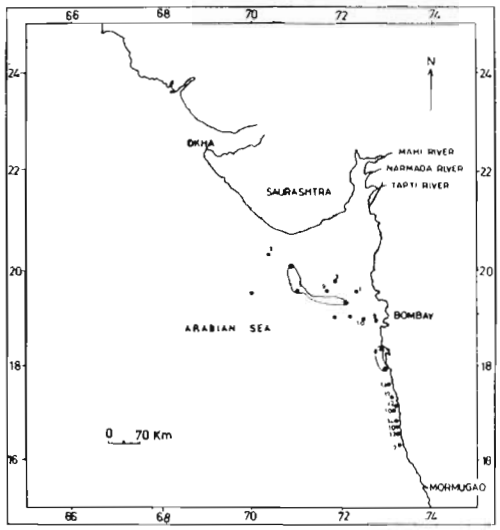
TEXT-FIG. 10 — Percentage distribution of *Memecylon* pollen.

much favoured for wind as well as water transport.

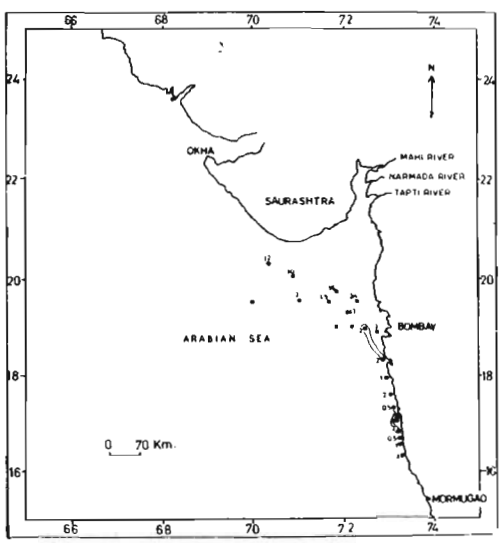
Distribution of nonarboreal Pollen Grains — The pollen grains of Poaceae (2-13 per cent) are present in all the samples (Text-fig. 11). Their percentage is higher in the samples off Bombay than those off Saurashtra. The members of Cyperaceae grow both on lake margins and the land (aquatic or upland) and their pollen percentage (0.5-24 per cent, Text-fig. 12) is higher in the samples off Saurashtra. The Asteraceae has been divided into Tubuliflorae, Liguliflorae and *Artemisia* type of



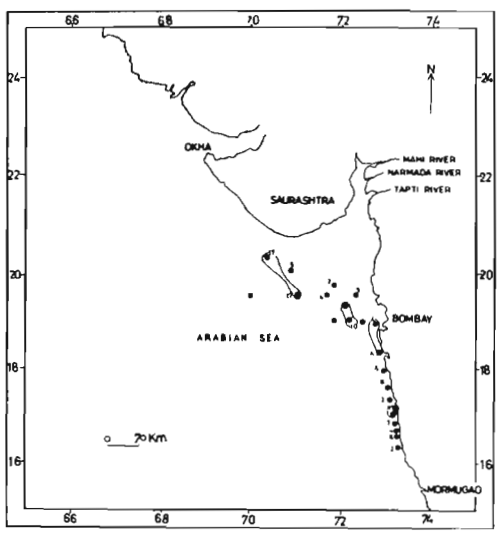
TEXT-FIG. 11 — Percentage distribution of Poaceae pollen.



TEXT-FIG. 13 — Percentage distribution of Tubuliflorae pollen.



TEXT-FIG. 12 — Percentage distribution of Cyperaceae pollen.



TEXT-FIG. 14 — Percentage distribution of *Artemisia* pollen.

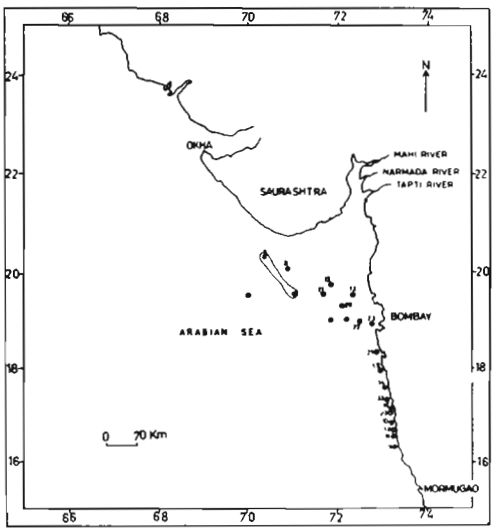
pollen. The pollen grains of Tubuliflorae (1-17 per cent) are common in all the samples and their relative frequency is higher in samples off Bombay (Text-fig. 13). Liguliflorae pollen (0.5-2 per cent) are found in a few samples (nos. 3, 9, 11, 13; present in nos. 1, 2, 4, 7, 8, 10) off Bombay and their representation is below 2 per cent.

The species of *Artemisia* are herbaceous to small shrubs; *A. parviflora* is a common herb which is found on the eastern side of Mahabaleshwar hills and on the road sides. *A. vulgaris* is abundant on the Ghats and Mahabaleshwar hills. The pollen (2-17 per cent) of this species have been found in all the samples (Text-fig. 14).

The relative frequency is 2-10 per cent except in two samples (22, 28) where it goes up to 17 per cent. The pollen grains of Euphorbiaceae belong to *Euphorbia* (0.5-2 per cent), *Phyllanthus* and *Homonoia*. The occurrence of *Phyllanthus* has been noticed almost in all the samples (1 to 4 per cent). The pollen of *Homonoia* have been recorded in sample no. 10 only. The herbaceous Lythraceous pollen (0.5-2 per cent) are more common in samples from the continental shelf off Bombay. The pollen of the herbaceous Fabaceae are occasionally found in some samples (up to 3 per cent). Caryophyllaceae pollen are common in the samples off Bombay. The pollen of *Justicia* (0.5-2 per cent), *Lepidagathis*, *Strobilanthes* and other types grouped under Acanthaceae (1-2 per cent) are poorly represented. *Lepidagathis*, an erect herb common in dry places, has been noticed in a few samples (1-2 per cent in sample nos. 4, 6, 8, 9, 10, 11). The pollen grains of *Strobilanthes* type have been recorded in a few samples (up to 1 per cent in sample no. 4 and 11; present in 1 and 6). *Strobilanthes* is a small shrub and is very common in under storey of evergreen and semievergreen forests. The pollen of *Ipomoea* (present in sample nos. 6 & 7), *Capparis* (less than 1 per cent in sample nos. 12, 22) and Laminaceae (present in sample no. 6) and Caryophyllaceae (0.5-3 per cent) are poorly represented in a few samples.

Distribution of Pteridophytic Spores — The spores of *Pteris* (0.5 per cent, present in sample nos. 6, 8, 10) and Polypodiaceae (2 per cent in sample no. 23, present in sample nos. 1, 6) have been identified. These spores are poorly represented in a few samples off Bombay. The spores of Osmundaceous, Ophioglossaceous and Selaginellaceous affinity have been grouped together as trilete spores and are common (8-43 per cent) in near shore sediments (Text-fig. 15). The presence of trilete spores may be explained from the river and lake discharge in the sea. The megaspore of Salaginellaceous affinity was recorded in sample no. 2 (off Bombay).

Distribution of Aquatic Spores and Pollen Grains — *Ceratopteris thallictroides*, a monotypic genus, grows throughout the tropics in quiet fresh water. The spores (0.5-1 per cent) of this plant are transported to



TEXT-FIG. 15 — Percentage distribution of trilete spores.

sea by the river and lake discharge and these have been recorded in sample no. 3 off Bombay. Pollen of *Polygonum* (1 per cent in sample no. 9; present in sample no. 7), *Typha* (present in sample nos. 2, 7), *Nymphaea* (1 per cent in sample no. 12; present in sample no. 8) and *Nymphoides* (1-4 per cent in sample nos. 9, 23 to 26; present in sample nos. 1 & 7) have been noticed. *Concentricystes* Rossignol (1962) is common in most of the samples (1-6 per cent) except in sample no. 26 where it goes up to 14 per cent.

Corroded grains which could not be identified have been found in all the samples (2-20 per cent). These grains are comparatively higher in the samples off Bombay. This may be because of the high rate of biological and chemical degradation and the physical effect of the water currents. As the samples do not represent off coast distance in one latitude, the corrosion effect could not be correlated with the distance. Fagerstrom (1964) concluded that in the marine environment dispersal and weathering processes are the most important component and the degree of corrosion is directly proportional to the distance off the coast. Absence or low number of thin-walled pollen such as those produced by the grasses in the marine sediments has been

noted by Koreneva (1964a), Stanley (1966a), Zagmijn and Veenstra (1967) and others.

The distribution of pollen/spores in marine sediments collected from the continental shelf off Bombay shows the significance of fluvial transport as an important factor controlling the pollen/spores influx. The wind transported taxa are poorly represented and most of the taxa seem to have been derived from the vegetation, relatively closer to the coast. It has been observed from the present study that the bottom sediments from the station numbers 22, 23, 24, 25, 26 27 and 28 have poor percentage of Rhizophoraceae with higher percentage of Chenopodiaceae and Cyperaceae. The growth of Rhizophoraceae is poor while that of Chenopodiaceae and Cyperaceae is comparatively higher on the Saurashtra coast. The pollen spectra of the bottom sediments from station nos. 22 to 28 is comparable to that of the vegetation in stand of the Saurashtra coast. The pollen of *Avicennia marina* have been found in one sample from the station number 26 (140 km off shore). *Avicennia marina* grows on the Saurashtra coast. This shows the transport of *Avicennia marina* pollen up to 140 km off the coast. On the other hand, samples from station nos. 1 to 13 show higher concentration of pollen of Rhizophoraceae. These samples have been collected along the coast (from the continental shelf) between Bombay and Marmugao. This result coincides with the vegetation along the coast in a general way.

The bottom sediments from the station numbers 14, 15 and 20 are almost barren of pollen/spores. The lithology of these sediments is sandy silt, sandy silt and silty sand respectively. Station numbers 14, 15 and 20 are approximately 73.5 km, 105 km, and 154 km from the nearest coast at water depth of 62.5, 70.0 and 88.5 m respectively. The poor representation of pollen grain in sample no. 20 (silty sand) is understandable which has more sand than silt. This observation to some extent matches with the finding of Cross *et al.* (1966) who showed that most of the sediments with more than 75 per cent sand are nearly barren of pollen and spores in the Gulf of California. The lithology of the sediments from station numbers 14, 15 and 22 is sandy silt. With varying depths, varying distances from the coast but with similar lithology, these sediments show different palynological results. Sample nos. 14 and 15 show poor yield of pollen/spores while the pollen/spore recovery from the sample no. 22 is quite high. It is not possible at the moment, exactly to interpret the reason about this variation in the percentage yield of pollen/spores from these samples having identical lithology. This may, however, be said that water depth of the stations and their distance (far or near) from the coast, are not the factors to explain the mentioned variation. Possibly the topography, certain chemical action or any other factor unknown to us have not allowed the deposition/preservation of pollen/spores in the sediments at the station nos. 14 and 15.

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