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PALYNOLOGICAL INVESTIGATIONS OF THE ARABIAN SEA: POLLEN/SPORES FROM THE RECENT SEDIMENTS OF THE GULF OF KACHCHH, INDIA

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ABSTRACT

The pollen analysis of the surface sediments from the Gulf of Kachchh, India shows mainly the type of the surrounding vegetation. The pollen grains of *Avicennia marina*, Chenopodiaceae, Poaceae and Cyperaceae are dominant in the assemblage. The shrubs are represented by the pollen grains of Chenopodiaceae and *Salvadora persica*. The pollen grains of *Acacia*, *Prosopis* and Rhamnaceae (*Zizyphus*) are poorly represented. The quantitative analysis shows higher percentage of the pollen/spores in the mouth than in the head region of gulf. On the other hand, the occurrence of the Hystrichosphaerids is higher in the head region than in the mouth of the gulf.

Key-words — Palynology, Chenopodiaceae, Poaceae, Cyperaceae, Hystrichosphaerids, Gulf of Kachchh, India.

सारांश

अरब सागर का परागाणविक अन्वेषण : कच्छ की खाड़ी (भारत) के वर्त्तमान अवसादों से प्राप्त बीजाणु/परागकण– राम रतन एवं अनिल चन्द्रा

कच्छ की खाड़ी के स्तरी अवसादों के परागाणविक विश्लेषण से मुख्यतया इसके आस-पास पाई जाने वाली वनस्पति का स्वरूप व्यक्त होता है। इस समुच्चय में एविसेनिआ मैरिना, कीनोपोडिएसी, पोएसी एवं साइप्रेसी के परागकणों की बाहुल्यता है। झाड़ीदार पौधे कीनोपोडिएसी कुल एवं साल्वेडोरा पर्सिका के परागकणों से निरूपित हैं। अकेसिआ, प्रोसोपिस एवं रहमनेसी (जिज़ीफ़स) के परागकण अल्प मात्रा में मिलते हैं। परिमाणात्मक विश्लेषण के आधार पर खाड़ी के शीर्ष-क्षेत्र की अपेक्षा मुख-क्षेत्र में परागकण/बीजाणुओं की उच्चतर प्रतिशतता व्यक्त होती है। इसके विपरीत मुख-क्षेत्र की अपेक्षा शीर्ष-क्षेत्र में हिस्ट्रिकोस्फ़ेयरिड्स अधिक मात्रा में मिलते हैं।

INTRODUCTION

THE palynological study of the oceanic sediments shows the relationship between marine and non-marine complexes. Such studies were carried out earlier by Koreneva (1964), Stanley (1966, 1969) Cross *et al.* (1966), Rossignol (1961), Horowitz (1966), Traverse and Ginsburg (1966), Muller (1959), Aoutin (1967) and Assemien (1969). Significant palynological contribution on the mangroves of India has been made by Das (1961-Calcutta, Goria & Sunberbone), Vishnu-Mittre and Guzder (1975—Bombay), Caratini *et al.* (1973—Pichavaram), Blasco and Caratini (1973—Pichavaram) and Mukherjee (1969, 1972—Gangetic Delta). On the basis of palynological studies Muller (1964) has shown the existence of mangroves in the Tertiary and Quaternary periods. Such studies are helpful in the interpretation of the palaeoclimate and may indicate the ancient shore lines (Assemien, 1969). Koreneva (1961) found that the content of spore and pollen in the terrigenous material of the surface sediments in the Mediterranean Sea is very low. She (1964) also observed the greatest concentration of the pollen grains in the argillaceous silts, high concentration in the depression sediments of the submarine relief and in the coastal region, where coarsely aleuritic and arenaceous fractions occur. Hystrichosphaerids are typical of near shore, shallow marine and brackish water environments

(Evitt, 1963). The fungal spores including other plant ingredients which are both terrigenous and marine in origin, do indicate the sedimentation and the distance from the coast.

In view of the great interest and importance attached to the oceanic sediments, a palynological exploration of these sediments from the Indian oceans was taken up in collaboration with the National Institute of Oceanography, Goa.

In 1982, Saxena, Chandra and Setty described the dinoflagellate cysts and acritarchs from the sediment cores of the Arabian Sea. Ratan and Chandra (1982) reported the occurrence of isolated thyriothecia from the subsurface sediments of the Arabian Sea.

The objectives of the present study are to find out the distribution and source of palynomorphs and their relationship with the major sediment types in the Gulf of Kachchh and also to observe the relationship of the pollen spectra with the surrounding vegetation in the high energy tide dominated environment in the Gulf of Kachchh. The present paper gives an account of the pollen/spore composition of the surface sediments (grab samples) from the Gulf of Kachchh and its relationship with the surrounding vegetation. The data on the pollen/spores, plant culticles and the hystrichosphaerids have also been discussed.

MATERIAL AND METHODS

The present study is based on the palynological analysis of 13 grab samples collected from the Gulf of Kachchh by the R. V. Gaveshani (Second Oceanographic Cruise, 1976). These samples were given to the Birbal Sahni Institute of Palaeobotany, Lucknow by the N.I.O., Goa for palynological investigations. The depth, latitude, longitude and texture of these sediments are shown in Table 1 and the location of the samples is shown in Text-fig. 1. The sediments are poor to extremely poor sorted and are polymodal indicating more than one source. The colour of the sediments is either medium light grey or light grey.

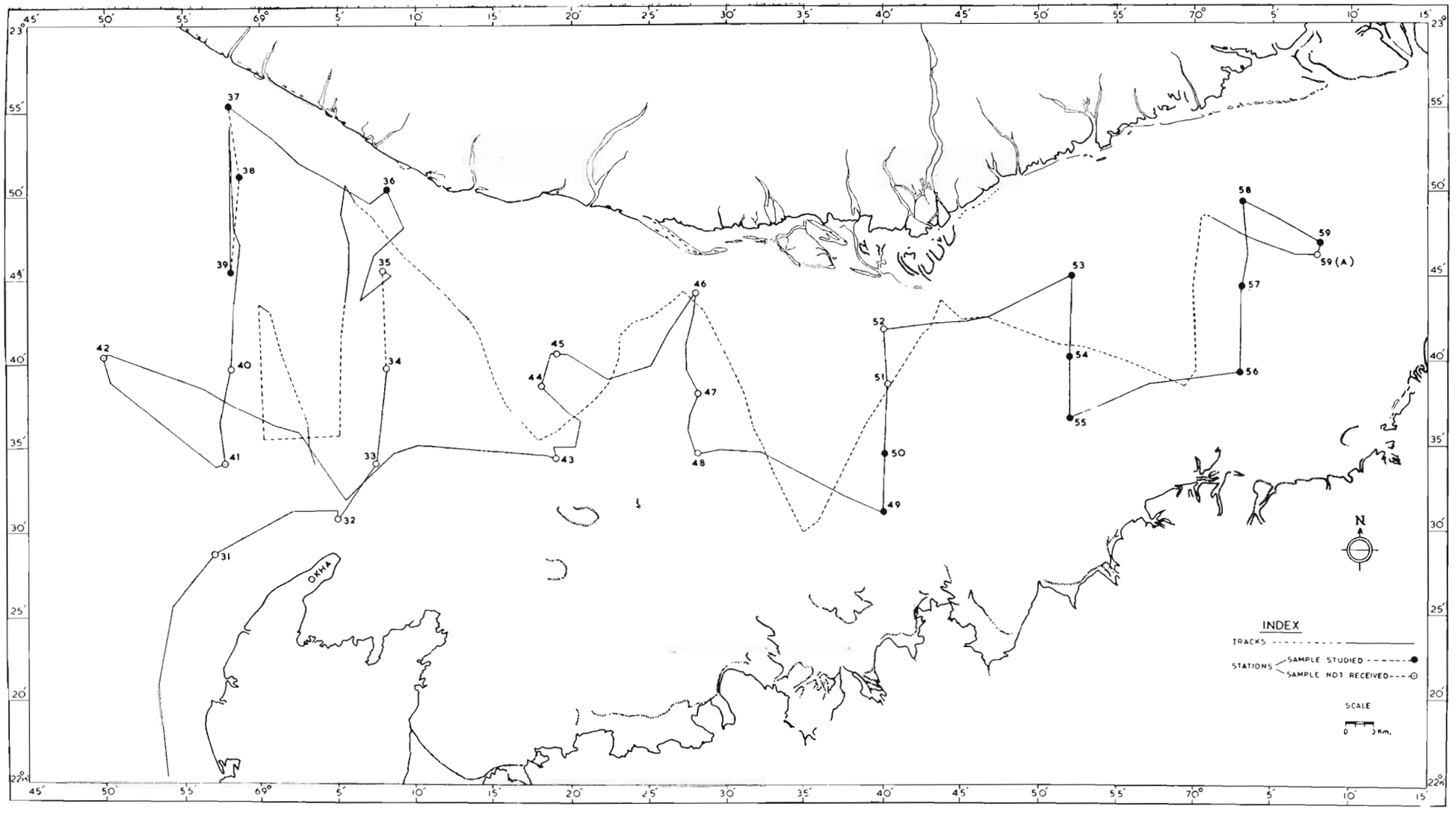
The samples were macerated by the standard procedure of Erdtman (1943). The pollen spectra are based on 100 grains per sample. The pollen identifiable up to family level have been assigned to their respective families. Plant cuticles have been categorized under two groups — those more than 100 μm and others less than 100 μm in size. The quantitative occurrence of the fungal spores was determined by counting them all under one group. Similarly all hystrichosphaerids have been counted under one group.

DESCRIPTION, BATHYMETRY AND GEOLOGY OF THE AREA

The Gulf of Kachchh, one of the identations found on either side of the Saurashtra

TABLE 1 — SHOWING THE STATION LOCATION AND OTHER DATA OF THE CRUISE SECOND R. V. GAVESHANI, GULF OF KACHCHH

No.	Station No. (Sample No.)	Position		Depth in m	Texture of the Sediments
		Latitude	Longitude		
1	36	22°50.2′N	69°08.2′E	17.0	Silty clay
2	37	22°55.4′N	68°57.9′E	16.0	Silty clay
3	38	22°51.0′N	68°58.6′E	15.0	Clayey silt
4	39	22°45.3′N	68°58.3′E	26.0	Silty clay
5	49	22°31.1′N	69°40.2′E	38.0	Sand silt clay
6	50	22°34.4′N	69°39.9′E	38.0	Silty clay
7	53	22°45.2′N	69°52.2′E	30.0	Sandy clay
8	54	22°41.7′N	69°52.2′E	39.0	Sandy clay
9	55	22°36.7′N	69°52.1′E	32.0	Clayey silt
10	56	22°39.4′N	70°03.1′E	22.0	Sand silt clay
11	57	22°44.4′N	70°03.1′E	21.0	Sand silt clay
12	58	22°49.5′N	70°03.0′E	21.0	Sand silt clay
13	59	22°47.0′N	70°08.2′E	15.0	Clayey silt



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

peninsula, has an area of about 7350 sq km and a maximum depth of 60 m. Its climate is semi-arid with the maximum rainfall of the order of 50 cm. It has, therefore, little run off from the land. The numerous rivers found on northern and southern coasts are mostly estuarine (Hashimi *et al.*, 1978). Bordering the Gulf at its head is the Rann of Kachchh, a desiccated region, which during the south-west monsoon gets innundated.

The Gulf is characterized by the strong prevailing water currents (average tidal range of 4 m) and rugged surface. Its floor is highly variable and consists of numerous topographic irregularities like pinnacles, as much as 10 m high separated by flat topped features. The topography at the north and at the middle of the Gulf is relatively more rugged as compared to the head of the Gulf (Hashimi *et al.*, 1978). The eastern part of the Gulf has rocks while most of the other areas are devoid of rocks. Near the mouth of the Gulf, Coralline algae and non-carbonate sands are found while reef corals are extensively developed in the centre. Towards the head, the corals are followed by shelly limestones and sand-stones and at the head, the bottom is composed of fine clays. Numerous islands also occur along the southern shores in water depths of 20 m or less.

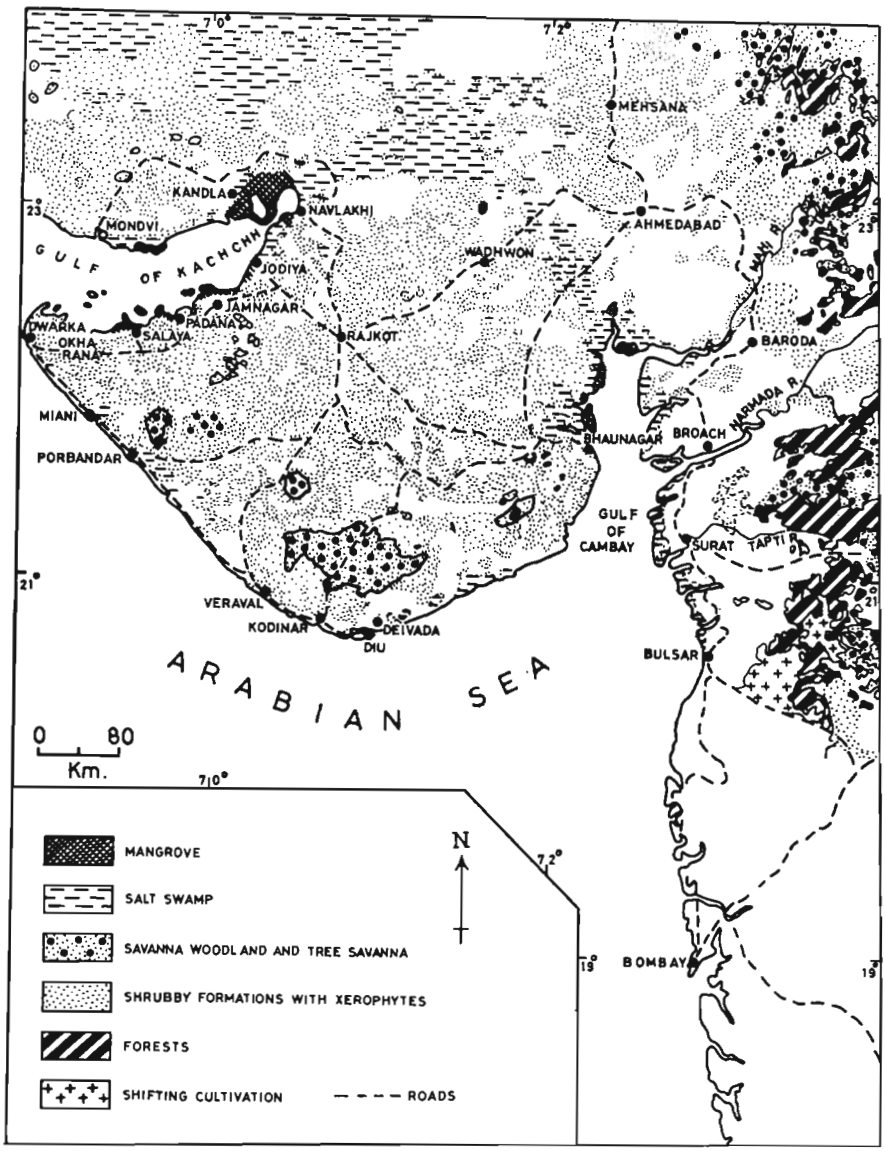
In 1972, Ahmad suggested that shelf will readily be formed in such situation where islands lie close to the mainland and the intervening basin would be rapidly filled by the sediments brought from the land. Kathiawar coast is marked by a lava interior. The south coast of Kathiawar appears to have been dominated by an East-West fault which might be a prolongation of the Narmada rift. The structural features of the lava influence the coast in north where basalt directly occurs on the shore. In other areas there is ribbon of coastal Tertiaries and Pleistocene wind blown sediments where terrestrial deposition is dominant and has stepped the coastal features (Ahmad, 1972).

The drainage divide of the area is formed by the discontinuous hilly back-bone in Kachchh. Rising from its southern slope, numerous streams abound from Kori creek in the west to the eastern terminus of the Gulf of Kachchh. They carve out their valleys for a few kilometers before uniting with the Gulf. North flowing streams (Kathiawar) unite with the Gulf and little rann, while south flowing streams get merge in the Arabian Sea. Thus the Gulf of Kachchh does not receive any permanent river.

VEGETATION SURROUNDING THE AREA

Mangrove Vegetation — The Gulf of Kachchh is surrounded by the largest ligneous halophytic formations of the region (Text-fig. 2). The growth of the mangrove vegetation is very poor in this area. The most common formation has a physiognomy of lowly cropped thickets (less than 2 m), continuous in some places but generally very open. The members of the Rhizophoraceae are very rare on the entire coast. *Avicennia marina* var. *acutissima* is the most important woody species which forms the gregarious population in this area. Under the best conditions, where the ruminants are absent, some *Avicennia* attain 7-8 m height and stand out distinctly from rest of the vegetation. The zonation is reduced to a zone of *Avicennia* (probably *A. marina* var. *acutissima*), behind which the back-mangroves are composed of *Salicornia brachiata* and a grass *Urochondra sentulosa* (Trin.) Hubbard. On the sandy clayey sites with high salinity, *Suaeda fruticosa* and *Atriplex stocksii* form the local thickets.

Tropical Thorny Forest — Shrubby xerophytic vegetation is mainly bushy and thorny. *Acacia arabica*, *Prosopis juliflora*, *Salvadora persica*, *Capparis decidua* and *Ziziphus* are some common plants of this region. The physiognomy of the vegetation is an under-shrubby discontinuous thicket and the soil appears almost naked, as though sterile, over vast areas. The vegetation becomes more dense locally, but it is never closed. Even amongst the dwarf under shrubs the flora is poor. It consists of *Suaeda fruticosa* (the commonest), *Salsola baryosma* and *Holoxylon salicornicum*. On the other hand, Poaceae and Cyperaceae seem to be better adopted to the hydromorphic conditions. These are more diversified and include *Aleuropus lagopoides*, species of *Cenchrus* (*C. setigerus*, *C. ciliaris*), *Sporopolus* (*S. marginatus*, *S. helvecticus*) and *Cyperus rotundus* amongst the sedges (Blasco, 1975, 1977).



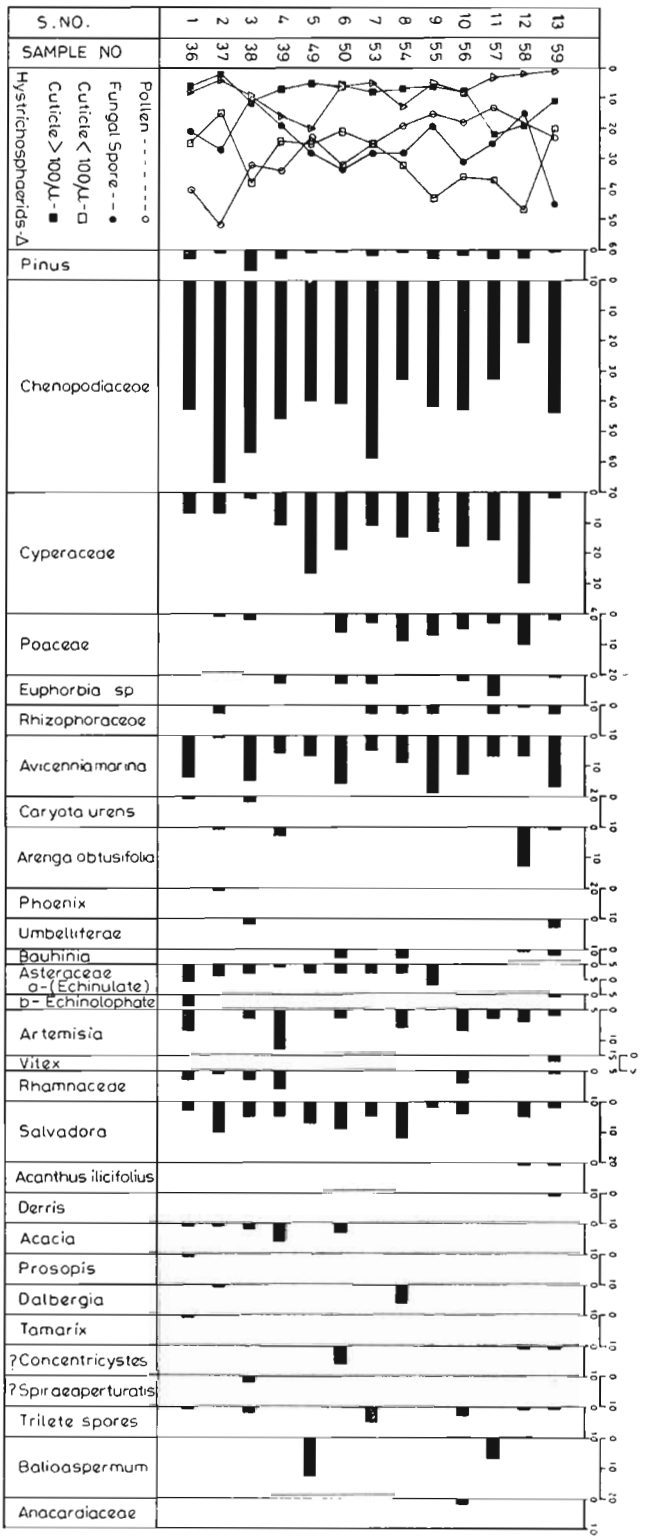
TEXT-FIG. 2 — A part of the map showing the vegetation map of Kathiawar (from Blasco, 1975).

Climate of the Area — The bioclimate of the mangroves of Kathiawar is hot with a rather cold season, sub-desertic with a very strong average thermal amplitude, i.e. about 12°C. The absolute minimum temperature in the Gulf of Kachchh is about 6°C during January. The soil is sandy loamy to silty loamy with moderately alkaline reaction. In January, the greater parts of Kachchh, Kathiawar and the area south of Cambay record temperature over 20°C, whereas the remaining north-eastern parts register between 17.5° and 20°C. During the month of April, the isothermal lines of 27.5° and 30°C trend north-south. The isobars of 1016 and 1017 mb. bend northward in Gujarat. The low pressure bars indicate pressure between 1002 and

999 mb. in July and the winds are westerly. The northern limit of the summer monsoon is marked by a line running from west to east and passing through the tip of the Gulf of Cambay. The climate of Gujarat in the south and south-west is mostly moist with an average rainfall of 150 cm; while the north-eastern portion is dry verging towards southern Rajasthan with a rain fall of about 50 cm. The topography and the direction of the winds govern the seasonal distribution of the rain fall which is uneven and irregular in several segments of the region.

POLLEN/VEGETATIONAL RELATIONSHIPS AND DISCUSSION

The pollen spectrum (Text-fig. 3) shows uniformity in pollen distribution in almost all the samples (4 to 24 km off the coast) collected from the Gulf of Kachchh. The pollen grains of Chenopodiaceae, Cyperaceae Poaceae and *Avicennia* are well-represented in all the samples. The dominance of shrubby and herbaceous pollen shows the open vegetation around the Gulf of Kachchh. The percentage frequency of the pollen grains of Chenopodiaceae is from 21-67%. Sample no. 37 (6 km off the coast) from the head region of the Gulf shows the highest percentage (67%) of Chenopodiaceae pollen. This is followed by the pollen grains of Cyperaceae (2-30%, highest in sample no. 58, 12 km off the coast), *Avicennia* (1 to 19%, highest in sample no. 55, 15 km off the coast), *Artemisia* (2-13%, highest in sample no. 39, 24 km off the coast), *Salvadora* (2-12%, highest in sample no. 54, 20 km off the coast), *Poaceae* (1-10%, highest in sample no. 58, 12 km off the coast) and other herbaceous pollen. The pollen grains of *Rhizophora mucronata* and *Rhizophora apiculata* are very much alike and those of *Bruguiera* and *Ceriops* are slightly different. All of them have been put under the family Rhizophoraceae for they all have the same ecology. The pollen spectrum shows very sparse occurrence of this group as is evident from the local vegetation also. The pollen grains of *Avicennia marina* have been found in all the 13 grab samples and this coincides with the dominance of *Avicennia* in the mangroves of this area. The members of Chenopodiaceae, viz., *Salicornia brachiata*, *Suaeda fruticosa* and *Atriplex stocksii* are dominant in the back mangroves while *Salsola baryosma* and *Haloxylon solicoricum* dominate the thorny vegetation and form the local thickets. The occurrence of Chenopodiaceae, *Avicennia marina*, Poaceae and Cyperaceae pollen and their uniform representation in all the samples can be understood by presuming that the travel time of a pollen grain from the source towards the Gulf is considerable to the extent that the pollen spectrum is not influenced immediately at the time of the pollination. The travel of the pollen grains is influenced by river-discharge, tidal cycles and the wind driven currents and this varies in duration from time to time and from particle to particle. The pollen/spores from different sources ultimately become mixed up so as to show their uniform distribution in various samples. Hirschberg and Schubel (1979) and Platt (1979) stated that much of the sediment is derived from the resuspension and this is an important mechanism near the sea bed. Praglowski (1977) showed that the transport by the currents and redeposition influence the pollen spectra. The small difference in the quantity of pollen deposition may be explained due to the action of water currents on the material sedimented on the bottom. The sediment which is stirred up every where from the bottom, from the basins rich in organic material and from the overlying unconsolidated, almost semifluid sediment stratum seems to remain in the lower water layers. This resuspended sediment is then transported by water currents and mixed up with the other sediment originating from different parts of the basin and from the different depositional strata. The resuspension of the pollen grains in the bottom and in the semifluid sediment is a continuous process. This is more intensive in shallow waters than in the deep water which occurs less in the central areas of the water basins than near the shores. Hashimi *et al.* (1978) on the basis of their study inferred that the nature of distribution of sediments is influenced by the high velocity tidal currents of the Gulf. As a sedimentary environment the Gulf may be said to be tide dominated. The principal tidal influence appears to have its role in transporting sediments from adjoining shelf into the



TEXT-FIG. 3 — Histogram showing the percentage frequency of pollen/spores in various samples.

Gulf. Redistribution of the sediments results from the interaction of the tidal current with irregular topography of the Gulf.

The genus *Pinus* grows in the Himalayas and its occurrence in all the samples from the Gulf of Kachchh obviously shows long distance transport by wind. The pollen grains of *Bauhinia*, *Caryota* and *Arenga* are mainly wind transported from the inland vegetation. The pollen grains of *Phoenix* and *Tamarix* which have been found in sample nos. 37 and 36 (6 km and 4 km off the coast) may be wind transported. The components of shrubby vegetation, *Acacia* (6%), *Prosopis* (1%) and Rhamnaceae (6%) are poorly represented. *Salvadora* is represented almost in all the samples (up to 12%). The pollen grains of Asteraceae have been grouped under Echinulate, Echninolophate and *Artemisia* types. *Artemisia* pollen grains have fair representation and are more common towards the head region of the Gulf (maximum up to 13%). The pollen grains of *Artemisia* are very small and are produced in large numbers. These are easily dispersed and so may be found in samples far from the nearest occurrence of this genus. On the whole, it has been found that the percentage frequency of the pollen/spores is higher in the grab samples collected from the mouth than those from the head region of the Gulf of Kachchh.

In addition to the pollen and spores, other plant fragments, formed by the break down of the plant matter, have been found in the bottom sediments. Cuticular material, dissociated woody tissues and other vascular fragments are also found in significant quantity in all the samples. The distribution of cuticle, woody fragments and fungal spores show higher concentration in the mouth region than in the head of the Gulf of Kachchh. We believe that the majority of the tracheids and fragmentary cuticles have been derived from the mainland. The coarser plant fragments settle earlier and near the shore. In general, the larger plant fragments are found near the shore. On the contrary, it has been observed that the percentage frequency of the hystrichosphaerids (Text-fig. 3) is higher in the surface sediments from the head region (5-15%) than those of the mouth (1-12%) in the Gulf of Kachchh. This may be because of the increase of marine influence in the head region. ?*Concentricystes*, an artificial genus of unknown affinity (probably fluviatile in origin), has been found in a few samples (nos. 50, 58, 59 approx. 18, 12 and 18 km off the coast respectively) from the mouth region. Another spore-like body ?*Spiraeaperturatis*, 10-15 μm in diameter, with spiral bands was found only in sample no. 38 (12 km off the coast).

CONCLUSION

The pollen grains of mangrove plants are present in all the bottom samples from the Gulf of Kachchh. The herbaceous pollen grains dominate the spectra. The inland thorny vegetation is represented poorly by *Acacia*, *Salvadora*, *Prosopis* and *Tamarix*. The wind transported pollen of *Arenga*, *Caryota* and *Phoenix* in our samples should have been derived from the western coast of India.

The presence of *Avicennia* pollen in significant percentage in our samples may be due to water turbulence. Pollen of the wind pollinated plants are shed into the air and most of them settle in a few kilometres unless the air is extremely turbulent. Once delivered to water, either directly or indirectly being washed away from the terrestrial surface, pollen grains behave in the same way as any other particle would do with the similar physical properties. So the distribution of pollen may be the result of sedimentary process. It has also been observed that the relative frequencies of pollen/spore are extremely low in the coarser sediments. Cross *et al.* (1966) showed that most of the sediments with more than 75 per cent sand are nearly barren of pollen and spore in the Gulf of California. Muller (1959), Hoffmeister (1954), De Jekhowsky (1963), and Van Andel and Postma (1954) have indicated the typical pattern of decrease of pollen and spore off the shore. This pattern, however, is not applicable in the Gulf of Kachchh (a restricted basin) where much control of pollen and spore distribution is exerted by both wind and water deposition from the three shores. Furthermore, the circulation is modified by various geomorphological features of the basin, wind pattern, etc. The high concentration of the pollen-spore in the mouth region of the Gulf of Kachchh may

be the result of higher deposition rate and the action of marine current.

Our studies based on the grab samples from the Gulf of Kachchh support the idea that the pollen once delivered to the water are sedimented in the same way as other particles do in the same range of size and specific gravity. The pollen types found in the sediments are mainly common to the species found on the bank. Proximity to the source vegetation, however, is not a limiting factor, for respectable concentration of pine pollen is found in the sediments. Pine pollen is buoyant and has been reported to travel great distance in the air. It is suggested that further palynological studies should be carried out on the sediments from the Indian oceans in space and time and this study is likely to add promising results to this interesting aspect of Oceanography — the marine palynology.

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