Study on the sedimentary facies, spore-pollen and palynodebris of Mud Bank and Vembanad Lake, Kerala

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The paper attempts a comparative study of sedimentary facies and the occurrence of palynofossil and palynodebris in Alleppey and Quilandy Mud Banks and Vembanad Lake, Kerala. Sediment cores from Quilandy offshore and Vembanad Lake were studied. The sediments at Alleppey are dominated by silty clay and the most dominant litho-unit in Quilandy is clay. In Vembanad Lake, the finer particles are concentrated in the middle part of the lake.Spores and pollen are more common near the shore and dinoflagellates dominate in a seaward direction. Spores are mostly represented by *Ceratopteris* and *Pteris* types while pollen, structured terrestrial and biodegraded terrestrial organic matters, foraminifera are also common. The structured and biodegraded terrestrial types are very common along the shore and foraminifera in the offshore region.

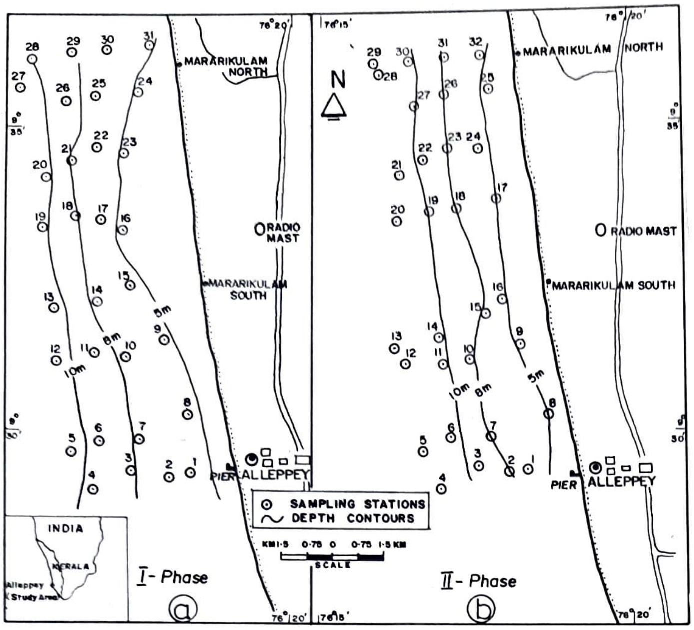
Key-words—Sedimentary facies, palynology, palynodebris, Mud Bank, Kerala.

INTRODUCTION

KERALA, situated at the southwest part of India, is bestowed with 41 west flowing rivers, estuaries and a coast line running up to 560 km. The coming up of Mud Banks is an unique phenomenon, appearing at certain selected locations along the Kerala Coast during the southwest monsoon. Mud Bank may be defined as patches of calm, turbid water with heavy load of suspended matter with a clayey substratum, which appear during the southwest monsoon along the southwest coast of India. Occurrence of Mud Banks has been reported since 1678. Bristow (1938) published a narrative account of Mud Banks based on his observations and previous work. Seshappa (1953) and Seshappa and Jayaraman (1956) started a systematic scientific investigation on Mud Banks. A comprehensive appraisal on the different modes and theories on the formation of Mud Banks and the multitudes of parameters involved in its triggering are described by Mallik and Ramachandran (1984). Detailed account of the sedimentological and geochemical aspects of the Alleppey and Quilandy Mud Banks were reported elsewhere (Ramachandran & Mallik, 1985; Ramachandran & Vasudevan, 1987; Mallik *et al.*, 1988; Ramchandran, 1989).

Vembanad Lake, the largest estuary of Kerala, extends to a length of 83 km with a maximum width of 8 km with an area of approximately 205 sq km. Five rivers, namely, Moovattupuzha, Meenachil, Manimala, Pamba and Achankovil debouch into the estuary. It has an opening at Cochin. A salt water barrage was commissioned at Thanneermukkom in 1974, which remains closed during January to May. This prevents mixing of saline water of the north with the fresh water of south during these months. Various sedimentological and geochemical aspects of Vembanad Lake sediments were discussed by Murthy and Veerayya (1972,1981), Veerayya and Murthy (1974) and others. Mallik and Suchindan (1984) discussed the bathymetry and mineralogy of the sediments of southern part of the lake and the mode of formation of the lake based on the study of landsat imagery. Various biological and chemical studies were conducted by Devassya and Bhattacheri (1974), Jayalakshmi *et al.* (1986) and Madhupratap (1979).

This paper attempts (i) to compare and contrast the sedimentological characteristics of the Alleppey and Quilandy Mud Banks with that of Vembanad Lake and (ii) to trace the sedimentary facies based on the palynological assemblage.



Text-figure 1. Sampling stations and bathymetry off Alleppey :(a) First Phase (b) Second Phase.

MATERIAL AND METHODS

The first phase sampling and surveying was carried out during July 1983 in an off shore area of 60 sq km between Alleppey Pier and Mararikulam. Surface sediment samples from 31 locations were collected using Petersen grab along with depth measurements using a lead line. The location were fixed using Mini Ranger III. During December 1983, the second phase survey was carried out in the same area and sediment samples and depth data from 32 locations were collected. In May, 1984, using a trawler" Devi", 33 grab samples were collected from Quilandy nearshore (Kadalur Point to Kadalur). Sampling stations were located using Theodolite intersections and depth measurements were carried out by a lead line. Collection of surface sediment samples and bathymetric survey in the southern part of Vembanad Lake was conducted during November-December 1981. Surficial sediment samples were collected from 88 locations and the position fixing was done using the method of theodolite intersections from two fixed points in the shore. Sediments were analysed by conventional sedimentological techniques (Carver, 1971).

For palynodebris analysis, 5 gm of sample were kept in Hydrofluoric acid (40%) for 48 hours to dissolve silica followed by several washes in cold water to neutralize the acid. The macerates were then spread with Polyvinyl alcohol on a cover slip and mounted on a glass slide with canada balsam.

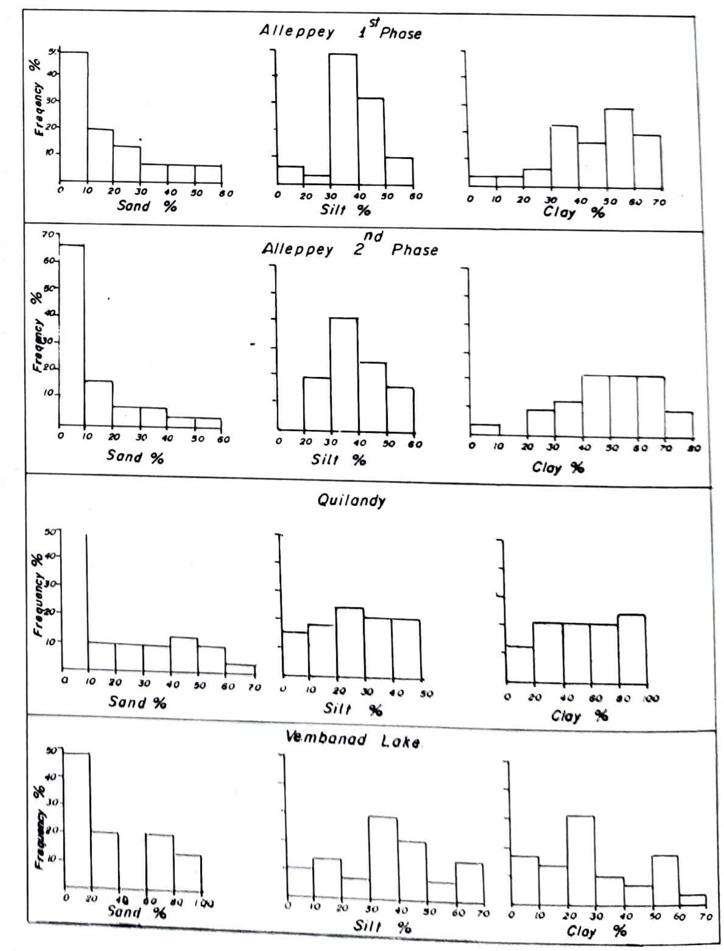
The samples for palynological investigation were boiled in water with 10% Potassium hydroxide solution for half an hour. It was washed several times with cold water and then treated with Hydrofluoric acid (40%) for 48 hours. The samples were then washed and acetolyzed and sieved (mesh size 10 μm). The slides were made in Polyvinyl alcohol and mounted in canada balsam.

RESULTS AND DISCUSSION

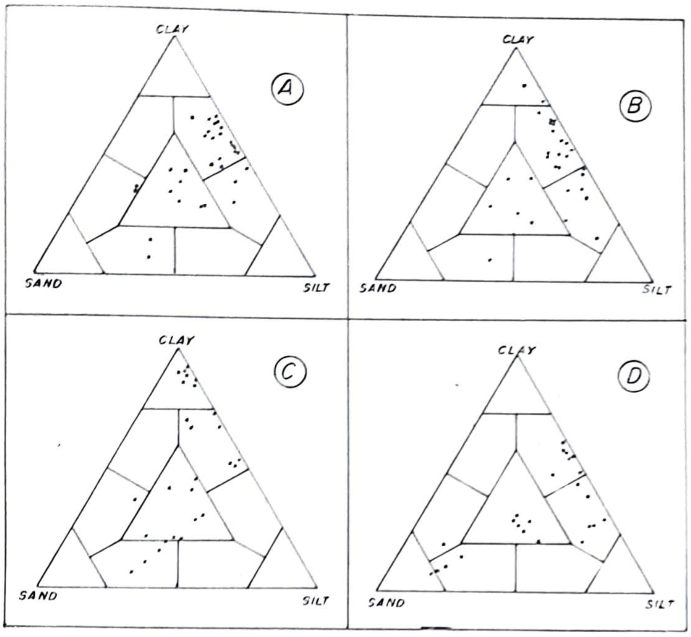
Alleppey First Phase—The bathymetry and locations for the first phase of sampling is given in Text–fig.1 . The 10 m isobath is parallel to the coast whereas, the 5 m and 8 m depth contours show an offshore shift in the central portion. Ramachandran and Mallik (1985) attributed this shift to the piling up of mud towards the central part during the Mud Bank formation, as documented by silt/clay ratio.

The textural entities of sand, silt and clay are present in varying proportions (Text–fig.2). Sand percentage ranges from 1.27 to 55.67 and half of the samples contain 10% sand. It shows that only a few samples contain sand above 30%.The range for silt is between 19.14 and 55.29%. Frequency distribution depicts a maximum number of samples yielding 30-40% silt. There is wide variation in the clay percentage (7.74 to 66.14) and majority of the samples contain clay above 30%.

The ternary diagram (Text–fig.3A) classifies most of



Text-figure 2. Histogram showing frequency distribution of sand, silt and clay in the sediments.



Text-figure 3. Ternary plot of sand-silt-clay :(A) Alleppey First Phase. (B) Alleppey Second Phase. (C) Quilandy and (D) Vembanad Lake.

the Alleppey First Phase samples as silt-clay followed by sand-silt- clay and clayey silt (Shepard, 1954). Clayey sand and silty sands are in minor amounts. Sediment distribution map (Text-fig.4) shows no appreciable textural gradation. From coast to offshore silty clay sediments cover major area. A small semicircular patch of clayey sand bordered by sand-silt-clay can be seen in the northern part. A tongue-shaped silty sand distribution near the pier is bordered by sand-silt-clay sediments and extends as a parallel patch up to the central portion.

Absence of rivers in the coastal stretch extending from Cochin to Thottapally is significant. The near shore sediment supply is mainly controlled by Cochin and Thottapally inlets during the tidal cycle and by the offshore mud deposits (Ramachandran & Mallik, 1985). During the Mud Bank formation the wave transformation and divergence help in the transportation and deposition of mud in the Mud Bank site.

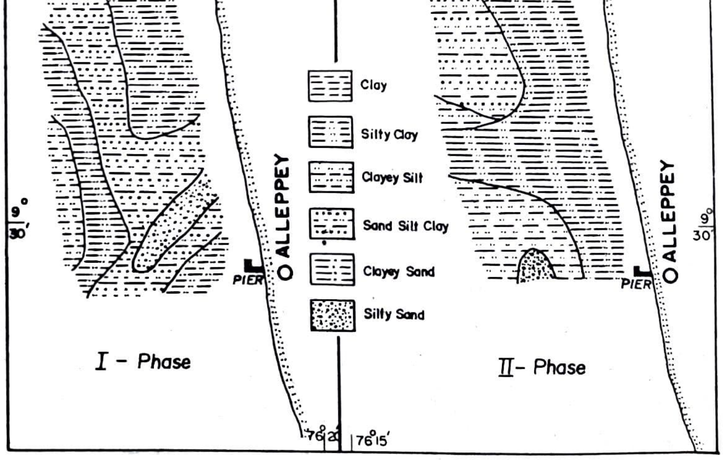
Alleppey Second Phase—The isobaths show a striking similarity with the coast unlike the first phase (Text–fig. 1). Mud erosion during the post-monsoon season causes more shift in the depth contours towards the coast. Reversal in the nearshore current direction from south to north after the monsoon results in the process of dispersion and transportation of sediments.

In comparison with the first phase samples, granulometric analysis is not suggestive of a textural fractionation and grading (Text-fig.2). With a sand range between 0.08 to 54.73% more than 65% of the samples are contained with 10% sand. Silt minima is 21.74% showing a higher frequency around 30-40% and ranges to maximum percentage of 58.27. Enrichment of clay compared to the first phase is not noticed with a per cent variance from 8.97 to 76.81 and an higher frequency between 40-70%.

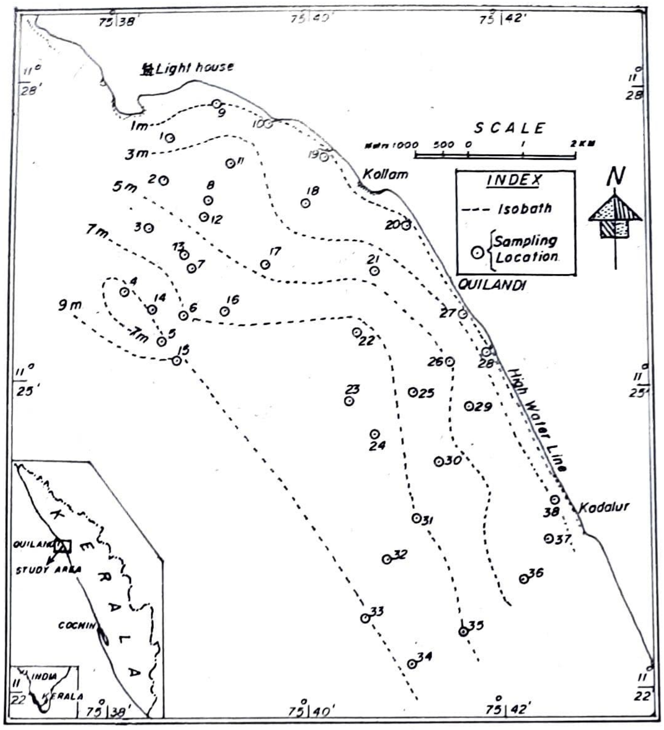
As in the case of first phase samples, silty-clay textural class predominate followed by sand-silt-clay and clayey-silt (Text-fig.3B). Only a single sample falls within the clay band and another sample in silty-sand zone. The surficial sediment distribution of sediments (Text-fig.4) is dominated by silty-clay texture with patches of sand-silt-clay. A small silty-sand zone in the north and clay patch in the centre are also observed apart from a tiny band of clayey-silt. Areal variations in the textural classes in both the phases do not indicate any sympathetic relationship in accordance with the sediment dynamics in the near-shore.

During the fair season (November-April), wave climate undergoes considerable change (Thomas & Baba, 1983). The effect of wave refraction on the direction of wave approach is more during fair season compared to rough season. The strong southerly long-shore current during the monsoon changes to a weak northerly current during October (Hameed, 1988). Consequently, the sediments are carried away by the longshore/offshore currents from the nearshore area. Ultimately, the sediments deposited during the Mud Bank formation gets eroded after its cessation.

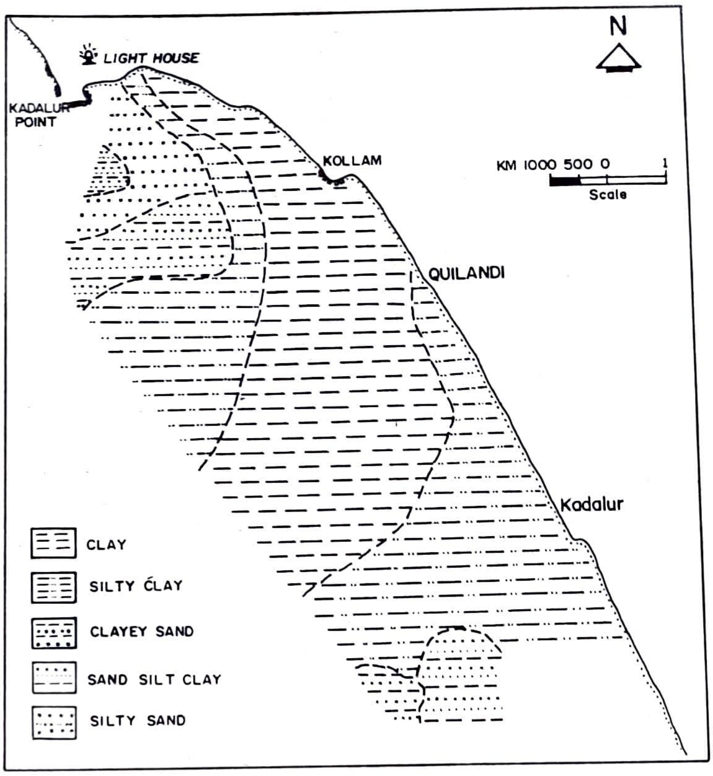
Palynological analysis involved a study of palynodebris and palynofossils grouped into 8 categories according to their ecological habitat. These are coastal, low land, fresh water, mangrove, high altitude floral element, ferns, fungal remains and foraminifera.



Text-figure 4. Sediment distribution off Alleppey.



Text-figure 5. Sampling stations and bathymetry off Quilandy.



Text-figure 6. Sediment distribution off Quilandy.

The term palynodebris (see Frederiksen *et al.*, 1982) is generally used to accommodate dispersed, particulate organic matter present in the sediments. Later workers like Pocock, Vasanthy and Venkatachala (1989) also included amorphous organic matter in it.

For the present investigation, palynodebris is classified in to inertinites, structured terrestrial, pollen and spore, charcoal, biodegraded terrestrial, amorphous (terrestrial and marine), amorphous (grey), structured marine, foraminifera, fungal and resin. Amongst these entities, structured terrestrial, biodegraded terrestrial and foraminifera are very common in Alleppey and Quilandy while in Vembanad Lake structure terrestrial and biodegraded terrestrial are found in abundance.

Alleppey— In Alleppey first and second phases there is no appreciable change in palynodebris depositional pattern. In all the samples, structured terrestrial and biodegraded terrestrial types are dominant in the proximity of the shores. Foraminifera are represented more away from the coast. Pollen and spore, charcoal,

Plate 1 →

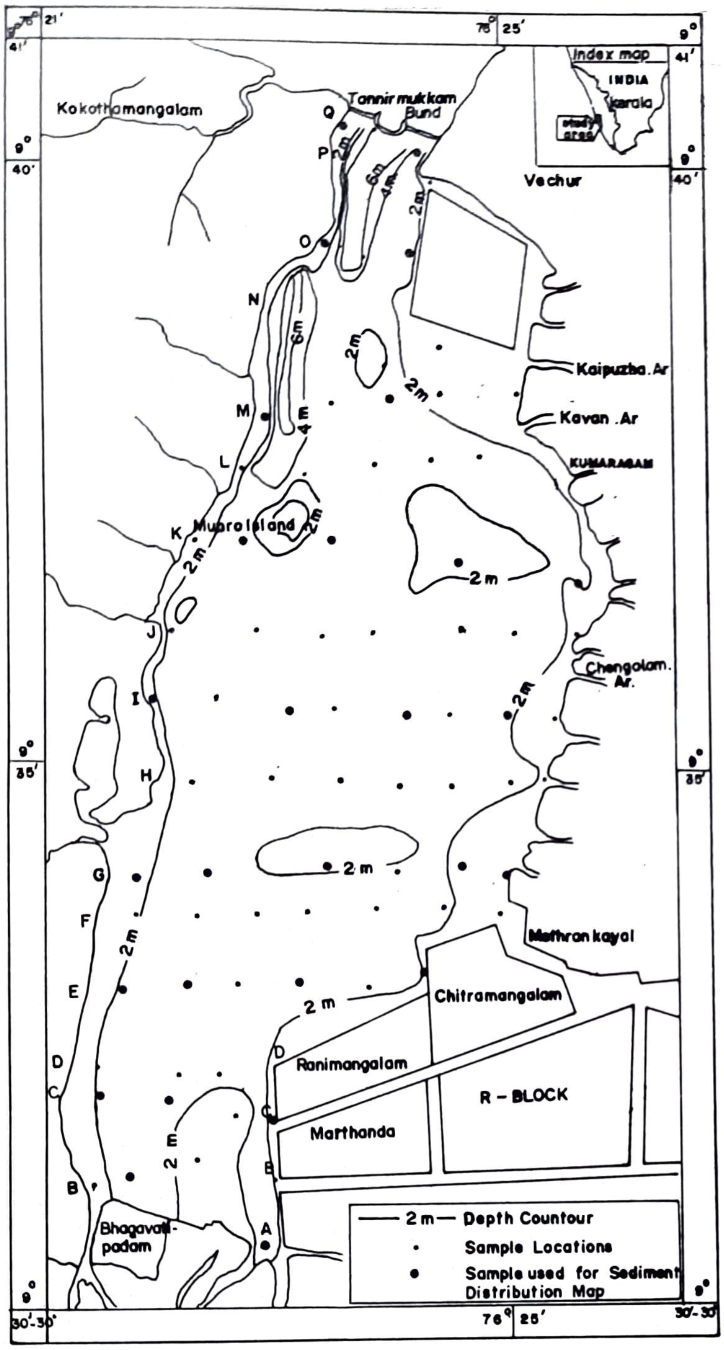
(All photomicrographs are enclosed ca. x 500, unless otherwise mentioned)

1. Pollen of Amaranthaceae
2. Pollen of Chenopodiaceae
3. Pollen of Poaceae
4. Pollen of Verbenaceae
5. *Podococcus* sp.
6. Pollen of Sonneratiaceae
7. Spore of *Pteris wallichiana*
8. Spore of *Polypodium brasilliense*
9. Pollen of Araliaceae
10. Pollen of Tiliaceae
11. Spore of *Cheilanthus tenuifolia*
12. Spore of *Adiantopsis radiata* (ca. x 1,000, note the clavate spines)
13. Spore of *Selaginella* sp.
14. Pollen of *Cullenia exalirata*
15. Pollen of Sapotaceae
16. Pollen of *Cocos nucifera*
17. Pollen of Acanthaceae (ca. x 1000)
18. Spore of *Adiantopsis radiata* (ca. x 1000, note the pointed spines)
19. Pollen of *Madhuca* sp.
20. Pollen of *Strobilanthes* (*Supuspa*) *scrobiculata*
21. Spore tetrad of *Adiantopsis radiata* (ca. x 1000)
22. Spore of *Ceratopteris thalictroides* (ca. x 250)
23. Pollen of *Durio* sp.

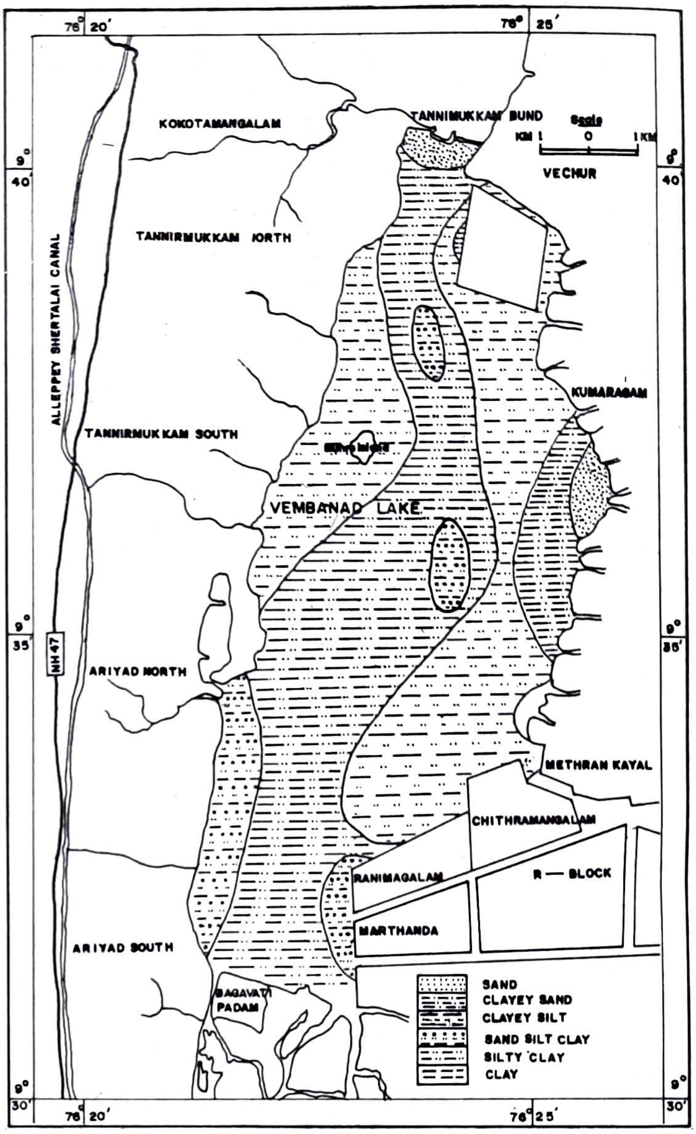
24,25. Pollen of *Hibiscus tiliaceous*

26. Pollen of *Bombax ceiba* (ca. x 1000)

Plate 1



Text-figure 7. Sampling stations and bathymetry in the Vembanad Lake.



Text-figure 8. Sediment distribution in the Vembanad Lake.

structured marine, fungal and resin are either absent or meagrely represented. Palynological contents in Alleppey first and second phases are more or less the same in their composition. In both phases fossils representing coastal and low land vegetation, ferns, phytoplankton and forminifera are well represented. Palynofossils of the coastal vegetation are mostly contributed by *Cocos* whereas the ones of lowland flood plain by *Ceratopteris*. The other fern spores generally found are *Osmunda*, *Polypodium* and *Pteris*. *Peridinium*, *Spiniferites* and *Tuber-*

Plate 2

→

1. Pollen of *Diospyros chloroxylan* (*ca.* x 1000)
2. Pollen of *Chrysalidocarpus* sp.
3. Spore of *Dendryphiella salina*
4. *Peridinium conicum*
5. Trochoid foraminifera
6. Pollen of *Madhuca indica*
7. Spore of *Trichopteris* sp. (*ca.* x 1000)
8. Spore of *Dryopteris* sp.
9. *Peridinium oblongum*
10. Unidentified pollen (*ca.* x 1000)
11. Pollen of Liliaceae
12. Dinoflagellate
13. Spore of *Spirogyra*
14. Spore of *Lycopodium* sp. (*ca.* x 1000)
15. Trochoid foraminifera
16. *Tuxtularia* sp.

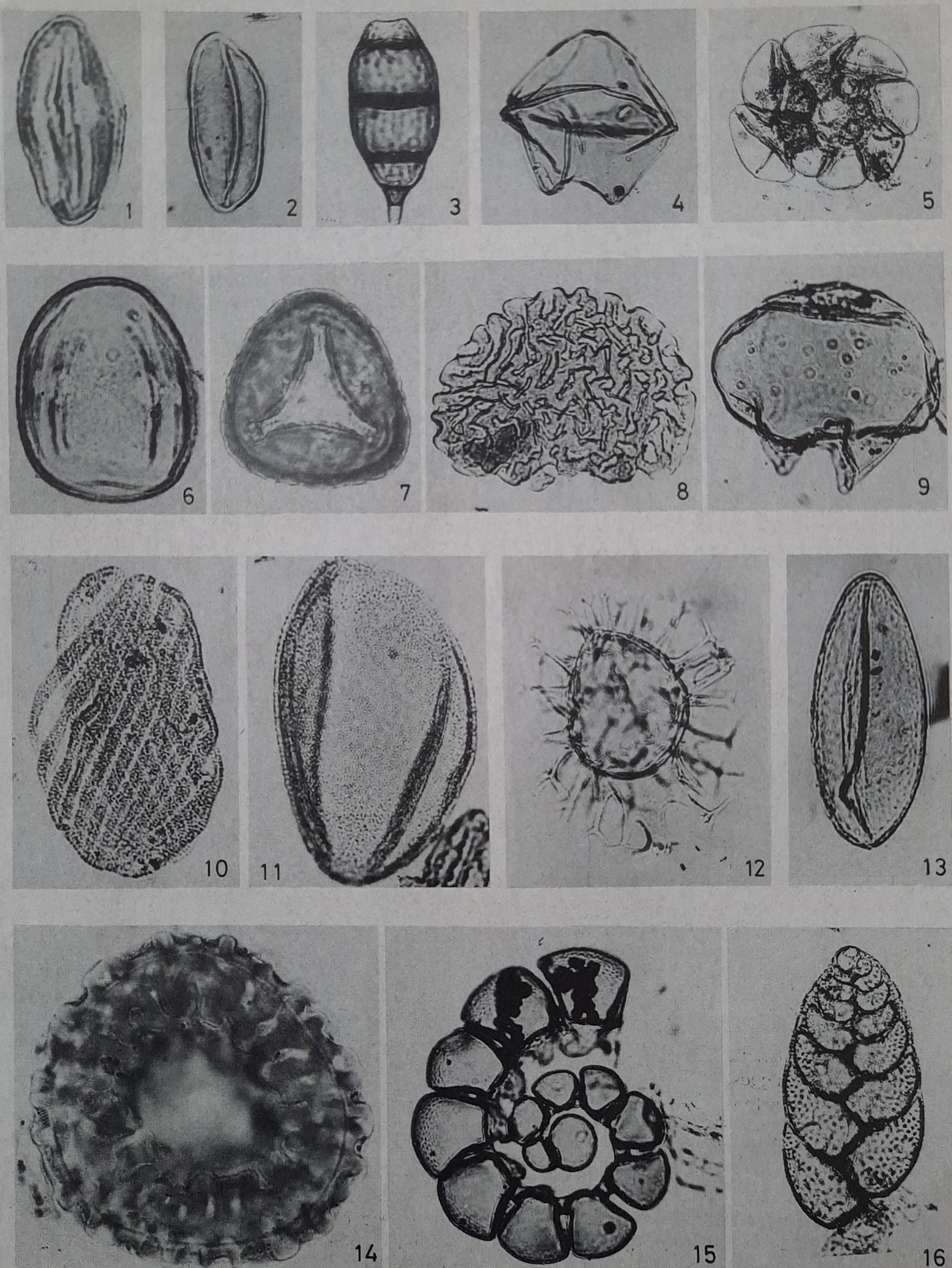


Plate 2

culodinium represent the phytoplankton population. Amongst foraminifera, *Globegerina, Globerotila, Textulara*, etc. are common.

The general pattern of distribution indicates that near the coast the coastal and lowland elements, ferns are more common while foraminifera are dominant seaward.

Quilandy—The physical setting of the Quilandy coast is characterised by rocky projections in the northern point. Text–figure 5 shows the irregular isobaths roughly parallel to the coast. The nearshore is gentler than the Alleppey area. The study area is an embayment of the coast with an effective trapping of the sediments transporting towards north from the Chaliyar River at the Kadalur Point.

The sediments are rich in fine clastics. Sand content in the sediments range from 0.21 to 63.84%. Approximately half of the samples contain 10% of sand (Text-fig.2). Silt admixture in the sediments is fairly high, giving a per cent range between 6.47 to 46.51 with a fairly uniform frequency distribution. Abundance of clay denotes a maximum variation from 6.87% to 92.58% with an even frequency.

Clay is the dominant textural class in the Quilandy sediments (Text-fig.3C). Silty-clay and sand-silt-clay are present in good amount. Clayey-sand and silty-sand are also represented in meagre amounts. In comparison with Allepey area, the Quilandy sediments are enriched in very fine clastics. This is evident from the areal variation of the textural composition of the sea bed (Text-fig.6). Central part is covered with clay sediments and extends upto Kadalur Point. The clay belt merges into the silty clay zone on both sides, which narrows to the north and widens at the south. Sand-silt-clay occurs as a narrow irregular patches in the west and southwest of Kollam and Kadalur. Sporadic patches of clayey sand are present in south of Kadalur Point and southwest of Kadalur. A small silty sand zone can be observed in the south of Kadalur Point.

Chaliyar is the main river system near the study area with an annual discharge of 7775 million m, bringing suspended and bedload to the area. During the southwest monsoon seasonal influx of river water is high with a high amount of suspended matter. Sediment core studies from Quilandy nearshore suggest piling up of muddy sediments during the Mud Bank formation (southwest monsoon). The dispersal pattern of the sediment indicates a shore ward movement of clay material (Mallik *et al.*, 1988). Movement of sediments and their ultimate deposition in the nearshore is controlled by the combined effect of wave approach and a general southerly transport of sediments by a strong persistent along shore current. Convergence of wave orthogonals near Kadalur Point and weaker divergence further south of Quilandy obtained from the wave refraction studies, facilitate mud deposition and hence support the above observation.

Palynological analysis of the samples shows the abundance of structure terrestrial and biodegraded terrestrial types near the shore line and abundance of foraminifera away from the coast. Charcoal is also frequently found in few samples near the coast. Pollen and spores, fungal remains and resin globules are rarely found in some samples, while amorphous types are totally absent.

The palynological assemblage in Quilandy differs greatly from that of Alleppey. The palynofossils representing coastal and lowland as well as ferns are not well represented whereas foraminifera are dominant. Amongst foraminifera *Globegerina* and *Globegerinoides* are common.

Vembanad Lake—The bathymetry of the area and location of samples are given in Text-figure 7. Average depth of the lake in the study area is 2-3 m with a maximum depth of 8.5 m. Major part of the area is covered by 2-4 m depth contour. There are two elongated patches of water depths exceeding 6 m. Two shallow patches (shoals) exist in the central part of the study area. The marginal areas close to the shore are shallow. Sediments in the estuary consist of varying admixture of sand, silt and clay. Sand percentage varies from 0.96 to 97.47. About half of the samples contain 0-20% sand (Text-fig.2). Silt range is between 7.47 and 65.94% with only one sample showing a value of 1.19%. Frequency distribution shows that silt is distributed more or less uniformly, about 50% of the samples contain 30-50% silt. Clay percentage varies from 1.34 to 64.05. About 30% of the samples contain 20 to 30% clay. Silty-clay and clayey-silt are the dominant textural classes in the sediments (Text-fig.3D). The silty-clay occupies the central part of the study area and clayey silt is found on either sides (Text-fig.8). Patches of sand are found in the eastern and southern side of Thanneermukkom Bund. Sand-silt-clay occurs as small bands in the area.

The pattern of sediment distribution in an estuary is mainly controlled by the source of the sediments and are modified by the hydrography and bottom topography. Study of heavy mineral assemblages reveal that the sediments are brought in by rivers draining through charnockites, khondalites and pegmatities of Western Ghats and adjoining foot-hills. Percentage of heavy mineral in the very fine sand fraction varies between 0.5 to 47.9. Terrigenous fractions constitute the major portion of the sediments. Biogenous sediments consist of shells and shell fragments. Organic matter varies from 0.5 to 13.9% with an average of 9.1%. There is a resemblance in the distribution pattern of organic matter and clay content in the sediments. Presence of framboidal pyrites indicates a reducing environment caused by the decomposition of organic matter.

The nature of sediment distribution with an elongated patch of silty-clay which is bordered on either side by clayey-silt implies a dispersal pattern of sediment in which the finer particles are concentrated in the middle of the lake. Predominance of sand rich sediments in the eastern part of the lake, in comparison to the western side is significant. Such an areal variation can be attributed to the increasing influx of river water in the eastern side of the lake. The rivers debouching into the lake while loosing the competency, deposit the coarser material load and transport the finer fractions to the middle part of the lake.

Veerayya and Murthy (1974) concluded that the southern part of the lake receives a good supply of fine material and the presence of fresh water conditions is responsible for the accumulation of finer fractions of the sediments in this part of the lake. With the commissioning of the Thanneermukkom salt water barrage the flow patterns in the lake has undergone considerable change. Except for the monsoon season, the barrage is closed to prevent the salt water incursion into the adjoining paddy fields. This has affected the sedimentation in the lake in three ways: (1) the barrage checks free flow of the sediments into the northern part of the lake during the lean season (pre- and post-monsoon), thereby increasing the deposition of sediments in the study area, (ii) contribution of sediments brought in by the flood tides to the southern part of the lake has become minimal and (iii) the flocculation and setting of finer particles in this part of the lake has been minimised due to the reduced influx of saline water. The present study has revealed a difference in the distribution pattern of sediments from that of Veerayya and Murthy (1974) which is attributed to the factors mentioned above.

Ecological implications of such a change in the sedimentological regime has a substantial bearing in the living communities. Estuarine organisms with varying life habits have different tolerence to particle size distribution and concentration (Sherk *et al.*, 1973). Depletion in salinity has adversely affected some groups of estuarine fauna and the increase in the incidence of pollutants in the lake comprising pesticides and insecticides drawn from the adjoining paddy fields and lack of flushing has deteriorated the quality of the environment having a lethal effect on the organisms.

Samples colleced from different transects show more or less a similar pattern of distribution of organic matter. Samples near the coast line are dominated by structured terrestrial and followed by biodegraded terrestrial organic matter. This condition is reversed in samples away from the shore, where biodegraded terrestrial organic matter is in abundance followed by structured terrestrial organic matter. Pollen, spores, charcoal, fungal remains and resin globlets are poorly represented. Foraminifera are almost absent or rare.

Palynological taxa comprise pollen representing coastal and lowland vegetation, ferns and dinoflagellates. Coastal elements are represented by *Cocos*, Amaranthaceae/ Chenopodiaceae, lowland flood plain by *Ceratopteris*, *Cullenia*, *Madhuca*, *Strobilanthes*, *Durio*, *Hibiscus*, *Bombax*, *Diospyros*, *Chrysalidocarpus* and Poaceae. Amongst pteridophytes, spores of *Pteris*, *Polypodium*, *Cheilanthus*, *Adiantopsis*, *Selaginella*, *Trichopteris*, *Dryopteris* and *Lycopodium* are occasionally found. *Spiniferites*, *Operculodinium* and *Peridinium* mostly stand for the dinoflagellates. Mangrove pollen, fungal elements and foraminifera are not well represented.

CONCLUDING REMARKS

Palynological assemblages of Quilandy and Alleppey phase 1 and 2 differ considerably with common abundance of fine clastics. In Alleppey phase 1 and 2, spores and pollen are quite common whereas in Quilandy they are rare. The reason, perhaps, for this disparity is that Quilandy is situated on a rocky shore with meagre vegetation and river outlets, whereas in Alleppey the shore is sandy represented by a flood plain with luxuriant vegetation. In Alleppey and Quilandy, structured terrestrial and biodegraded terrestrial organic matter are found in abundance near the coast whereas foraminifera are observed in plenty away from it. Spores and pollen are also found better represented along the coast.

In Vembanad Lake, structured terrestrial organic matter occur in abundance along the coast while biodegraded terrestrial organic matter is found away from it. Foraminifera are not common in the sediments. Palynofossils do not show much variations in the distribution pattern along the different transects of the lake because of a common source and a small distance of transport involved. The increase in abundance of foraminifera and phytoplankton seawards is significant. The land derived organic matter are most abundant close to the shoreline. Vembanad Lake represents a restricted environment and hence the distribution of organic matter is significantly different from Alleppey sites.

REFERENCES

Bristow, R.W. 1938. *History of Mud Banks. I & II*. Cochin Government Press, Cochin.

Carver, R.E. 1971. *Procedures in Sedimentary Petrology*. Wiley -Interscience, New York.

Devassy, V.P. & Bhattacheri, P.M.A. 1974. Phytoplankton ecology of Cochin backwater. *Indian Jl.Mar. Sci.* **3** : 46-50.

Frederiksen, N.O., Evitt, W.R., Hedlund, R.W., Nichols, D.J., Gensel, P.G., Markgraf, V.& Staplin,F.L.1982. The future of Palynology. *Palynology* **6** : 1-7.

Hameed, T.S.S.1988 Wave climatology and littoral processes at Alleppey. *In*: Baba, M. & Kurian, N. P. (eds)– *Ocean Waves and Beach Process*. CESS, Trivandrum : 67-90.

Jayalakshmi, K.V., Kumaran, S.& Vijayan, M. 1986 Phytoplankton distribution in Cochin backwaters— a seasonal study. *Mahasagar Bull. natn.Inst. Oceanography* **19** : 29-37.

Jose Anto V. 1971. On the grain size distribution of Cochin backwater sediments. *Bull. Dept. Mar. Bio. Ocean. Univ. Kerala* **5** : 109-122.

Madhupratap, M. 1979. Distribution of community, structure and species succession of Copepods from Cochin backwaters. *India Jl. Mar. Sci.* **8** : 1-8.

Mallik, T.K. & Suchindan, G.K. 1984. Some sedimentological aspects of Vembanad Lake, Kerala, west coast of India. *Indian Jl. Mar. Sci.* **13** : 159-163.

Mallik, T.K.& Ramachandran, K.K.1984. Mud Banks of Kerala coast- A state of the art report. *Kerala State Commit. Sci. Techn. Environ., Trivandrum*

Mallik, T.K., Mukherji, K.K. & Ramachandran, K.K.1988. Sedimentology of the Kerala Mud Banks (Fluid Muds?). *Mar. Geol.* **80** : 99-118.

Murthy, P.S.N. & Veeryya, M. 1972. Studies on sediments of Vembanad Lake. Part-1: Distribution of organic matter. *Indian Jl. Mar. Sci.* **1** : 45.

Murthy, P.S.N.& Veerayya, M. 1981. Studies on the sediments of Vembanad Lake, Part IV. Distribution of trace elements. *Indian J. Mar. Sci.* **10** : 165-172.

Pocock,S.A.J., Vasanthy, G. & Venkatachala, B.S. 1987-88. Introduction to the study of particulate organic materials and ecological perspectives. *Jl Palynol.* **23-24** : 167-188.

Ramachandran, K.K. 1989. Geochemical characteristics of Mud Bank environment— a case study from Quilandy, west coast of India . *Jl. geol. Soc. India* **33** : 55-63.

Ramachandran, K. K. & Mallik, T.K.1985 . Sedimentological aspects of Alleppey Mud Bank, west coast of India. *Indian Jl Mar. Sci.* **14** : 133-135.

Ramachandran, K.K. & Vasudevan, G. 1987. A comparative evaluation of the sedimentology and geochemistry of Alleppey and Quilandy Mud Banks, Kerala. *Seminar on recent geoscientific studies in the Arabian sea off India.* Abstract : 84-85.

Seshappa, G. 1953. Phosphate content of Mud Banks along Malabar coast. *Nature* **171** : 526-527.

Seshappa, G. & Jayaraman, R. 1956. Observations on the composition of bottom mud in relation to the phosphate cycle in the inshore of the Malabar coast. *Proc. Indian Acad. Sci.* **43** : 288-301.

Shepard, F.P. 1954. Nomenclature based on sand-silt-clay ratios. *Jl Sed. Petrol.* **24** : 151-158.

Sherk, J.A., O'Connor, J.M. & Newman, D.A. 1973. Effects of suspended and deposited sediment of estuarine environments. Estuarine Res. **11** : 541-558.

Thomas, K.V. & Baba, M. 1983. Wave climate off Valiathura, Trivandrum. *Mahasagar Bull. natn. Inst. Oceanography* **16** : 415-421.

Veerayya, M. & Murthy, P.S.N. 1974. Studies on the sediments of Vembanad Lake, Kerala State. Part III: Distribution and interpretation of bottom sediments. *Indian Jl. Mar. Sci.* **3** : 16-27.