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Environmental Impact on Coastal Wetlands since 4 ka in Cauvery Delta: Palynology and Thecamoebian Study

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Abstract: Palaeoclimate and Palaeoecological study was carried out in ~2 m sediment core deposited since 4 ka in an estuarine environment along Uppanar River mouth, Cauvery Delta. Palynological and thecamoebian evidences indicate (1) a basal fluvial lacustrine depositional environment (~4-3 ka) characterized by sandy sediment, with low salinity and dominance of non-pollen forms like foraminiferal linings and thecamoebians with a low percentage of pollen and spores and (2) an estuarine environment (since 3 ka) characterized by clayey sediment with high salinity and a good percentage of mangrove and terrestrial pollen along with non-pollen forms. A shift in the depositional environment since ~3 ka indicates monsoonal and geomorphological changes in the coastal wetland. During this period dominance of *Avicennia* and Cheno/Ams indicate low freshwater runoff from land suggesting a weakened monsoon condition enhanced by anthropogenic activity.

Keywords: Palynology, Thecamoebians, Uppanar River, Cauvery delta, Climate.

INTRODUCTION

The interaction between marine and freshwater generates hydrodynamics unique to estuaries in which both the variation in freshwater inputs and the flood and ebb tidal surges are essential for maintaining estuarine health (Ananda Rao and Sastry, 1974; Chapman, 1977; Tomlinson, 1986). Coastal wetlands in general have a greater variety of life forms than those occurring on land. The pollen/spores, marine/freshwater palynomorphs and thecamoebians are the potential proxies to monitor environmental fluctuations (Ellison, 1989; Patterson and Kumar, 2002; Lahr et al. 2006). The evidences of thecamoebians from Indian ecosystems are descriptive in nature (Das and Chattopadhyay, 2003). Farooqui and Gaur (2007) reported the palaeoclimatic and palaeosealevel data based on thecamoebians from Harappan site in Porbander and Bet Dwarka in Gujarat.

River mouths are subjected to frequent salinity changes depending on the interplay of tidal influx and the fresh water input from land. The river systems in the east coast of India are essentially monsoon driven and as such the sediments embedded in their deltas are considered as excellent repositories of past monsoon records to which the biotic forms have responded. Thus, fresh water thecamoebians preserved in the sediment supported by pollen/spores data are suitable proxy for monitoring climate and ecological changes. There are records of intermittent relative sea level rise and fall during late Holocene from Pulicat lagoon and other contemporary sites along the east coast (Banerjee, 2000; Farooqui and Vaz, 2000). Recent shoreline changes due to erosion and subsequent geomorphological variations with the passage of time are conspicuous through satellite maps in the Pichavaram estuary (Yeon CHO et al., 2004) which is liable to change the ecology, leaving impact on biotic forms. The vertical variation in the palynological and thecamoebian assemblages in the sediments responding to ecological changes during late Holocene was studied from the mouth of Uppanar river. This work utilizes the potential of fresh water thecamoebians as proxy for monitoring ecological changes in the river mouth in order to infer climatic fluctuations.

STUDY AREA

The Uppanar river (Lat. 11°43' N, Long. 79°46' E) flows between Cuddalore in Chidambaram taluk and joins with the Bay of Bengal by the mouth of Gadilam river. The Uppanar river feeds the Pichavaram estuary which is an open type of estuary with semidiurnal tides and tidal effects reaching up to a height of about 1m. The mean tidal level in this estuary is about 90 cm and the maximum level is about 120 cm. The average depth of

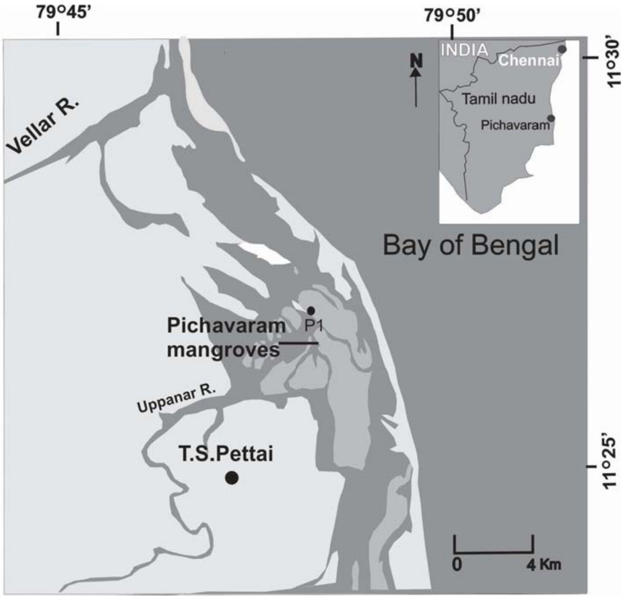

Fig.1. Map of the Pichavaram mangrove showing Uppanar river mouth with sampling location.

Pichavaram estuary is about 3 m near the mouth and 2 m towards the upstream. The estuarine area close to the mouth of the estuary is dominated by salt tolerant *Avicennia* and *Suaeda* sp. along with small to large salt pans completely devoid of vegetation.

MATERIALS AND METHODOLOGY

A 2 m deep sediment core was collected by manually operated 'Eijelkamp-Piston corer' from the exposed estuarine area (Latitude 11°26.701' N; Longitude 79° 48.033' E) at the mouth of the Uppanar river (Fig1). Immediately, after collection the core was sub-sampled at 2cm intervals. The samples were stored in air-tight polythene bags without any preservative. ^{14}C radiocarbon dates of the organic carbon were obtained from Birbal Sahni (BS) Institute of Palaeobotany, India and calibrated following Stuiver et al. (1998). In laboratory sediment colour was known using Munsell color chart (2000) and texture was analyzed on the basis of percentage of sand in the sediment following soil density method (USDA, 1992). Salinity was calculated in 10g of air dried soil sample dissolved in 100ml of deionized water. The samples were homogenized for 30 minutes before measuring the salinity using 'Orion-5 star (Thermo-Orion, Scientific Equipment, USA) at standardized 25ºC temperature. For palynological and thecamoebian study, 10 g soil samples were treated with warm 10% potassium hydroxide and later sieved through 150 mesh (105µm). The filtrate was settled overnight and the supernatant drained. The residue was treated with 40% hydrofluoric acid. The sample was then acetolysed, following Faegri and Iverson (1989). The acetolysed samples were caught in 650 mesh size (10 µm) and the residue was mounted on glass slides in glycerine jelly. The samples were studied under a high power light microscope (Olympus BX-52). The pollen/spore spectra prepared is the percentage of total palynological counts in the air dried 10 g sample. Pollen atlases of Guinet (1962) and Tissot et al. (1994) and reference slides from the herbarium of Birbal Sahni Institute of Palaeobotany were consulted for identification of the palynomorphs. The minimum pollen sum of 300 grains was aimed, but this was not achieved in all samples. Data is represented in the pollen diagram as an average percentage of the total count of the land pollen and arranged in different groups such as mangroves, evergreen/moist deciduous, dry deciduous and non arboreal taxa. Apart from these freshwater taxa, freshwater algae, thecamoebians, dinoflagellate cysts and foraminiferal linings were also studied but were not included in the pollen sum.

RESULTS

Lithology, Salinity Status and Radiocarbon Dates

The Core P1 towards the mouth of the Uppanar river comprises of a sandy zone (Phase-I) from 200-105 cm with sand (85.3%), silt (5.3%) and clay (6.1%) sediment showing Munsell colour code of 5Y4/2 and salinity ranging from "1.5 to 2.5. Phase II is predominantly sandy clay with clay (74.3%), silt (4.9%) and sand (20.4%) having a Munsell colour code of 5Y3/2 and salinity ranging from 4 to 5.8. The base of the sediment sequence (195cm) dates back to 3260 cal BP, at 85cm the sediment dates back to 2430 cal BP and at 45 cm depth to 1710 cal BP. Calibrated radiocarbon dates from core P1 are plotted against depth (Fig.2). The plotted P1 dates suggest an age-depth profile with two distinct parts: a steeply inclined (i.e. high sedimentation rate) lower part and a less steeply inclined (i.e. reduced sedimentation rate) upper part.

Palynomorph and Thecamoebian Assemblage

Palynological, geochemical and thecamoebian study of sediment core (2m) from Uppanar River mouth shows 2 major phases of environmental changes that defined the status of mangroves since 4 ka (Figs.3a and b).

Phase I is characterized by a few Rhizophoraceae members (true mangroves) eg., *Rhizophora apiculata, Rhizophora mucronata* and *Ceriops decandra* (Plate 1) along with a low percentage of back mangroves and their associates such as *Avicennia marina* (1.0%), *Avicennia officinalis* (1.1%), *Excoecaria agallocha* (1.2%), *Sonneratia*

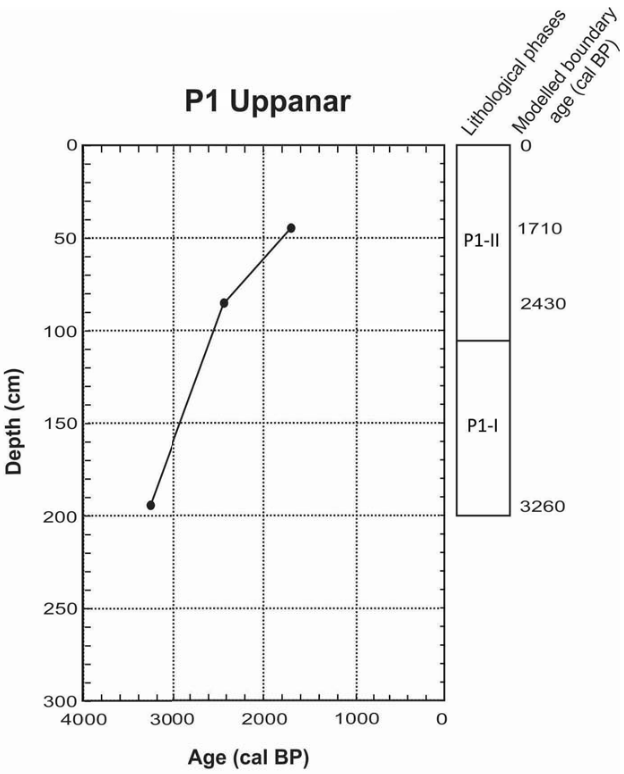

Fig.2. Age-depth model, P1, based on linear interpolation. Solid dots show the median calibrated ages.

apetala (2.0%), *Acanthus ilicifolious* (0.6%), *Conocarpus erectus, Lumnitzera racemosa*, *Aglaia elaegnoidea, Nypa fruticans* and *Acrostichum aureum* (0.4%). A good percentage of Poaceae pollen along with the foraminiferal assemblages dominated by the calcareous benthic forms, especially of rotalid taxa, *Ammonia* sp. (15.5%) and Thecamoebians thecamoebians (4.3%) such as *Centropyxis aculeata, Centropyxis arcelloides, Arcella vulgaris, Arcella artocrea* and other freshwater algal forms like *Botryococcus* and *Pediastrum boryanum* indicates a fluvial lacustrine depositional environment in this phase.

In Phase II, besides the pollen grains of mangroves and their associates, e.g. *Rhizophora apiculata* (2.1%), *Rhizophora mucronata* (3.0%), *Excoecaria agallocha* (4.6%), *Sonneratia apetala* (4.6%), *Avicennia officinalis* (10.1%), *Avicennia marina* (6.1%), *Acanthus ilicifolius* (9.2%), *Conocarpus erectus, Lumnitzera racemosa* (4.6%), *Aglaia elaegnoidea, Nypa fruticans* and *Acrostichum aureum* (5.1%), the presence of pollen of terrestrial taxa belonging to family Malvaceae (6.1%), Meliaceae (3.9%), Sapotaceae (3.2%), Palmae (3.7%) and genera *Azadirachta indica*, *Barringtonia* sp., *Syzygium gardneri*, *Cedrela odorata*, *Hopea* sp., *Holoptelea integrifolia*, *Casuarina equisetifolia* (3.9%), *Thespesia populnea* and *Cocos nucifera* (4.3%) indicate that the area was a land-ocean interface zone. A good percentage of pteridophytic spores (Plate 2) like *Polypodium, Pteris longifolia, Adiantum decoratum, Selaginella flagellata, Vittaria graminifolia, Cyathea trichiata, Lycopodium dichotomum* and *Pityrogramma calomelanos*, fungal spores (11.45%) such as Microthyriacites, Desmidiopora, Dictyosporites, Involutisporonites, Dicellaesporites, Dyadosporonites, Chytrid spore, Tetraploa sp., Pluricellaesporites and algal cysts (8.2%) together with terrestrial herbaceous taxa belonging to family Chenopodiaceae (12.9%), Poaceae, Liliaceae, Asteraceae (6.4%) and taxa like *Alternanthera ficoidea, Acacia* sp., *Ocimum basilicum, Polygonum densiflorum, Caryophyllus* sp., *Solanum trilobatum, Dendrophthoe falcata, Amaranthus spinosus*, *Caesalpinia* sp., *Guizotia scabra*, *Blumea lacera*, *Justicia* sp., *Artemisia nilagirica*, *Cyperus esculentus* and *Cyperus exaltatus* are also present. The Aquatic taxa includes *Hygrophila auriculata, Typha latifolia, Nymphaea* sp. and *Myriophyllum* sp. Dinoflagellate cysts of *Operculodinium* and *Spiniferites* (7.7%) along with the foraminiferal assemblages (8.21%) are an indicator of tidal influence during the period whereas freshwater thecamoebian *Centropyxis* (7.46%) along with the fresh water algal remains indicate freshwater input through river in the coastal wetland.

DISCUSSION

The characteristics of the estuarine bottom sediments in terms of texture and the palynological assemblages indicate the presence of two distinct sedimentary units in the core. Sediment in Phase I is characterized by high percentage of fine sand, low salinity with low percentage of mangrove pollen. The presence of foraminiferal linings along with terrestrial herbaceous taxa shows both marine and terrestrial influx at this depth. The high sand and low concentration of pollen species suggests a fluvial lacustrine depositional environment during the strengthened monsoon phase. The warm and humid climate during middle to late Holocene also played a major role in sediment input and supply of inland water that shaped the past land forms and vegetation (Bryson and Swain, 1981; Van Campo and Gasse 1993; Van Campo et al., 1996; Bera et al., 1997; Bera and Farooqui, 2000; Chauhan and Suneethi 2001). The Phase II sediments show a sharp change in sediment texture due to higher percentage of fine clay sediment in Phase II. Considering the sediment lithology together with palynological characteristics, the sediment of Phase II may be categorized as low energy estuarine deposit. Predominance of clayey sediment, high salinity, presence of mangroves with a good percentage of hinterland taxa

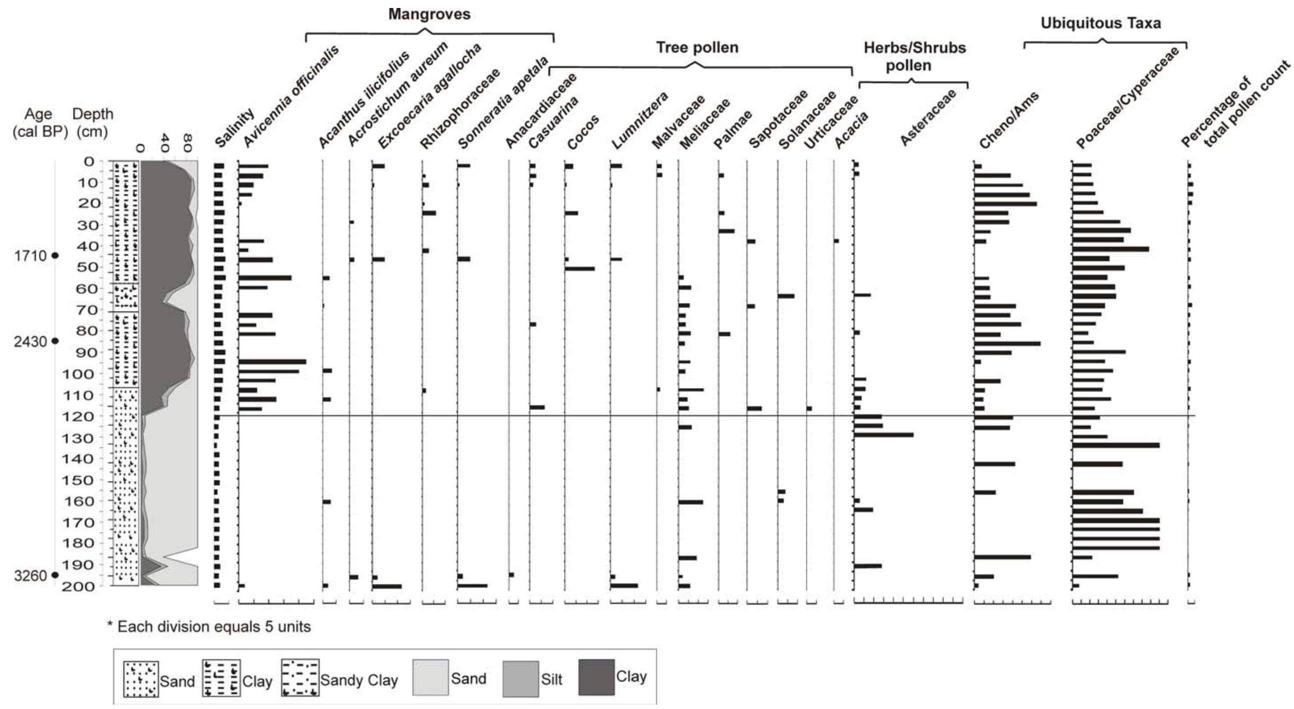

Fig.3a. Percentage count of mangrove, trees and herb/shrub pollen in core P1 of Uppanar River, Tamil Nadu.

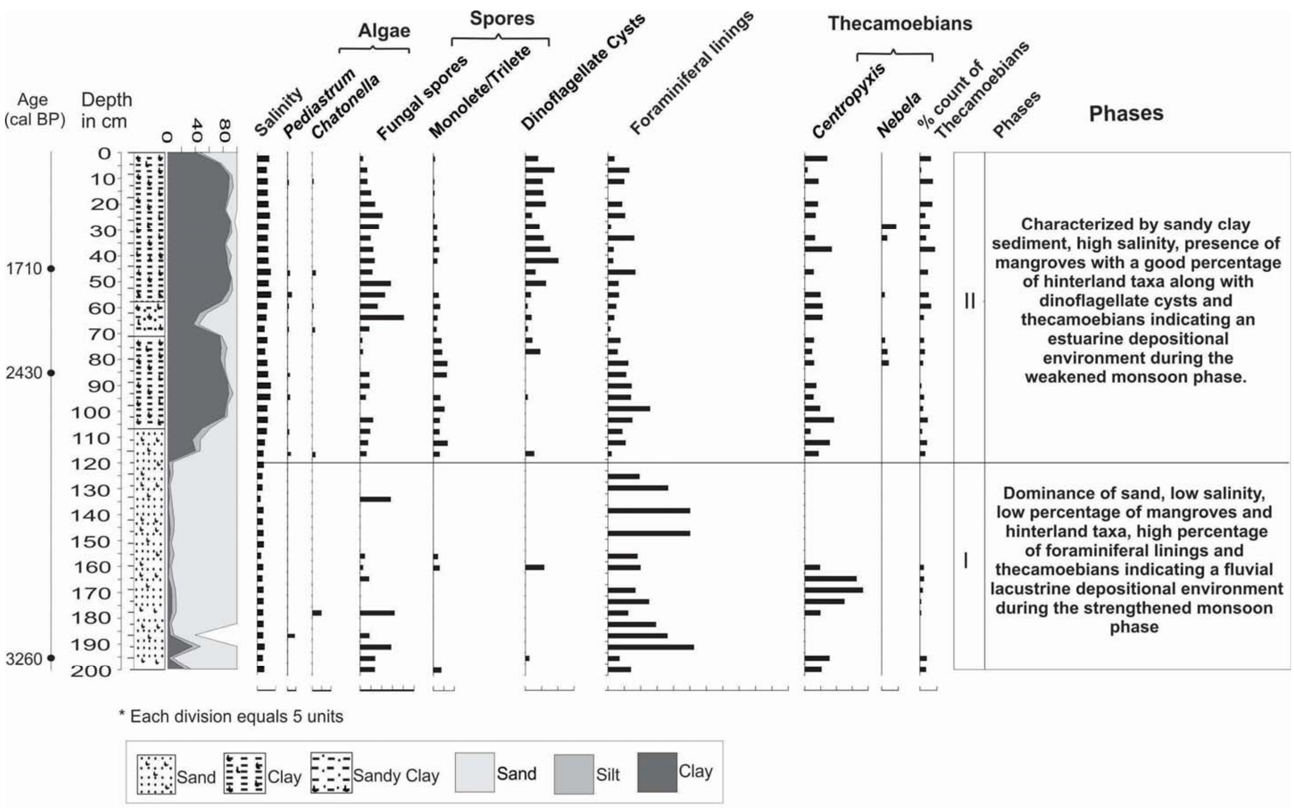

Fig.3b. Percentage count of freshwater algae, thecamoebians, dinoflagellates cysts and foraminiferal linings in core P1 of Uppanar river, Tamil Nadu.

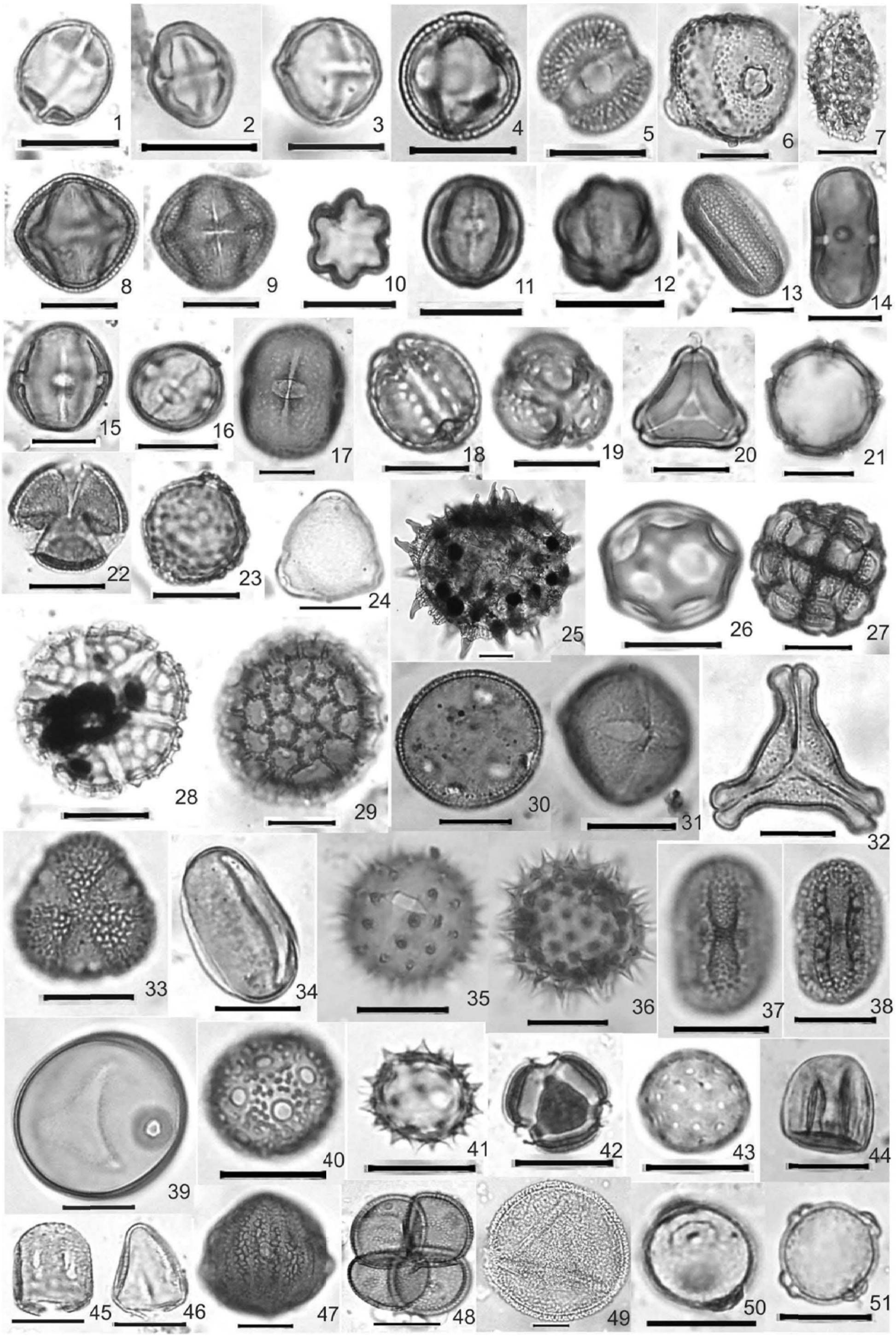

Plate 1. Pollen forms identified in palynological assemblage. *1.Rhizophora mucronata*; 2. *Rhizophora apiculata*; 3. *Ceriops decandra*; 4. *Avicennia marina*; 5. *Avicennia officinalis*; 6. *Sonneratia apetala*; 7. *Nypa fruticans*; 8, 9. *Excoecaria agallocha*; 10. *Conocarpus erectus*; 11, 12. *Lumnitzera racemosa*; 13. *Acanthus ilicifolius*; 14. *Aglaia elaegnoidea*; 15. *Azadirachta indica*; 16. Meliaceae; 17. Sapotaceae; 18, 19. *Barringtonia* sp.; 20. *Syzygium gardneri*; 21. *Cedrela odorata*; 22. *Hopea* sp.; 23. *Holoptelea integrifolia*; 24. *Casuarina equisetifolia*; 25. *Thespesia populnea*; 26. *Alternanthera ficoidea*; 27. *Acacia* sp.; 28. *Ocimum basilicum*; 29. *Polygonum densiflorum*; 30. *Caryophyllus* sp.; 31. *Solanum trilobatum*; 32. *Dendrophthoe falcata*; 33. *Caesalpinia* sp.; 34. Liliaceae; 35. *Guizotia scabra*; 36. *Blumea lacera*; 37, 38. *Justicia* sp.; 39. Poaceae; 40. *Amaranthus spinosus*; 41. Asteraceae; 42. *Artemisia nilagirica*; 43. Chenopodiaceae; 44. Cyperaceae; 45. *Cyperus esculentus*; 46. *Cyperus exaltatus*; 47. *Hygrophila auriculata*; 48. *Typha latifolia*; 49. *Nymphaea* sp.; 50, 51. *Myriophyllum* sp.

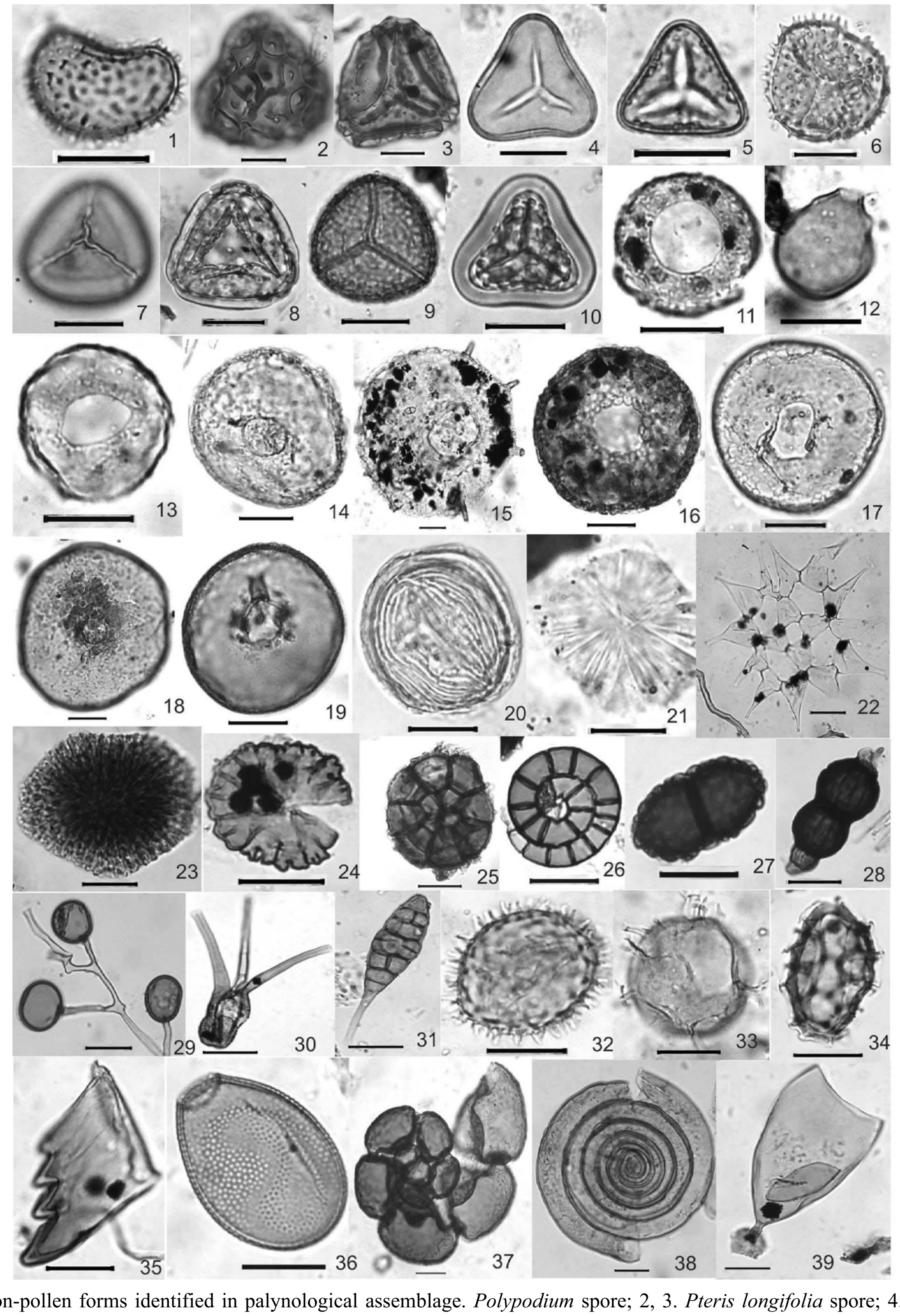

Plate 2. Non-pollen forms identified in palynological assemblage. *Polypodium* spore; 2, 3. *Pteris longifolia* spore; 4. *Acrostichum aureum* spore; 5. *Adiantum decoratum* spore; 6. *Selaginella flagellata* spore; 7. *Vittaria graminifolia* spore; 8. *Cyathea trichiata* spore; 9. *Lycopodium dichotomum* spore; 10. *Pityrogramma calomelanos* spore; 11. *Arcella megastoma*; 12. *Nebela* sp.; 13, 14. *Arcella* sp.; 15. *Centropyxis aculeata*; 16. *Centropyxis arcelloides*; 17. *Arcella vulgaris*; 18. *Arcella artocrea*; 19. Unidentified sp.; 20. *Pseudoschizea*; 21. *Botryococcus*; 22. *Pediastrum boryanum*; 23. Microthyriacites; 24. Desmidiopora; 25. Dictyosporites; 26. Involutisporonites; 27. Dicellaesporites; 28. Dyadosporonites; 29. Chytrid spore; 30. *Tetraploa* sp.; 31. Pluricellaesporites; 32. Dinoflagellate cyst; 33. *Spiniferites ramosus*; 34. *Polykrikos schwartzii*; 35. Scolecodont fragment; 36. Egg shell; 37. Foraminiferal lining; 38. *Cornuspira* sp.; 39. Tintinid lorica remains

along with dinoflagellate *Spiniferites* cysts and foraminifera linings suggest low energy estuarine environment. The increase in freshwater algal remains and moderate percentage of thecamoebians indicate a slow moving fluvial ecosystem. The fresh water algal forms find conducive environment in low energy limnic ecosystems (Reynolds, 1984) and thecamoebians are known to be associated with aquatic vegetation and algae (Medioli and Scott, 1983) in lentic ecosystems. During Phase II dominance of back mangrove *Avicennia* sp. and Cheno/Ams indicate low freshwater runoff from land suggesting a weakened monsoon enhanced by coastal anthropogenic activity (Srivastava et al., 2012; Srivastava and Farooqui, 2012). Therefore, it is inferred that the fluvial energy in the river system was weak perhaps responding to weak monsoon and drier climates. Climatic amelioration from warm and cool (Van Campo, 1986; Singh, 1971; Mooney, 1997) in the beginning of late Holocene and a gradual shift towards cooler climate during 2500 to 1000 years BP coupled with a sea standstill or a fall in sea level (Gellatly et al. 1988; Etheridge and Morgan, 1989; Mazari et al. 1995) has been reported. A strict and long-term drought during middle-late Holocene has been recorded through different proxies from Asia and Africa (Booth et al. 2005, Kaniewski et al. 2008). A steady weakening in the Asian summer monsoon between 3000 cal BP and 1500 cal BP have been accounted from low and mid-latitudes in India and China (Selvaraj et al. 2008; Liu et al. 2009), and is usually interpreted as a response to decreasing summer insolation (Overpeck et al. 1996).

CONCLUSION

The palynological succession in the sediment from the Uppanar River mouth reveals a shift in the environmental conditions during Late Holocene since ~3 ka. The river remained an active channel between ~4-3 ka, responding to the strengthened monsoon condition. After this period the presence of salt tolerant mangroves and freshwater thecamoebians indicate a lentic/shallow estuarine ecosystem. The evidence of marine dinoflagellate cysts, foraminiferal linings and salt tolerant mangrove pollen indicate fluvio-marine sediment depositional environment. A shift in the depositional environment since ~3 ka indicates low freshwater runoff from land suggesting a gradual weakening of monsoonal conditions enhanced by anthropogenic activity. Since, thecamoebians are short lived and readily tend to preserve its thecate body, its presence and absence in the sediments particularly in the river mouth/estuaries serve as suitable proxy for monitoring short term high resolution palaeoecological fluctuations particularly in coastal ecosystems.

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