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NON-POLLEN PALYNOMORPHS AS ENVIRONMENTAL INDICATORS IN THE SURFACE SAMPLES FROM MANGROVE IN COSTA RICA

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ABSTRACT: Different organic walled non-pollen palynomorphs were identified from thirteen surface silty and sandy sediment samples in the southern part of Costa Rica, where mangroves are widespread. Non-pollen palynomorphs are numerous and diverse in comparison with the scarce pollen and spores of vascular plants. They are represented by dinoflagellate cysts, algal palynomorphs of Chlorophyta, cyanobacteria, fungal spores and hyphae, microforaminifers, scolecodonts and phytoliths. The most frequently represented are *Botryococcus* and microforaminifers whose frequencies change depending on the salinity of environments related to marine influence. Chlamydospores of the fungus *Glomus* are related with erosive processes. Cyanobacteria of the *Rivularia*-type may be connected to an increase in eutrophication by organic phosphate within an estuary. Non-pollen palynomorphs data are important as a palynological complement in the coastal regions of Costa Rica. Non-pollen palynomorphs are associated with pollen of *Rhizophora*, *Laguncularia*, *Avicennia*, Poaceae, Cyperaceae, and spores of various mangrove vegetation ferns.

Key words: Non-pollen palynomorphs, surface sediments, mangrove, estuary, Costa Rica.

RESUMEN: Diferentes palinómorfs no polínicos de paredes orgánicas, fueron identificados en trece muestras de sedimentos limosos y arenosos en la parte sur de Costa Rica, donde los manglares están ampliamente distribuidos. Los palinómorfs no polínicos son numerosos en comparación con la poca cantidad de polen y esporas de plantas vasculares. Están representados por cistos de dinoflagelados, palinómorfs de algas de Chlorophyta, cianobacterias, esporas de hongos e hifas, microforaminíferos, escolecodontos y fitolitos. Los más frecuentes son *Botryococcus* y microforaminíferos, cuya frecuencia es dependiente de la salinidad de ambientes influenciados por el mar. El palinómorfo *Glomus* puede ser un indicador de procesos erosivos. La cianobacteria tipo *Rivularia* puede estar ligada a una eutroficación del estuario. Datos sobre palinómorfs no polínicos están asociados con polen de *Rhizophora*, *Laguncularia*, *Avicennia*, Poaceae, Cyperaceae y esporas de varios pteridofitos característicos de la vegetación del manglar.

Palabras claves: Palinómorfs no polínicos, sedimentos superficiales, manglar, estuario, Costa Rica.

INTRODUCTION

The mangrove ecosystems in the southern part of Costa Rica are important because their plants, principally trees and shrubs, prevent increases in soil salinity, erosion of the coastal plains and they are an essential source of food for different organisms. Pollen grains from sediments of different age are used as reliable indicators of past mangrove vegetation and may provide important data for palaeoecological and palaeoenvironmental reconstructions. According to Grindrod (1985), pollen that accumulates in mangrove has low mobility, seldom being redistributed by tides. Studies of the relationship between modern pollen from surface sediments and vegetation in mangrove swamps revealed that pollen and spores of terrestrial and aquatic vascular plants are not abundant (Jaramillo & Bayoná, 2000; Horn, 1985; Rodgers III & Horn, 1996; Zamora et al., 2007 a, b).

In addition to pollen and spores of vascular plants, surface sediment samples include different non-pollen palynomorphs (NPPs) which are organic-walled microfossils composed of sporopollenin-like or chitin (pseudochitin) polymers (Traverse, 1988). Often non-pollen palynomorphs are more resistant to corrosion and oxidation than pollen and spores, and they are not destroyed during chemical treatment of the samples for palynological analysis (van Geel, 1986; Guy-Ohlson, 1992; Rull & Vegas-Vilarrúbia, 1999; Komárek & Jankovská, 2001).

The study of NPPs started during the early 1970s in the Netherlands. Since that time, hundreds of morphological types of NPP were described and many of them have been identified. There is an increasing interest in the use of them for palaeoenvironmental reconstructions (van Geel, 2006; Prager et al., 2006, and Chmura et al., 2006), for evaluation of historical land use changes and exploring the ancient occupation in multiproxy study of the lake sediments (Riera et al., 2006; Argant et al., 2006).

In Costa Rica, one article has been recently published where microforaminers and scolecodonts were registered in Pliocene-Quaternary sediments (Zamora et al., 2007a). There are no studies on fossil and sub-fossil fungal palynomorphs

in Costa Rica, but their use may be very productive for the mangrove where they are numerous and diverse. Corrigan (1986) described pollen assemblages for southern Costa Rica, but not really details of NNP. Important studies to understand the history of uplift and closure of the southern isthmus were made by Mc Dougall (1996) and Ibaraki (2002) using just foraminifers as proxies. Until recently, the NPPs have not been described as an important microfossil that may significantly help in environmental and palaeoenvironmental reconstructions.

In order to widely use NPPs for the environmental and palaeoreconstructions in Costa Rica, we decided to study them in the surface sediments of the present mangrove and surrounding areas from the different localities. The aim of the study is to present the preliminary data on NPPs acquired from an estuary system, and compare the different studied localities environmental characteristics along this section of the river and mangrove. Within these approaches, available literature on NPPs was used for their identifications and their environmental characteristics.

THE STUDY AREA AND ITS ENVIRONMENT

Costa Rica is located in the southern part of the Central American isthmus between the Pacific Ocean and the Caribbean Sea. Costa Rica is the part of an active margin where the Cocos plate subducts beneath the Caribbean plate with a rate of 9.0 cm/yr (De Mets et al., 1994). The study was conducted in the eastern part of Osa Peninsula in southern Costa Rica (Fig. 1). This area lies within one of the most tectonically active areas of the region close to the interaction of three plates (Caribbean, Cocos, Nazca). High rates of uplift have been proposed in this region (Gardner et al., 1992) related to the subduction of the Cocos ridge. Pinter (1988) and Gardner et al. (1992) proposed for this area an uplift rate of 6.5 mm/yr. Some other regional models have been proposed to explain the complex tectonics and geologic characteristics of this area (Hey, 1977; Lonsdale & Klitgord, 1978; Wilson & Hey, 1981; Tournon, 1984; Barrit

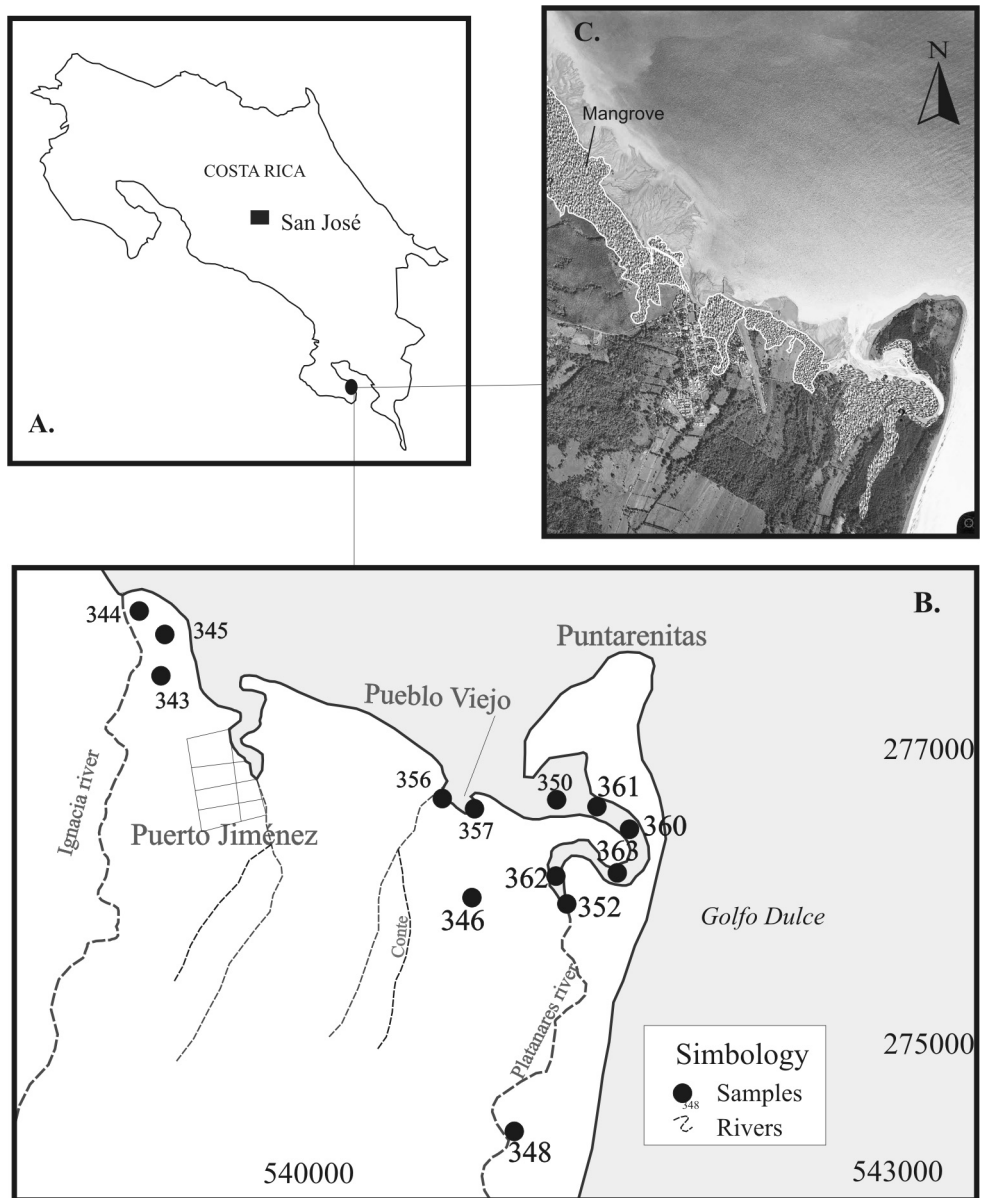


Fig. 1: Map of the studied area: A - regional map of Costa Rica; B - aerial photo (Terra 1998) where delimitation of mangrove is shown; C - the map showing sampling localities for palynological study.

& Berrangé, 1987; Berrangé & Thorpe, 1988; Di Marco 1994; Gardner et al., 1992; Vannucchi et al., 2006; Meschede et al., 1998; Meschede & Barckhausen, 2001; Buchs, 2003).

The main outcrops, situated around of the studied mangroves are Pliocene-Quaternary deposits related with the Osa Group and Puerto Jiménez

Group. These deposits are overlying unconformably (Corrigan, 1986; Berrangé, 1989) the basement of the region (Tournon, 1984; Di Marco, 1994; Di Marco et al., 1995).

Osa Peninsula is characterized by a tropical climate (temperatures range between 21 and 31°C). Precipitation varies between 4500-6500

mm/year (Herrera, 1985). There are two distinctive seasons during the year: dry and rainy. Humidity is ranging between 75% and 90% respectively to the seasons. Three main rivers and some smaller drainage of the studied area flow into the Golfo Dulce. This gulf is described as a tropical fjord due to its morphology and depth (Richards et al., 1971; Quirós, 2003).

The mangrove development along sheltered tropical and subtropical coasts depends on seawater influence, tides, and freshwater inputs during heavy rains or storms (Blasco et al., 1996). Mangrove swamps spread along the Pacific Ocean coast are presently five genera characterizing them: red mangrove (*Rhizophora*), black mangrove (*Avicennia*), white mangrove (*Languncularia*), tea mangrove (*Pellicieria rhizophorae*) and button wood mangrove (*Conocarpus erecta*) (Simberloff, 1983). The present increased mangrove disturbance in Costa Rica and its consequent retrogradation is sometimes related to sea level changes; in some areas degradation may be linked to the expansion of cultivated plants, fruit-trees, some palms, *Melina*, coffee, cocoa, grasses and vegetable and herbaceous weeds. Development of pastures and extension of cropping may result an increased risk of mangrove disappearance.

MATERIAL AND METHODS

Sampling

Thirteen surface sediment samples were collected from the mangrove swamps at a depth between 0-5 cm (Fig. 1). The collected samples are represented predominantly by silt or sandy silt. The distance between sampling localities is about 0.2~0.5 km. The samples were collected in the mangrove near the beach (344, 345, 343, 356, and 357), at the bottom of the estuary (350, 363, 360, 363, and 362), in the mouth of the Platanares river (352), in the limits of the mangrove area (346), and at the shore of the Platanares river (348). The collected samples were dried in an electric furnace at 60°C. The dry samples were sieved ($D=200\ \mu\text{m}$) in order to remove plant remains.

Chemical treatment

The chemical treatment of the samples was performed according to Faegri & Iversen (1975). The dry samples, 50g in weight, were treated as follows: cold HCl (10%) and boiling NaOH (5%) for 15 minutes. Inorganic substances were separated from the organics by a dense liquid - a water solution of ZnCl_2 (density 2.2 g/cm³). The residual organics were mounted in glycerine-jelly to prepare the microscope slides.

The slides are stored in the Centro de Geologia Costeira e Oceânica (CECO) at the Institute of Geosciences, Federal University of Rio Grande do Sul, Brazil.

General characteristic of principal NPP

Here, we mention only the most representative NPPs encountered in the surface sediments of the mangroves in the studied area. Their characteristics are accompanied by wide bibliography references that may be useful for the future study of NPPs, both from the surface, and the Quaternary sediments in Costa Rica.

NPPs are widely distributed in the aquatic environments of the coastal plains. They are the zygospores, coenobiums and colonies of Chlorophyta (Cross et al., 1966; van Geel, 1976; van Geel & van der Hammen, 1978; Pals et al., 1980) from freshwater environments, and may also be evidence of freshwater input into saline aquatic environments during pluvial periods (Medeanic, 2006 b).

Among the NPPs, there are dinoflagellate and acritarch cysts which are indicators for marine environments (sea water influence by tides and marine transgressions (Dale, 1976; Hoek et al., 1995; Grill & Quattrocchio, 1996).

Cyanobacteria are distributed in a wide range of habitats as free-living organisms, and as symbionts in terrestrial and aquatic environments. They are very sensitive to nutrient status of environments (Whitton & Potes, 2000), and may serve as indicators for environmental changes. Their abundance may indicate an eutrophication, as a

result of agricultural and domestic effluents enriched by phosphate (Knoja et al., 2007). Currently, cyanobacteria are rarely used for palaeoecological reconstructions due to their destruction resulting from attrition in the sediments or from the chemical treatment for palynological analysis. The palaeoecological value of heterocysts and akinetes in cyanobacteria has been reported by van Geel et al. (1994), Tomitani et al. (2006).

The microforaminifers represent chitinous inner tests of different benthic and planktonic foraminifers and are widely spread in the oceans and in the seas (Wilson & Hoffmeister, 1952; van Veen, 1957; Pantic & Bajaktarevic, 1988). Biological affinities of microforaminifers have not been established yet. The informal classification of microforaminifera is based on morphology, including number of chambers and the types of chambers arrangement (Stancliffe, 1989).

Chitinous fungal palynomorphs, resistant to destruction, are represented by ascospores, fruit-bodies and hyphopodia (van Geel & Aptroot, 2006). The importance of fossil fungal remains for palaeoenvironmental reconstructions has been reported in various publications (Elsik, 1976; Jarsen & Elsik, 1986; van Geel, 1986; Pirozynski et al., 1988; Graf & Chmura, 2006). Implications of fungal palynomorphs for the elevated salinity environments of the coastal plains existing during the Quaternary have not yet been sufficiently elaborated (Graf & Chmura, 2006; Medeanic, 2006a; Limaye et al., 2007). The abundance and taxonomic variability of *Glomus* and its importance for dune stabilization was shown by Cordazzo & Stümer (2007), who studied the distribution of *Glomus* in the roots of *Panicum racemosum*, the species that fixes and supports dunes. Limaye et al. (2007) registered an increase in *Glomus* in the sediments formed during the Late Glacial Period in India related to active erosion processes under a dry and continental climate.

Scolecodonts are the jaws of polychaete annelids. They are fossilized due to their chitinous teeth and dwelling tubes. According to Limaye et al. (2007), representative amounts of scolecodonts are important indicators of sediment deposition near the shelf or near the beaches.

Phytoliths are opal microscopic bodies of biogenic origin formed in the different part of plants (Geis, 1978; Barboni et al., 1999). They are an important tool for the recognition of palaeovegetation of the coastal plains whose species have a great number of silica-bodies and silicified epidermal cells (Lu & Liu, 2003). For the tropical region, the application of phytoliths, especially cereals including *Zea mays*, may provide information about human activity in the region and agriculture development (Smithson, 1956; Bartlett et al., 1967; Kondo & Sase, 1986; Piperno, 1989; Piperno et al., 1990; Fisher et al., 1995). The phytoliths have limited capacity to be transported and are indicators of local, rather than long-distance, input.

RESULTS

Most NPPs were identified after comparison with illustrations from the available literature. Their relative frequencies were based on a "total NPPs sum" and are shown in figure 2 and in table 1. The most frequent NPPs are represented in the Plates I-III. Palynological material in the residues was relatively abundant in NPPs, while pollen and spores of vascular plants were rare or even sporadic (figure 3, table 2). The order of samples is presented from a NW to SE trending profile.

A brief report on the characteristics of NPP and their occurrences in the surface sediments in southern Costa Rica is given below.

Microalgae

Microalgal palynomorphs are most frequent in many surface samples but their percentages differ depending on various factors such as salinity, influence of tides, rivers and freshwater inputs during heavy runoff, depth, and nutrient status. Microalgal palynomorphs are represented by dinoflagellate cysts and colonies and zygospores of Chlorophyceae and Zygnemataceae.

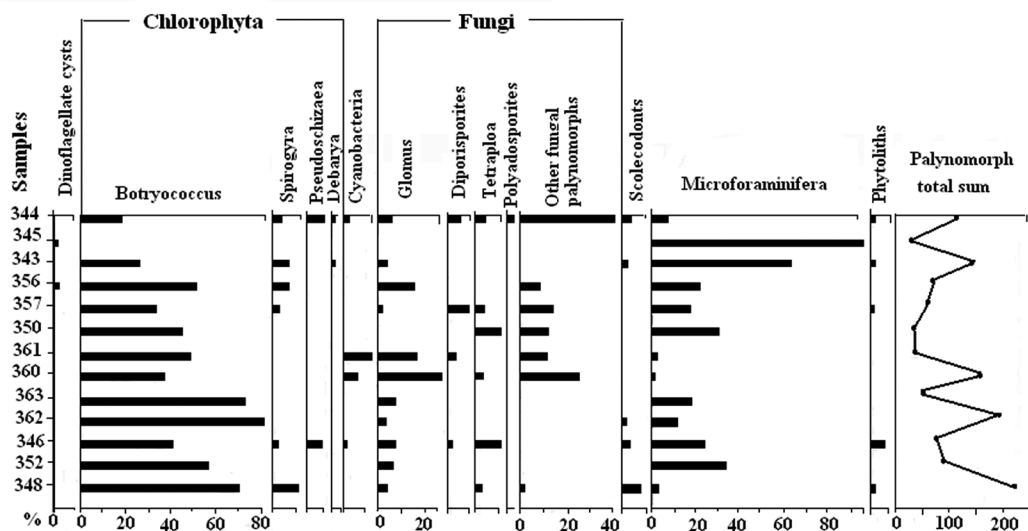


Fig. 2: Percentage palynodiagram of NPP from the surface samples in the southern part of Costa Rica.

Dinoflagellate cysts

In our samples, dinoflagellate cysts were rare and sporadic and poorly preserved. They were encountered only in the surface samples from the beach or near the beach (345, 356, and 357), where tidal influence is stronger than in other studied localities.

Chlorophyceae - Botryococcus

Colonies of *Botryococcus* (Plate I: 1) were recorded in most surface samples, except sample 345, proving their distribution in the environments of elevated salinity of lagoons and salt and brackish-water marshes (Guy-Ohlson, 1992; Medeanic, 2006 a, b). The frequency of colonies is variable (Table 1, Fig. 2). The most abundant colonies are encountered in surface sediments (348, 362, 363, and 356), influenced by tides, and in the bottom surface sediments in the Platanares river, subjected to tidal influence (348).

Zygnemataceae - Spirogyra

The zygospores of *Spirogyra* (Plate I: 2, 3) do not exceed 11.2%. The most frequent *Spirogyra* are encountered in high-salinity localities which obtain

fresh water from the Ignacia river (344, 343), in the beach of Pueblo Viejo (346), and in the bottom of the Platanares river, influenced by tides (348).

Zygnemataceae - Pseudoschizaea

We encountered *Pseudoschizaea* (Plate I: 5) only in two samples at the localities subjected by the freshwater input of the Ignacia river (344) and the Platanares river (346).

Cyanobacteria

The encountered cyanobacteria are represented by *Spirulina* (Plate I: 6), *Rivularia* (Plate I: 7), and *Anabaena?* (Plate I: 10), only at localities characterized by some eutrophication due to sewage and domestic effluents (344). They were rarely encountered at the estuary (360, 361), where recurrent changes in salinity may have occurred and erosion processes are observed.

Anabaena

Filamentous cyanobacterium *Anabaena* is widely spread in tropical and subtropical regions

Table 1

Non-pollen palynomorph taxa and their relative frequency (%) from the surface samples of the Southern Costa Rica.

Non-pollen palynomorph taxa	Samples												
	344	345	343	356	357	350	361	360	363	362	346	352	348
Dinoflagellate													
Cysts indet.	-	2.4	-	2.5	1.3	-	-	-	-	-	-	-	-
Chlorophyta													
<i>Botryococcus</i>	18.3	-	24.3	50.0	32.5	43.5	46.5	37.6	72.7	82.3	40.5	58.3	70.0
<i>Spirogyra</i>	4.2	-	5.8	5.0	2.5	-	-	-	-	-	2.5	-	11.7
<i>Pseudoschizaea</i>	9.2	-	-	-	-	-	-	-	-	-	5.1	-	-
<i>Debarya</i>	1.4	-	1.1	-	-	-	-	-	-	-	-	-	-
Cyanobacteria													
<i>Anabaena</i>	-	-	-	-	-	-	-	2.1	-	-	-	-	-
<i>Spirulina</i>	0.7	-	-	-	-	-	-	1.6	-	-	2.5	-	-
<i>Rivularia</i>	1.4	-	-	-	-	-	14.0	-	-	-	-	-	-
Fungal palynomorphs													
<i>Glomus</i>	5.0	-	3.7	10.0	1.3	-	18.6	29.5	9.1	4.1	7.6	7.8	4.6
<i>Diporisorites</i>	3.5	-	-	-	10.0	-	4.6	-	-	-	2.5	-	-
<i>Tetraploa</i>	2.8	-	-	-	1.3	8.7	-	1.3	-	-	10.1	-	2.3
<i>Polyadosporites</i>	2.8	-	-	-	-	-	-	-	-	-	-	-	-
<i>Type A</i>	7.0	-	-	-	7.5	-	-	0.5	-	-	-	-	-
<i>Type B</i>	-	-	-	-	7.5	13.0	10.0	15.9	-	-	-	-	-
<i>Hyphae</i>	33.1	-	-	10.0	10.0	-	4.0	6.3	-	-	-	-	0.9
Other indet.	-	-	-	-	6.2	4.3	-	2.1	-	-	-	-	-
Phytoliths	1.4	-	2.1	-	2.5	-	-	-	-	-	5.1	-	2.3
Scolecodonts	1.4	-	10.5	-	-	-	-	-	-	0.8	2.5	-	7.0
Microforaminifera	7.7	97.6	62.4	22.5	17.5	30.4	2.3	3.2	18.2	12.8	21.5	34.0	1.2
Total sum	142	41	189	80	80	46	43	189	55	243	79	103	257

in eutrophic alkaline freshwater and salt lakes. It is represented by free floating trichomes with heterocysts intercalated and akinetes (Van Geel et al., 1994; Komárek & Komarková-Legnerová, 2002). Filaments resembling *Anabaena* were found only in one surface sample (360) in the bottom of the estuary (Plate I: 8).

Rivularia

Identifications of colonies of *Rivularia* sheet were made according to recently published article of Limaye et al. (2007). According to Knoja

et al. (2007), *Rivularia* colonies occur in apparently very different habitat, including the marine littoral, lakes, ponds, and even fast flowing streams where organic phosphate is presumably available. Colonies of sheets of *Rivularia* (Plate I: 7) were encountered in two samples. Rare colonies of *Rivularia* sheets were encountered in a locality near the beach, adjacent to a farm (344), where domestic and agricultural effluents are mixed with the surface water. Frequent colonies of sheets of *Rivularia* were recorded in the surface sample from the bottom of the estuary (361), characterized by recurring changes in salinity and eutrophication by domestic effluents, probably,

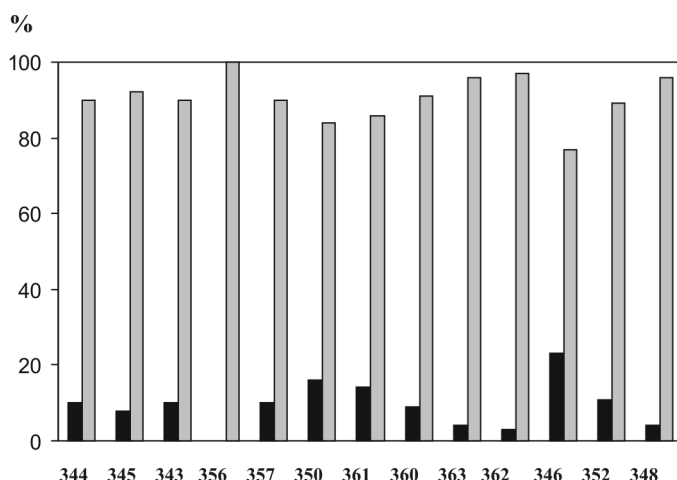


Fig. 3: Percentage diagram of relationship between pollen and spores of vascular plants (columns in black) and NPP (columns in gray) from the surface samples in the southern part of Costa Rica: axis x – number of the samples, y – percentage.

rich in phosphate. We do not exclude that the cyanobacteria occurrences could be the result of low-oxygen environment conditions, even in shallow areas of the estuary (Berrangé, 1987), or in deep anoxic areas (Svendsen et al., 2006).

Spirulina

We encountered spiral trichomes of *Spirulina* in the surface sediments from mangrove (346) and in other samples together with *Rivularia* (344), and *Anabaena?* (360).

Fungal palynomorphs

We found a great number and a wide diversity of fungal spores and hyphae, varying from unicellular to multicellular. Some fungal spores have a very distinctive morphology and some of them may be easily identified. The most frequent are *Glomus*, *Polyadosporites*, *Tetraploa* and *Diporisorites*. Some relatively frequent fungal spores (*Type A* and *Type B*) were not identified and their biological affinities were not established. Abundant fungal spores and hyphae in some localities may be related to their transport by freshwater input from adjacent mangroves.

Glomus

Chlamydospores of *Glomus* were encountered practically in all studied samples (Plate II: 1-3). *Glomus* was most abundant in the surface sediments in the estuary (361 and 360) around which erosive processes are actually evident. Insignificant quantities of *Glomus* were found in samples 350 and 345, and lowest quantities were encountered in 343, 362 and 357.

Diporisorites

Rare and sporadic spores of *Diporisorites* (Plate II: 4) were encountered in surface samples characterized by major frequencies of fungal palynomorphs (Table 1, Fig. 2).

Polyadosporites

Registered *Polyadosporites* correspond to multicelled teliospores of *Ravenelia*, parasiting on Fabaceae, and distributed predominantly in the Neotropics (Hernández et al., 2007). Teliospores of *Ravenelia* are closely resembled to *Polyadosporites*, found in the surface sediments in the gallery forest of Paraná River in Brazil (Medeanic et al., 2004). In studied surface sediments, *Polyadosporites* was

Table 2

Pollen and spore taxa and their presence (+), absence (-) from the surface samples of the Southern Costa Rica .

Pollen and spore taxa	Samples												
	344	345	343	356	357	350	361	360	363	362	346	352	348
MAGNOLIOPHYTA													
<i>Alchornea</i>	+	-	+	-	-	-	-	-	-	-	-	-	-
<i>Alnus</i>	-	-	-	-	-	-	-	-	-	-	+	-	-
Apiaceae	+	-	-	-	-	-	-	-	-	-	-	-	-
Asteraceae	+	-	+	-	-	+	-	+	-	-	+	-	-
<i>Avicennia</i>	-	-	+	-	-	-	-	-	-	-	-	-	-
Brassicaceae	-	-	-	-	-	-	-	-	-	-	+	-	-
Bursenaceae	-	-	+	-	-	-	-	-	-	-	+	-	-
<i>Carya</i>	+	-	-	-	-	-	-	+	-	-	+	-	-
<i>Cecropia</i>	-	-	+	-	+	+	+	+	-	+	+	-	-
Chenopodiaceae	-	-	-	-	-	-	-	-	-	-	+	+	-
Convolvulaceae	-	-	+	-	-	-	-	-	-	-	-	-	-
<i>Cordia</i>	-	-	+	-	-	-	-	-	-	-	-	-	-
Cyperaceae	+	-	+	-	+	+	+	-	-	+	+	-	-
Juncaginaceae	+	-	+	-	-	-	-	-	-	-	-	-	-
Fabaceae	+	-	-	-	-	-	-	-	-	-	-	-	-
<i>Languncularia</i>	-	-	+	-	-	-	-	-	-	-	+	-	+
Malvaceae	+	-	+	-	-	-	-	-	-	-	-	-	-
Urticaceae	+	-	+	-	+	+	+	+	-	+	+	+	-
Palmae	-	-	-	-	-	-	+	-	-	-	+	+	-
Piperaceae	+	+	+	-	+	-	-	-	-	-	+	-	+
Plantaginaceae	-	-	+	-	-	-	-	-	-	-	-	-	-
Poaceae	+	-	+	-	+	+	+	+	-	+	+	+	+
<i>Polygonum hydropiperoides</i>	+	-	-	-	-	-	-	-	-	-	-	+	-
<i>Rhizophora</i>	-	-	+	-	+	+	+	+	+	+	+	-	-
Scrophulariaceae	-	-	+	-	+	-	-	-	-	-	-	-	-
Solanaceae	-	-	-	-	-	-	-	-	-	-	+	-	-
Typhaceae	-	-	-	-	+	-	-	-	-	-	-	-	-
Ulmaceae	+	-	+	-	-	-	-	-	-	-	+	-	-
PTERIDOPHYTA													
<i>Azolla</i>	-	-	-	-	-	-	-	+	-	-	+	-	+
<i>Alsophylla</i>	-	-	-	-	-	+	-	-	-	-	+	+	+
Cyathaceae	+	-	+	-	+	-	+	+	-	+	+	-	-
<i>Dicksonia</i>	-	-	-	-	-	-	-	-	-	-	+	-	-
<i>Dryopteris</i>	-	-	-	-	-	+	-	-	-	-	+	-	-
<i>Microgramma</i>	-	-	+	-	-	-	-	+	-	-	-	-	-
<i>Osmunda</i>	-	-	-	-	-	+	-	-	-	-	+	+	+

Table 2 (continuation)

Pollen and spore taxa and their presence (+), absence (-) from the surface samples of the Southern Costa Rica .

Pollen and spore taxa	Samples												
	344	345	343	356	357	350	361	360	363	362	346	352	348
PTERIDOPHYTA													
Polypodiaceae	+	-	+	-	+	+	-	-	+	-	+	+	+
Pteridae	-	-	-	-	-	-	-	+	+	+	+	+	+
<i>Salvinia</i>	-	-	-	-	-	-	-	-	-	-	-	-	+
Total sum of taxa	15	1	21	0	10	10	7	10	3	7	24	9	9

registered only in one surface sample (344), in the locality of the Ignacia river confluence (Plate II: 7). These teliospores may have been transported by rivers from the adjacent forested areas. Other sources may be connected with agricultural activities of farmers who plant fruit trees and vegetables on their land (situated near the locality of sampling) that are favourable for these fungi.

Tetraploa

Little is known about the biology and distribution of *Tetraploa*, although their fossil and sub-fossil records are common in the sediments of coastal plains subjected to sea-water input. Spores of *Tetraploa* are common in the sediments of coastal plain environments of elevated salinity, such as mangrove (Rull & Vegas-Vilarrúbia, 1999) and salt-and-brackish-water marshes (Medeanic, 2006a; Medeanic et al., 2007). The most frequent spores of *Tetraploa* were registered in the mangrove (346), where relatively rich pollen-and-spore assemblage was defined (Table 2, Plate II: 8-9). *Tetraploa* was frequently recorded in the surface sediments at the bottom of the estuary (350), surrounded by mangroves. In general terms, it was not encountered in areas of stronger influence of tides (345, 343, and 356).

Other fungal spores

Fungal palynomorphs of *Type A* (Plate II: 5-6) and *Type B* (Plate II: 10) were most frequent in the sample 344, in the locality of the Ignacia

river confluence. It is hypothesized that these spores were transported by a river from the forested areas where the diversity of fungi may be higher than in the mangrove swamps. Another explanation of the high frequency of these fungi may be related to fruit-tree and vegetable planting in the surrounding areas.

Hyphae

The most abundant hyphae are encountered in locality 344 (Plate II: 11), where there is significant freshwater input from the Ignacia river. Notable frequencies of hyphae are observed in localities 356 and 357, influenced by the freshwater influxes of the small drainage Pueblo Viejo. The hyphae are predominant in the surface sediments of these sites which are subject to significant rivers and temporal freshwater inputs during strong pluvial periods. They are rare in the estuary samples, and are absent in the most of other samples (Table 1, Fig. 2).

Vegetative remains

Phytoliths

Microscopic silica bodies and silicified epidermal cells of grasses composed of opal are sporadic and are relatively rare in the surface samples near the beach (344 and 357), in mangrove (346), and at the shore of Platanares river (348). They are represented by different morphological types. The most frequent phytoliths are elongate

Table 3

Non-pollen palynomorphs from the surface sediments of the Southern Costa Rica the coast and palaeoecological implications

Non-pollen palynomorphs	Morphology characteristic	Distribution	Palaeoecological implications
Microalgae			
Dinoflagellate cysts	Various ornamentation organic-walled marine microflora (cysts), 40-70 µm in diameter	The oceans and the seas	Marine influence (transgressions) and the coastal plains under sea water influence (tides)
<i>Botryococcus</i>	Colonial green algae, 10-80 µm in diameter	Freshwater-brackish water environments	Brackish-water environments (mangrove, lagoon, intertidal marshes)
<i>Spirogyra</i>	Green algae oval, ellipsoidal zygospores 20-30x 15-68 µm in diameters	Freshwater fluvial, lacustrine environments	Significant freshwater input into intertidal marshes or mangrove
<i>Debarya</i>	Green algae zygospores 35-48µm in diameter	Freshwater fluvial, lacustrine environments	Significant freshwater input into intertidal marshes or mangrove
<i>Pseudoschizaea</i>	Green algae (zygnemataceous) zygospores, 35-50 µm in diameter	Grow at the edge of stream and in the ponds	Freshwater input (rivers) into intertidal marshes
Cyanobacteria			
<i>Rivularia</i>	Colonial blue-green algae (heterocysts and trichomes) 40-95 µm in diameter	Brackish-water environments	Eutrofication of aquatic environments or reccurred changes in salinity in estuary
Fungi			
<i>Glomus</i>	Spores varying in size 30-75 µm in diameter, usually with hyphae attachment	Coastal plains, in principal plant that fix and support dunes dunes, salt matshes	Indicator of erosion around the area, vast distribution in coastal plains
<i>Tetraploa</i>	Spores with four appendices, 35- 60 µm in diameter	Sporadically in salt and brackish-water marshes and mangrove	Salt and brackish-water marshes and mangrov
<i>Polyadosporites</i> (biological affinities - Ravenelia)	Fungal multicelled teliospores with smooth outer layer, 90-100 µm in diameter	Warm and tropical climate of Neotropic where Fabaceae species are abundant	Coastal plains subjected by freshwater input; may indicated on cultivated plants
Hyphae	Chitinous unicelular to multicelular dichotomously branched	Numerous hyphae in organic rich sediments	Indicative of humid and warm climate, freshwater input during pluvial periods and transport by rivers
Phytoliths	Different morphological types of biogenic siliceous microscopic bodies and mineralized epidermal casts	Different terrestrial ecosystems where grasses predominate	Indicators of plant-taxa and relative vegetation cover density (especially, in Poaceae, Cyperaceae and Palmae)
Scolecodonts	Chitinous mouth part of annelid predominantly marine worms in form of jaws and maxillae, 80-200 µm	Salt marshes, mangrovs and beaches	Indicators of shallow water basins near the beaches
Microforaminifera	Coiled plani-and-trochospiral chitinous inner tests of juvenile foraminifera, 40-150 µm in diameter	Oceans and seas	Sea water incursions of tides or sea-level oscillations (transgressions), the most frequent in the surface sediments near sea shore and in estuary

(Poaceae, Plate III: 1). Phytoliths of *Palmae* type are circular crenate (Plate III: 2, 3). Sporadic frequency phytoliths have dumbbell contours (Plate III: 4), and phytoliths of roundel shape are rare (Plate III: 5), both of these type belong to Panicoid phytoliths of Poaceae.

Charcoal particles

Charcoal particles were extremely rare in studied samples. Their low frequency may indicate a low incidence of fire generated by anthropogenic causes in the region.

Invertebrates

Scolecodonts

In our samples, scolecodonts are relatively rare (Plate III: 6-7). They are encountered in the palynological slides from different localities near the beach (344, 343 and 362), in mangrove swamp (346) and one locality, situated not far from the beach (348). They are associated with microforaminifers, some indefinite chitinous parts of arthropods, and other palynomorphs (Fig. 2, Table 1). They are not observed in the surface sediments at the bottom of the estuary which may indicate on their low capacity for transport.

Microforaminifera

In most samples, microforaminifers are more frequent than other palynomorphs (Fig. 2). Many of them are diverse in morphology and in size. The planispiral and trochospiral type forms, resembling *Globigerina*-type, are common (Plate III: 8-9). In some samples, microforaminifers of a single chamber type are rare. The preservation of the microforaminifers is directly related to deposition processes. Poor preservation may be the result of redeposition the sediments by different reasons (heavy rain-off, tides, marine transgressions and by other unpredictable reasons). Some samples have a poor preservation that may be indicative of sedimentary conditions. High frequencies of microforaminifers

are encountered in surface samples from localities near the beach (343 and 345), and in samples from the estuary bottom (350 and 352). The frequencies of microforaminifers decrease closer to the beach, in areas influenced by rivers (344 and 356), and in the estuary with freshwater input (361, 360, 363, and 362). A few microforaminifers were encountered in the surface sample of mangrove swamp near the estuary (346). Microforaminifers are rarely observed in the beach (357), and at the locality, subjected by domestic effluents from the houses of the Pueblo Viejo community. Microforaminifers are low-frequent in mangrove situated relatively far from the estuary where tidal influence is insignificant, and the influence of the Platanares river is strong.

DISCUSSION

The value of the encountered NPPs for paleoecological reconstructions is summarized in the Table 3, where identified taxa of palynomorphs are mentioned, as well as morphological and ecological characteristics, and implications for environmental reconstructions. This table may serve as practical guide, helping in their interpretation. Not all NPPs were identified and we hope that in the future they will be identified and described, as well as their usage. This endeavor will progress as more data is gathered and contribute to World Bank Data on NPPs. Generalizing our results, we propose that in the different localities of the studied mangrove swamp areas, the NPPs are differentiated by taxa frequency and diversity, and their abundance, depending on environmental characteristics. In most of the samples, the microforaminifers and *Botryococcus* are predominant, indicating permanently elevated salinity environments. The localities, situated closely to marine influence (principally, by tides) are characterized by presence of marine indicators, such as dinoflagellate cysts and a few frequencies of freshwater algal palynomorphs. On the contrary, in the samples of the localities situated relatively far from marine influence, the frequent freshwater algal palynomorphs are encountered. The presence of cyanobacteria may be the result of domestic effluence leading to eutrofication with

phosphate enrichment (*Rivularia*). The samples, most diverse and rich in NPPs, are from the localities influenced by rivers.

Below, the characteristics of NPPs assemblages from the different localities are given.

The samples from the beach are characterized by notable frequencies of microforaminifers, *Botryococcus* and fungal palynomorphs, rare phytoliths and scolecodonts. Dinoflagellate cysts - sporadic and rare, probably, due to poor preservation, are the most probably transported by tides and/or may have been redeposited.

In localities of freshwater inputs by rivers into the mangrove swamps, the taxonomic variety of NPPs significantly increases (especially, fungal palynomorphs, some freshwater zygospores of *Spirogyra* and *Pseudoschizaea*). They are associated with relatively rare pollen and spores of vascular plants, where indicative for mangrove vegetation - *Rhizophora*, *Avicennia*, *Cecropia*, *Urticales*, *Alchornea*, *Piperaceae*, *Poaceae*, *Cyperaceae* and rare spores of some ferns were encountered.

The samples from the bottom of the estuary are similar to the samples located closely to the beach, because of the predominance of *Botryococcus* and microforaminifers, sporadic *Tetraploa* and rare scolecodonts. Nevertheless they are differentiated by a complete absence of freshwater algal palynomorphs and a notable abundance of *Glomus* (as a result of soil erosion in the surrounding areas), and other fungal palynomorphs (Types A and B). The presence of cyanobacteria is probably linked to eutrophication. Pollen and spores of vascular plants are rare, represented by *Rhizophora*, *Poaceae*, *Cyperaceae*, *Asteraceae* and *Urticales*. Spores of the aquatic fern *Azolla* were encountered in just one sample, characterizing mangrove swamp vegetation.

The samples from the bottom and shore of the Platanares river, where salinity considerably decreases are characterized by a significant decline in microforaminifers and fungal palynomorphs. Colonies of *Botryococcus* predominate, and the frequencies of *Spirogyra*, scolecodonts and indefinite chitin parts of *Arthropoda* increase. Rare pollen of *Piperaceae*, *Poaceae* and sporadic spores of *Azolla*, *Alsophylla*, *Osmunda*, *Polypodiaceae*, *Pteridae*, and *Salvinia* may indicate a relatively low salinity.

The samples from the main mangrove area are characterized by notable frequencies of *Botryococcus* and microforaminifers, *Tetraploa*, rare *Spirogyra* and *Pseudoschizaea*, scolecodonts and phytoliths. They are associated with pollen, characterized mangroves, such as *Avicennia*, *Bursenaceae*, *Cecropia*, *Urticales*, *Piperaceae*, *Poaceae*, and *Rhizophora*.

The samples from the bottom of the Platanares river are characterized by lower quantities of NPPs. Probably, an anoxic environment was created due to the capacity of mangrove plants to block water flow. The higher quantities of NPPs were found at localities with more energy of the river and with greater freshwater input or rivers' entrance.

CONCLUSIONS

NPP assemblages from the surface sediments in southern Costa Rica mangroves are reported for the first time. Palynological data obtained from the surface samples show relatively low frequencies of pollen and spores, but abundant and diverse NPPs. This fact reinforced us to perform an analysis of their distribution at the different localities, taking into account ecological characteristics and patterns mentioned in the published articles. We used a great number of useful bibliographies which were helpful in determining NPP implications for environmental characterization.

This work has focused on surface samples of an estuarine environment and the obtained results show information related to dynamics and occurring processes in these environments. They may serve as important tools for understanding tectonic history of uplift and subsidence with further studies and possibility of dating. Thus, the implications of NPPs are very useful for palaeogeographic reconstructions in dynamic areas, such as the geological setting of Costa Rica.

The different NPPs may serve as valuable indicators for the evaluation of rapid changes in mangrove environments, and therefore the comparison with the spatial distribution of different NPPs in the mangrove in the present is useful.

Tectonic events could influence NPPs preservations, but those composed of chitin (fungal palynomorphs, microforaminifers and scolecodonts) may continue to be preserved in sediments, recording past sedimentation conditions.

NPPs are certainly may be useful for palaeoecological reconstructions of coastal environments influenced by sea level oscillations, drainage river system and climatic changes and tectonic.

Implications of all above mentioned palynomorphs can lead to general and detailed palynological conclusions about past environments of coastal plains. Further research of NPPs may significantly contribute for interpretations based on pollen and spores and assist in improving detailed palynological conclusions.

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PLATE I

Algal palynomorphs and cyanobacteria:

1 – *Botryococcus*, 2, 3 – *Spirogyra*, 4 – *Mougeotia*, 5 – *Pseudoschizaea*, 6 – *Spirulina*, 7 – *Rivularia*,
8 – unidentified, 9 – unidentified, 10 – *Anabaena*?

Scale: 10 μm .

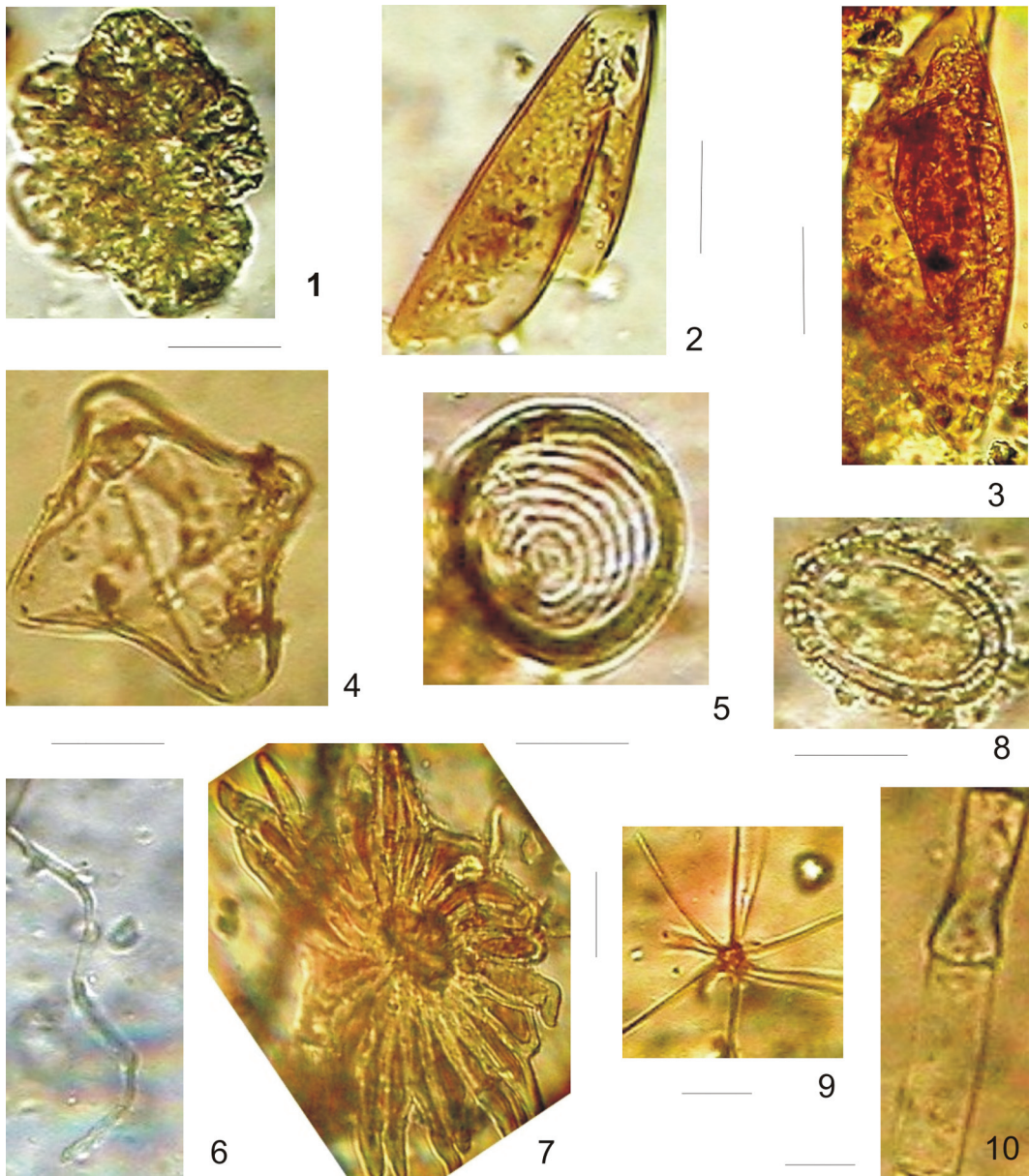


PLATE II

Fungal palynomorphs:

1-3 – *Glomus*, 4 – *Diporisorites*, 5,6 – *type A* (unidentified), 7 – *Polyadosporites*, 8,9 – *Tetraploa*, 10 – *type B* (unidentified), 11 – hyphae, 12 – unidentified.

Scale: 20 μm .

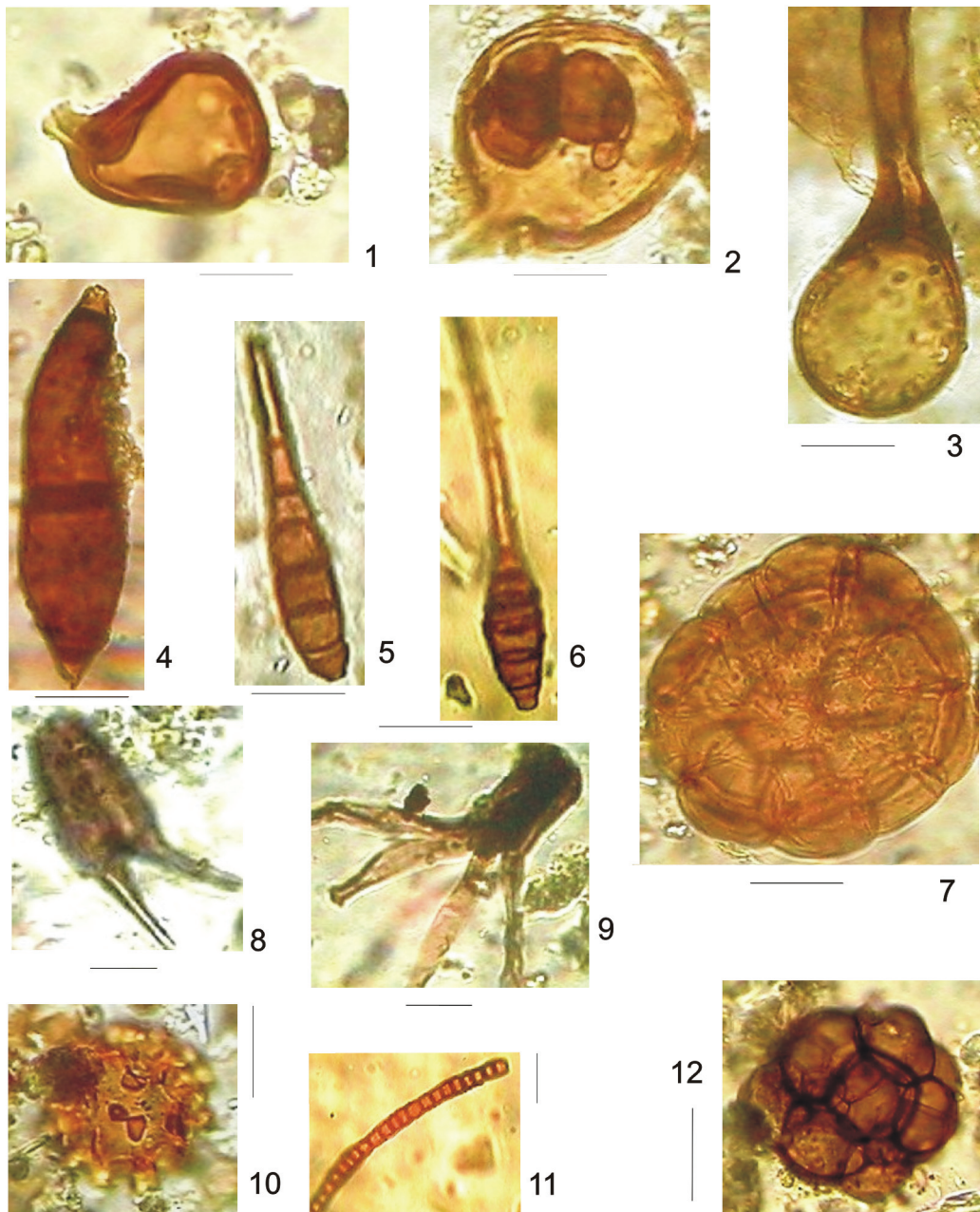


PLATE III

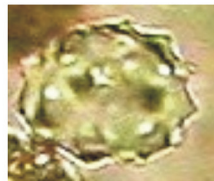
Phytoliths, scolecodonts and microforaminifers:

1-5 – phytoliths, 6,7 – scolecodonts, 8,9 – microforaminifera.

Scale: 10 μm .



1



2



3



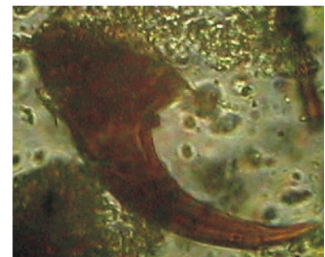
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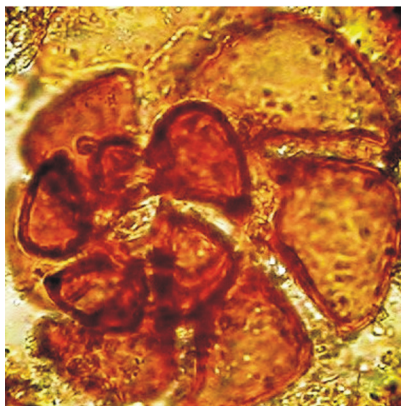
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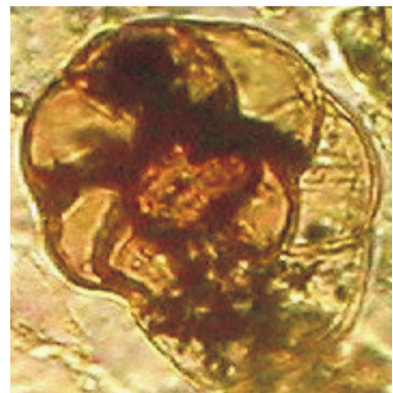
6



7



8



9

