The palynomorphs from surface sediments of intertidal marshes in the estuarine part of the Patos lagoon

Svetlana Medeanic

CNPq, CAPES, UFRGS, Instituto de Geociências, CECO
Av. Bento Gonçalves, 9500, CEP 91509-900, Porto Alegre, RS, Brasil. svetlana.medeanic@ufrgs.br

ABSTRACT – The eight samples from the surface sediments of intertidal marshes on the margin of the Patos Lagoon Estuary were studied by palynological analysis. Pollen and spores of vascular terrestrial and aquatic plants were identified and compared with present vegetation cover of intertidal marshes in order to establish the relationship between pollen-and-spore assemblages and the vegetation cover. The recognized pollen-and-spore assemblages generally coincide with the currently existing vegetation in the intertidal marshes, but show a higher diversity. Other observed palynomorphs include: zygospores and colonies of freshwater chlorococcales, cysts of acritarchs and dinoflagellates, fungal spores, and microforaminiferal linings. Marine algae cysts are a distinguishable characteristic of palynomorph assemblage from surface sediments of intertidal marshes. The anthropogenic impact on this region is emphasized by pollen of introduced plants, such as, *Pinus, Eucalyptus,* and others.

Key words: Palynology, vegetation, intertidal marshes, Rio Grande do Sul, Brazil.

RESUMO – **Os palinomorfos nos sedimentos superficiais de marismas atuais na parte estuarina da laguna dos Patos**. São apresentados os resultados palinológicos de oito amostras coletadas nos sedimentos superficiais de marismas atuais na parte estuarina da Laguna dos Patos. A composição taxonômica de pólen e esporos identificados foi comparada com cobertura vegetal de marismas atuais para estabelecer a correspondência de dados palinológicos e vegetação atual de marismas. Outros palinomorfos encontrados incluem zigosporos e cistos de algas de água doce e marinha, esporos de fungos e invólucros de microforaminiferos. O impacto antrópico nesta região é expresso pelo pólen de plantas introduzidas tais como *Pinus, Eucalyptus,* e outros.

Palavras chave: Palinologia, vegetação, marismas atuais, Rio Grande do Sul, Brasil.

INTRODUCTION

The reconstruction of past vegetation is usually based on pollen and spores of terrestrial and aquatic vascular plants, recorded in corresponded sediments (Gritchiuk & Zaklinskaya, 1948; Bryant, 1978; Sheshina, 1980; Druschits *et al*., 1986; Jackson, 1994; Traverse, 1988; Busk, 1997; Hjell, 1997; Woo *et al.*; 1998, Mulder & Janssen, 1999). The non-conformity between pollen-and-spore assemblages from surface sediments and vegetation cover may be caused by the varying pollen productivity of plants, unequal pollen and spore dispersion capacity, and the mode of pollination (Dimbleby 1967; Berezina & Tyuremnov 1973; Faegri & Iversen 1989; Paez *et al.,* 1997). The destruction of pollen grains and spores may result in the decrease of the taxonomic variety of fossil pollen and spores, and a rise in the discrepancy between recent pollen-and-spore assemblages from surface sediments and existing vegetation cover (Berezina & Tyuremnov, 1973; Bryant, 1978; Traverse, 1988; Tauk, 1990; Brush & Brush, 1994). The sporopollenin-like fungal and algal palynomorphs, resistant to destruction, may also help reconstruction of palaeoenvironments (Cross *et al*., 1966; Graham, 1971; Traverse, 1988). The pH of environments is an important factor, influencing the preservation of palynomorphs in sediments. The alkaline conditions of environments are disadvantage for the preservation of palynomorphs in sediments (Bryant *et al*., 1994).

Based on the palynological study of the core material from the bottom of the Patos Lagoon, Lorscheitter (1983), and Cordeiro and Lorscheitter (1994) made the first reconstruction of the past history of the vegetation in the Coastal Plain of Rio Grande do Sul during the Holocene. With this study, the past intertidal marshes were confirmed. The pollen of Chenopodiaceae-Amaranthaceae, *Typha domingensis* Pers. and spores of *Azolla filiculoides* Lam. were indicated as reliable indicators for intertidal marshes. The new recent palynological records have demonstrated the significant increase of intertidal marshes in the same region during the maximum of the last marine transgression, which occurred around 5000-6000 years BP (Medeanic *et al.,* 2001; Clerot *et al.,* 2003). All these reconstructions were made without previous study of palynomorphs from surface sediments of different ecosystems, spread over the Coastal Plain of Rio Grande do Sul, and establishment of their correspondence to vegetation cover.

The first data on palynomorphs from surface sediments of intertidal marshes in the estuarine part of the Patos Lagoon were represented by Medeanic (2003). Besides pollen and spores of vascular plants, the cysts of acritarchs and dinoflagellates, microforamineral linings were found. The palynomorph assemblage is characterized by frequent pollen of Cyperaceae, Poaceae, Juncaceae, Juncaginaceae, relatively rare Chenopodiaceae, Fabaceae (*Vigna luteola* (Jacq.) Benth type), Asteraceae (*Senecio* L. type). They, in generally, correspond to vegetation cover of the intertidal marshes distributed in this region. Next to the territory, the establishment of relationship between palynomorph taxa from the surface sediments of the Bahía Blanca Estuary, Argentina, and vegetation cover of surrounding areas was made by Grill and Guerstein (1995). The prevalence of pollen of halophilous herbs corresponds to the predominance of these plant taxa in the neighboring vegetation cover where species of Amaranthaceae, Asteraceae, Chenopodiaceae, Poaceae, Cyperaceae are most frequent. In addition, these authors indicate the importance of marine palynomorphs (acritarch and dynoflagellate cysts), which have indicative value for coastal environments of elevated salinity.

Palynological data from surface sediments of mangroves, analogues of salt marshes from south hemisphere till latitude 24º, from Eastern Venezuela are characterized by frequent pollen taxa of *Acrostichum aureum* L., *Cocos nucifera* L., *Rhizophora* L., *Avicennia* L. These plants are certain indicators of mangroves. The correspondence between pollen and plant taxa in this region prove a great possibilities of pollen analysis for palaeoenvironment reconstructions of past mangrove spreading (Rull *et. al.,* 1999).

In this paper, the detailed characteristics of palynomorph assemblage from the surface sediments of recent intertidal marshes in the Coastal Plain of Rio Grande do Sul are represented. These data are based on the samples, collected from the different places of intertidal marshes of the estuarine part of the Patos Lagoon. The obtained pollen-and-spore assemblage was compared with the currently existed vegetation cover, described by Costa and Davy (1992), Cordazzo and Seeliger (1995), Costa *et al.* (1997), and Azevedo (2000).

MATERIALS AND METHODS

Studied area

The studied area is located in the estuarine part of the Patos Lagoon, between the beach of Cassino and the city of Rio Grande (Fig. 1). The climate of this region is warm-temperate, due to the influence of the warm Brazil and the cold Falkland currents (Vieira & Rangel, 1988). The average annual temperature is about 18ºC, averaging 24.6ºC in January, and 13.1ºC in July. The average annual atmospheric precipitation is about 1200 mm. The recent intertidal marshes (marismas) in the Patos Lagoon estuarine region occupy approximately 70 km^2 with individual units varying between 0.9 and 39.8 km^2 (Costa *et al.,* 1997). In the estuarine part of the Patos Lagoon, the intertidal marshes include brackish-water and salt marshes, developing in a regime of fluctuating sea level, as a result of tidal rhythms, seasonal changes in wind direction, changing the salinity, depth, and temperature. The biodiversity of intertidal marshes depends on many factors, among them: frequency of tidal cycles, weather and topography, connection with channels, creeks, and temporary freshwater influxes (Chapman, 1974). The important factor influencing the vegetation cover of saline habitats is the concentration of sodium chloride in substrate that depends on the duration of tidal flooding, rainfall, geomorphology, and the effect of freshwater influxes (Rieley & Page, 1990). The plant distribution here is correlated to the static gradient of inundation from land to sea (Davy & Costa, 1992). The intertidal marshes divide in: constantly flooded oligohaline, frequently flooded mesohaline, occasionally flooded, and rarely flooded marshes (Costa, 1992). Intertidal marsh communities consist mainly of halophilous perennial and annual herbs.

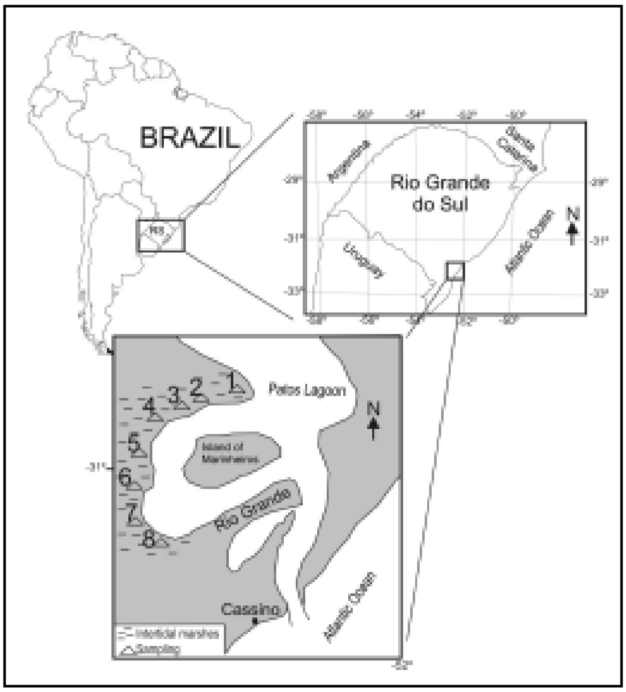


Fig. 1. Map, showing studied area and locations of the sampling (1-8) in the intertidal marshes.

The present intertidal marshes in the estuarine part of the Patos Lagoon, like those in many other parts of the world, are under threat from land use. During the last two-three decades, the tendency of diminution of intertidal marshes and their plant taxonomic variety are observed (Costa and Davy, 1992). Recently, the plant diversity of intertidal marshes in the estuarine part of the State Rio Grande do Sul has been reduced, due to land being used for agriculture, pasturages, and road constructions. A high level of pollution of the Patos Lagoon, especially of its estuarine part, led to abnormal quatities of some plants and decrease others. Nowadays, the species of C*henopodium album* L., *Apium graveolens* L., *Ipomea cairica* (L.) Sweet are wide spread in intertidal marshes of this region, sometimes in abnormal quantity, as a result of organic waste deposits (Costa *et al.,* 1997).

The species of families of Cyperaceae, Poaceae, and Juncaceae are most frequent in the intertidal marshes in the estuarine part of the Patos Lagoon (Cordazzo & Seeliger, 1995, Azevedo, 2000). The species of *Cladium jamaicensis* Crantz*., Cotula coronopifolia* L.*, Crinum americanum* L.*, Cyperus giganteus* Vahl*, Hibiscus cisplatinus* St.-Hil.*, Juncus acutus* L.*, Limonium brasiliense* (Boiss.) O. Ktze*, Paspalum vaginatum* Sw.*, Pluchea sagittalis* (Lam.) Cabr.*, Salicornia gaudichaudiana* Mog.*, Scirpus maritimus* L.*, S. olneyi* A. Gray*, Senecio bonariensis* Hook & Arn.*, Spartina alterniflora* Lois.*, S. densiflora* Brongn.*, Rumex argentinus* Rech.*, Triglochim striata* Ruiz & Pav.*, Typha domingensis* Pers.*, Vigna luteola* (Jacq.) Benth. are frequent. The species of minor occurrences belong to the families of Asteraceae, Chenopodiaceae, Fabaceae, and Malvaceae.

Sampling for palynomorph analysis

To perform this study, during field work in January, 2002, the eight locations from intertidal marshes, situated on the margin of the Patos Lagoon estuary were chosen. Eight samples were collected by soil knife from the surface layer of silt or silty sand at a depth of 1 to 3 cm from each location (Fig. 1). The chosen square before sampling was cleaned from growing plants and roots.

Chemical treatment of samples

All collected samples were desiccated in a furnace under a temperature of 60^{o}C. The samples of 50 g in weight were treated as follows: cold HCl (10%) and NaOH (5%), boiling for 15 minutes. Inorganic substances were separated from the organic matter by "dense liquid" – an aquatic solution of $ZnCl_2$ (density 2.2 g/cm^3). The residual organic material was mounted in glycerol-jelly to prepare the slides. The slides are conserved in the Center of Coastal Geology and Oceanic Studies of the Institute of Geosciences of the Federal University of Rio Grande do Sul.

Palynomorph study

The examination of the obtained organic material included the taxonomic identification of different palynomorphs (pollen and spores of vascular terrestrial and aquatic plants, zygospores of Chlorophyta, cysts of dinoflagellates and acritarchs, and fungal spores). The taxonomic definition of pollen and spores was based on the collection of pollen and spores of recent plants, distributed on the Coastal Plain of the state of Rio Grande do Sul. In order to avoid the invalid definitions, pollen were identified as *sensu lato* (to family or genus level). Currently, morphology and taxonomy of recent pollen, both in the State of Rio Grande do Sul, and in Brazil, are not complete.

The taxonomic determination of zygospores of coccal freshwater green algae was based on Van Geel (1976), Van Geel & Van der Hammen (1978), Van

Geel *et al*. (1980/81, 1986), Canter-Lund & Lund (1995), and others. Other found palynomorphs, as cysts of dinoflagellates and acritarchs, were identified according to Tomas (1997), Pals *et al*. (1980). One taxa of fungal spore was determined according to Garcia (1997).

The relationship between the palynomorph taxa (%) was established from "total palynomorph sum". For the samples 2-5, 7, 8, more than 200 grains of palynomorphs per sample were counted. The total sum of all palynomorphs in the samples 1 and 6 was less than 200 grains per sample. The full list of palynomorph taxa (pollen and spores of vascular plants, zygospores of Chlorophyta, fungal spores, cysts of dinoflagellates, and acritarchs) and their percentages are represented in Table 1 and shown on Figure 2. The frequency (%) of zygospores and colonies of different freshwater algal palynomorphs is shown in Figure 3. The obtained data were plotted on the percentage palynodiagram, using the Tilia Software, designed by Grimm (1987).

The comparison between obtained pollen and spores taxa from surface sediments and taxonomic composition of vegetation cover of intertidal marshes in the estuarine part of the Patos Lagoon, described by Cordazzo & Seeliger (1995), Costa *et al*. (1997), Costa & Davy (1992), Davy & Costa (1992) is shown on the Table 2.

The four plates of microphotographs (Figs. 4-41) show the most frequent palynomorphs from the surface sediments of the studied area.

RESULTS

In the samples from the surface sediments, the frequency of pollen of arboreal plants, AP, is ranging between 2.2-22.8%. Pollen grains of *Pinus maritima* Mill. (0.4-21.4%) and Palmae (0.4-1.7%) are more frequent. Other arboreal pollen, present as single grains, are *Alchornea* Sw., *Eucalyptus* L'Herr., Caprifoliaceae, *Ilex* L., Lauraceae, and others (Tabs. 1, 2). Nonarboreal pollen, NAP-16.6-60.9% are

TABLE 1 – Percentage of palynomorphs, observed in the samples from surface sediments of intertidal marshes in the estuary of the Patos Lagoon, * number of grains of palynomorphs for the sample 1 were not counted).

Palynomorph taxa	Samples							
	1	2	3	4	5	6	7	8
Arboreal pollen, AP								
Palmae	1*	0.6	0.4	1.7	0.4		1.4	1.3
Pinus maritima Mill.	16*	21.4	12.2	6.6	0.4	10.5	9.2	12.5
Other AP	1*	0.8	3.9	1.4	1.4	7.4	6.0	5.6
Non-arboreal pollen, NAP								
Asteraceae	1*	6.1	0.9	5.4	30.5	2.1	18.4	9.4
Chenopodiaceae	3*	4.4	7.9	22.8	14.4	4.2	9.2	10.9
Cyperaceae	1*	6.5	3.5	6.1	3.6	9.4	6.9	13.1
Fabaceae		0.6	0.4	0.5	0.4	1.1		0.3
Juncaceae			1.3	2.4	0.4	1.1	2.3	1.9
Juncaginaceae	1*	0.8	0.4	0.5	0.2	1.1	1.8	0.9
Poaceae		9.3	0.4	13.2	2.3	10.5	13.8	14.1
Typhaceae		1.2		0.2			1.4	2.8
Other NAP	2*	0.6	1.8	3.0	1.8	10.5	1.4	7.5
Spores, S								
Anthoceros L.		8.1	0.4	2.2		3.2	0.9	0.9
Phaeoceros L.	2*	20.6	23.6	4.7	1.1	4.2	4.6	3.8
Monolete psilate		2.0	1.3	0.3	0.4		1.8	0.6
Monolete verrucate	2*	1.0	1.3	0.3	0.4	1.1	0.5	0.3
Trilete psilate	1*	0.8	1.8	0.2	0.4	1.1	0.9	1.3
Trilete echinate		0.8	0.4	0.2	0.2		0.9	0.6
Azolla filiculoides Lam.	12*	0.6	0.4	2.5	0.4	4.2	2.8	1.6
Lophosoria C. Presl.	1*		0.4		0.7	2.1	1.4	1.3
Lycopodiella Holub	8*	1.4	1.8	0.2	0.2	4.2	0.9	0.6
Algae								
Chlorophyta	5*	7.3	26.2	23.0	21.7	10.5	9.7	5.3
Dinophyta	7*	0.8	0.4	0.3	0.2	5.3		
Acritarcha	5*	1.4	0.9	0.5	0.2		0.5	0.3
Fungi	6*	1.8	5.7	0.5	17.1	4.2	1.4	1.3
Microforaminifera			0.4	0.3	0.4	1.1	0.5	
Total Sum	46	495	229	591	557	95	217	320

mainly represented by Amaranthaceae (*Blutaparon* Raf. type), Asteraceae (*Senecio* L. type), Chenopodiaceae (*Chenopodium* L. type), Cyperaceae (different morphological types), Juncaceae (*Juncus* L. type), Juncaginaceae (*Triglochin* L. type), Fabaceae (*Luteola vigna* (Jacq.) Benth. type), Poaceae (different morphological type), Typhaceae (*Typha* L. type) (Tab. 2).

The spores of bryophyts (1.1-24.0%) are relatively abundant and represented by *Anthoceros* L., *Phaeoceros* L., and *Sphagnum* L. The spores of Pteridophyta (2.9-13.8%) present by monolete psilate, monolete verrucate, trilete psilate, trilete echinate morphological types. Other spores of Pteridophyta are less numerous and less diverse. Among them, megaspores of aquatic fern – *Azolla filiculoides* Lam. are relatively frequent (till 4.2%). Spores of *Lophosoria* Presl. and *Lycopodiella* Holub are constantly present in all studied samples. Other spores of ferns, such as *Anogramma* Link., *Blechnum* L., *Equisetum* L., *Huperzia* Bernardi, *Lycopodium* L., *Ophioglossum* L., *Osmunda* L., and *Selaginella* Beauvois are rare.

Besides pollen and spores of vascular plants, the zygospores and colonies of coccal Chlorophyta (5.3-26.2%) were identified. Colonies of *Botryococcus* Kütz (0.6-10.9%) and zygospores of *Spirogyra* Link (3.1-49.5%) are encountered more frequently, than zygospores of *Debarya* (De Bary) Witrock (0-1.9%), *Mougeotia* C.A. Agardh (0-0.9%) and *Zygnema* C.A. Agardh (0-1.2%). The cysts of acritarchs (0.2-1.4%) are represented by *Cymatiosphaera* (Wetzel) Deflandre and *Micrhystridium* Deflandre, and dinoflagellate cysts (0.2-5.3%) present by *Operculodinium* Wall. Rare exemplars of microforaminiferal linings are encountered in some samples (Tab. 1, Fig. 2,). Fungal spores (0.5-5.7%) represented predominantly by *Tetraploa* Berk & Br. Other morphological indeterminate types of fungal palynomorphs are rare.

DISCUSSION

The different quantities of palynomorphs were connected to the lithology of the studied samples. The lowest frequency of palynomorphs was observed in samples 1 and 6, represented by sandy silt. The most concentration of palynomorphs was in the samples 2-5, 7, and 8, represent by silt (Tab. 1).

TABLE 2 – Pollen and spore taxa from the surface sediments and vegetation cover of intertidal marshes in the estuarine part of the Patos Lagoon. Data on vegetation cover are extracted from Costa & Seeliger (1988), Costa (1992), Costa *et al*. (1997), Azevedo (2000).

Plant taxa	Pollen and spores	Vegetation cover
Trees and shrubs		
Alchornea Sw.	+	–
Caprifoliaceae	+	–
Ephedra L.	+	–
Eucalyptus L'Herr.*	+	–
Ilex L.*	+	–
Lauraceae*	+	–
Loranthaceae	+	–
Magnoliaceae*	+	–
Melastomaceae*	+	–
Moraceae–Urticaceae	+	–
Palmae	+	–
Pinus maritima *Mill.	+	–
Myrsine L.	+	–
Rubiaceae	+	–
Salix L.*	+	–
Smilax L.	+	–
Trema Lour.	+	–
Herbs		
Amaranthaceae (*Blutaparon* Raf.)	+	+
Amaryllidaceae (*Crinum* L.)	+	+
Apiaceae	+	–
Asteraceae	+	+
Asteraceae (*Senecio* L.)	+	+
Brassicaceae*	+	+
Chenopodiaceae	+	+
Commelinaceae	+	–
Cyperaceae	+	+
Gunneraceae (*Gunnera* L.)	+	+
Fabaceae	+	+
Fabaceae (*Vigna luteola* (Jacq.) Benth.)	+	+
Juncaceae	+	+
Juncaginaceae (*Triglochin* L.)	+	+
Lamiaceae	+	–
Malvaceae (*Hibiscus* L.)	+	+
Onagraceae (*Ludwigia* L.)	+	–
Poaceae	+	+
Primulaceae	+	–
Scrophulariaceae	+	–
Solanaceae	+	+
Verbenaceae (*Phyla* Lour.)	+	+
Aquatic plants		
Azolla filiculoides Lam.	+	+
Myriophyllum L.	+	–
Typhaceae	+	+
Utriculariaceae	+	–
Mosses		
Anthoceros L.	+	–
Phaeoceros L.	+	–
Sphagnum L.	+	
Ferns		
Monolete psilate	+	–
Monolete verrucate	+	–
Trilete psilate	+	–
Trilete echinate	+	–
Anemia Sw.	+	–
Lophosoria C. Presl.	+	–
Lycopodiella Holub	+	–

* introduced plants, + presence, – absence

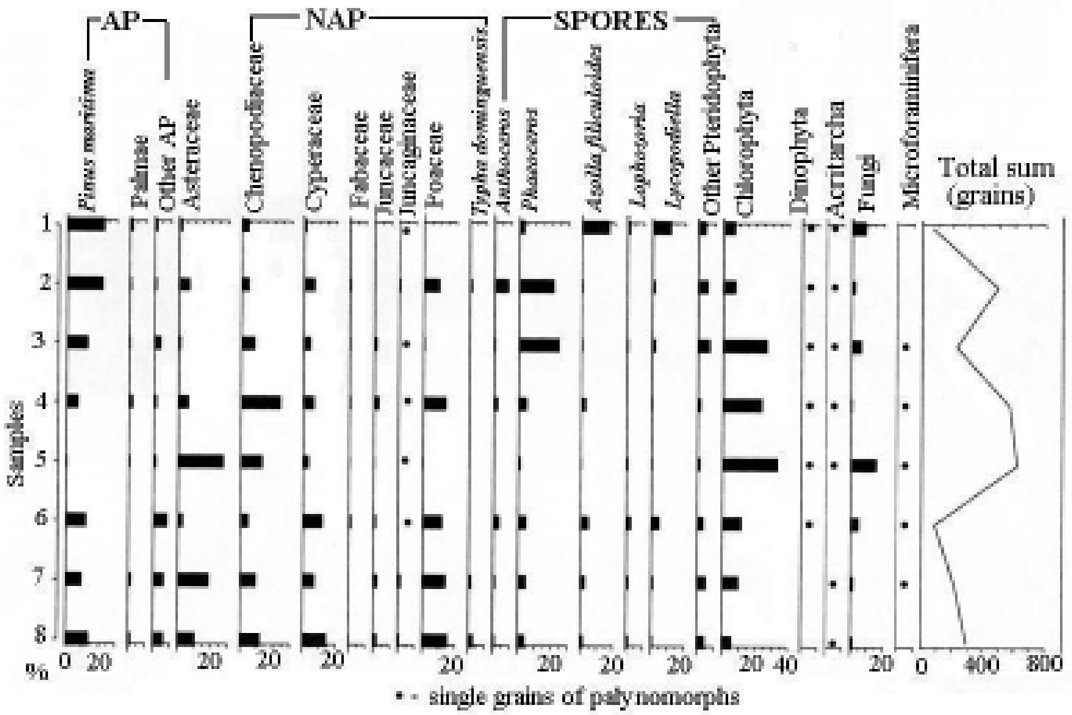


Fig. 2. Percentage pollen diagram of the surface samples. Total sum for percentage calculation includes arboreal pollen (AP), non-arboreal pollen (NAP), non-arboreal pollen of aquatic plants (NAP aquatic), cysts of acritarchs and dinoflagellates, and fungal spores.

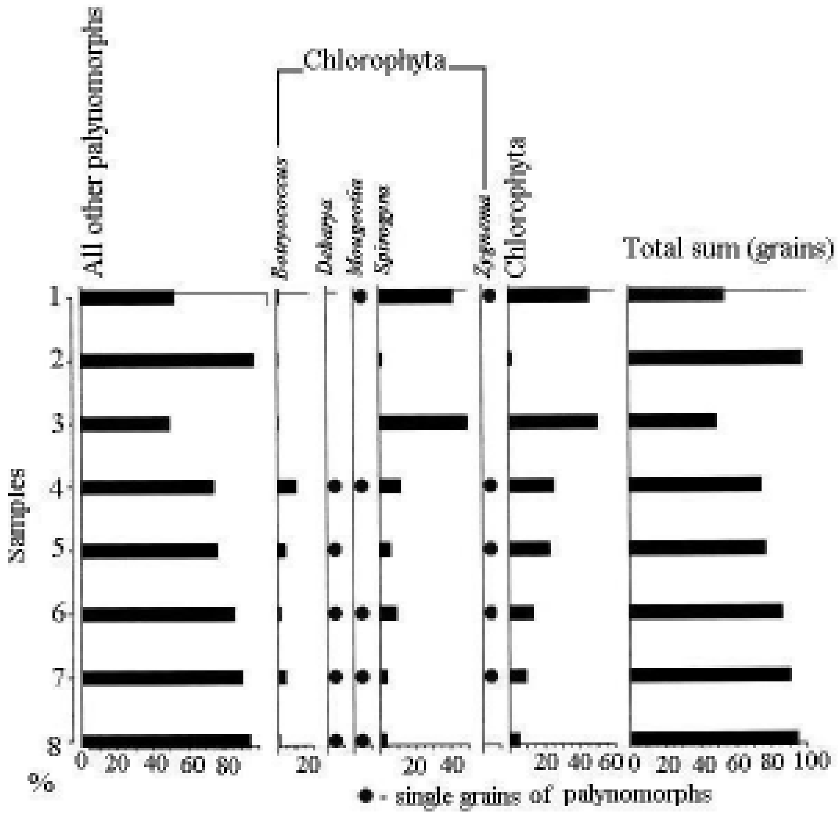


Fig. 3. Percentage diagram of chlorophycean and zygnematophycean coccal algae, registered in the surface samples of intertidal marshes. Total sum for percentage calculation includes zygospores and colonies of algae.

The pollen-and-spore assemblages do not correspond completely to the vegetation cover of inertidal marshes, described by Cordazzo & Seeliger (1995), Costa & Davy (1992), Costa (1992), Costa *et al*. (1997), and Azevedo (2000). The presence of arboreal pollen in the surface samples, and the absence of arboreal plants in intertidal marshes are explained by wind transport of that pollen by air and current inflows from the neighbouring terrestrial areas. Probably, in this same way, the pollen of *Alchornea* L., *Ephedra* L., species of Caprifoliaceae species, Palmae, *Pinus maritima* Mill., *Myrsine* L., *Smilax* L., and *Trema* L. were transported and deposited on the soil. The predominance of pollen of introduced plants of *Eucalyptus* L'Herr., and Pinus *maritima* Mill. is explained by the high pollen productivity of these anemophilous (wind pollination) species, and high capacity of pollen in wind transport. Today, in the region, these introduced plants are common, as used for ornamentation. The single grains of pollen, belonging to plants – indicators of the Atlantic Rainforest, such as *Ilex* L., Lauraceae, Melastomaceae, Moraceae-Urticaceae (Reitz *et al*., 1988) were transported by air or water influxes into intertidal marshes. Today, these species together with species of Magnoliaceae and others (Tab. 2) are widely used for ornamentations of parks and gardens in the extreme south of Brazil.

The herbaceous pollen from surface sediments coincides *in sensu lato* with taxonomic composition of herbaceous terrestrial and aquatic plants growing in intertidal marshes (Tab. 2). Pollen of Asteraceae (*Senecio* L. type), Cyperaceae, Poaceae, Chenopodiaceae (*Chenopodium* L. type), Amaryllidaceae (*Crinum* L. type), Gunneraceae (*Gunnera* L. type), Fabaceae (*Vigna luteola* type (Jacq.) Benth.), Malvaceae (*Hibiscus* L. type), Juncaceae (*Juncus* L. type), Juncaginaceae (*Triglochin* L. type), Polygonaceae (*Rumex* L. type), Typhaceae (*Typha* L. type) are important indicator taxa of intertidal marshes in the estuarine part of the Patos Lagoon. Other herbaceous taxa, represented by Amaranthaceae (*Blutaparon* Raf. type), Apiaceae, Brassicaceae, Commelinaceae, Lamiaceae, Onagraceae (*Ludwigia* L. type), Primulaceae, Scrophulariaceae, Solanaceae, Verbenaceae, came from the neighbouring wetlands and dunes (Table 2).

The low capacity of moss and fern spores being transported by wind is well known (Traverse, 1988). The relatively low frequency of fern spores in surface samples was, probably, caused by their allochtonous origin, i. e. they were transported by permanent or temporal water influxes, channeled into intertidal marshes from the adjacent wetlands. The rare grains of spores of different ferns, such as *Anemia* Sw., *Anogramma* Link, *Blechnum* L., *Dicksonia* L'Hér., *Hyperzia* Bernardi, *Lophosoria* Presl., *Lycopodiella* Holub, *Microgramma* Presl., *Osmunda* L., Polypodiaceae (Table 2) were transported by water influxes from the adjacent areas without influence of salt water and more favourable for their growing.

Relatively high frequency of moss spores, especially, *Phaeoceros* L., makes it possible to propose their distribution *in situ.* The spores of the aquatic fern, *Azolla filiculoides* Lam., were observed in all surface samples. Its high frequency corresponds to the botanical data on the wide spreading of *A. filiculoides* Lam. of intertidal marshes in the estuarine part of the Patos Lagoon (Cordazzo & Seeliger, 1995).

The high frequency of zygospores and colonies of the green coccal algae *Botryococcus* Kütz and *Spirogyra* Link in the surface sediments give new additional information about their distribution in environments of elevated salinity. Maybe, some these algal palynomorphs were transported by freshwater influxes, rivers, channels into studied locations of intertidal marshes. The obtained data on the frequency of *Spirogyra* zygospores in surface sediments of intertidal marshes agree with phycologists' data about wide spreading of *Spirogyra* in the Patos Lagoon (Coutinho & Seeliger, 1984, Torgan *et al*., 2001). A great number of *Botryococcus* colonies of the different morphological types were registered from the Holocene lagoonal sediments formed during the last marine regression (after at about 5000 years BP) in the Tramandaí region (Medeanic *et al.,* 2003), confirmed opinion about distribution of some morphological types of *Botryococcus* colonies in environments of elevated salinity (Torgan *et al*., 2001). The zygospores of "pure" freshwater algae (*Mougeotia* C. A. Agardh, *Debarya* (De Bary) Witrock, and *Zygnema* C. A. Agardh, encountered in a small quantity, or even as single elements in the samples, probably, were transported by freshwater influxes, rivers and channels from adjacent wetlands, freshwater marshes, and small rivers into intertidal marshes.

The cysts of marine acritarchs (*Cymatiosphaera* (Wetzel) Deflandre and *Micrhystridium* Deflandre), dinoflagellate (*Operculodinium* Wall), and microforaminiferal linings are important palynomorphs, characterizing the surface sediments of intertidal marshes. They show the close relationship between the intertidal marshes and the Ocean. The variations in frequency of these marine indicators in the samples are connected with a marine influence. A significant increase in marine palynomorphs in the samples is an evidence of constant marine influences on the area, and on the contrary, the absence, or low frequency of such marine indicators may prove an occasional marine influence. In addition to the opinion of Rampino and Sanders (1981), these palynomorphs may serve as indicators of eustatic sea level fluctuations during the Holocene and may contribute to the evaluation of episodic growth of tidal marshes.

In comparison to pollen data from surface mangrove sediments, the above mentioned palynomorphs are characterized by the predominance of pollen of herbaceous plants, wide spread in the region (Asteraceae, Cyperaceae, Juncaceae, Poaceae). The exotic pollen in surface sediments is connected to wide introduction of exotic plants on the region.

The fungal spores are relatively rare and differed by low taxonomic diversity. Increase in frequency of fungal spores in some samples corresponded to a decrease (or even absence) in marine palynomorphs. This fact may indicate that environments of elevated salinity are less favorable for distribution of fungi. The predominance of fungal spores of *Tetraploa* Berk & Br. between other fungal spores may indicate on dispersed spores of *Tetraploa in situ*, in the intertidal marshes.

CONCLUSIONS

The various palynomorphs from the surface sediments of intertidal marshes in estuarine part of the Patos Lagoon were studied. The observed palynomorphs include pollen and spores of terrestrial and aquatic vascular plants, algal zygospores, colonies and cysts, fungal spores, and microforamineral linings.

The obtained data on pollen-and-spore assemblage from the surface sediments were compared to the currently existing vegetation in present day intertidal marshes in the estuarine part of the Patos Lagoon.

Pollen-and-spores assemblage generally corresponds to the existing vegetation on estuarine part of the Patos Lagoon. These results suggest a close relationship between local taxonomic plant composition of intertidal marshes and the nonarboreal pollen, encountered in superficial sediments. The pollen of the most important intertidal marsh plant taxa are represented by Amaryllidaceae, Asteraceae (*Senecio* type), Chenopodiaceae, Cyperaceae (different morfological types), Fabaceae (*Luteola vigna* (Jacq.) Benth. type), Juncaceae (*Juncus* L. type), Juncaginaceae (*Triglochin* L. type), Poaceae (different morphological types), Polygonaceae, and *Typha* L.

The difference between pollen-and-spores assemblages and vegetational cover concludes in higher diversity of pollen than plants. An identified pollen spectra represents the native local vegetation of intertidal marshes and particularly vegetation from adjacent areas. Some pollen and spores, recorded in surface sediments characterize dunes, wetlands, coastal forests, and exotic plants.

Relatively diverse spores of ferns in the samples, probably, were transported by current influxes in intertidal marshes from the neighbouring areas.

All studied samples are characterized by a constant presence of the zygospores and colonies of Chlorophyta (*Botryococcus* Kütz and *Spirogyra* Link are predominant). By their constant presence in studied samples they may be included in palynomorph assemblages, characterizing surface sediments of intertidal marshes in the estuarine part of the Patos Lagoon.

The marine indicators-cysts of acritarchs of *Cymatiosphaera* (Wetzel) Deflandre and *Micrhystridium* Deflandre, rare cysts of dinoflagellates (*Operculodinium* Wall), and microforaminiferal linings are important palynomorphs to distinguish palynomorph assemblages of intertidal marshes. Such criteria, as frequency of marine palynomorphs in surface sediments of intertidal marshes may be proposed for botanists as additional characteristics to classify the different types of intertidal marshes due to marine influence.

The spores of fungi are rare and differ by low variety. Constant presence of fungal spores *Tetraploa* Berk & Br , in the samples allows us to consider them as palynomorphs *in situ*.

The disturbance of native ecosystems in the estuarine part of the Patos Lagoon by human impact is revealed by frequent exotic pollen: *Pinus maritima* Mill., *Eucalyptus* L'Herr., *Ilex* L., *Salix* L., some species of Lauraceae, Magnoliaceae, Melastomaceae, Moraceae-Urticaceae.

The obtained data are important for an establishment of model palynomorph assemblages from intertidal marshes and use them for the Holocene palaeoenvironmental reconstructions.

The represented results are the first data, received from the surface sediments of intertidal marshes in the estuarine part of the Patos Lagoon. In the future we will plane to enlarge an area for the study of surface sediments of intertidal marshes and increase the number of samples for analysis. A close cooperation with the botanists who deal with taxonomy and ecology of plants, distributed in the intertidal marshes is needed.

Besides, the obtained results will serve as useful information for the Latin American Pollen Database.

ACKNOWLEDGEMENTS

This study was carried out under the project "Applied palynology for palaeoenvironmental and paleoclimatic reconstructions on the Coastal Plain of Rio Grande do Sul during the Holocene" supported by CNPq (grant nº 1234567-99) and CAPES. I am grateful to Dr. Marie Pierre Ledru (Institut des Sciences de Evolution, Palaeoenvironments, Montpellier, France) and Dr. Silvia Grill (Universidad Nacional del Sur, Argentina), for revision, useful comments and suggestions. I am indebted to Dr. Lezilda Carvalho Torgan at the Museu de Ciências Naturais da Fundação Zoobotânica do Rio Grande do Sul for her assistance in microphotography of palynomorphs and advices related to chlorophycean algae. The author is grateful to Dr. Maria Luiza Lorscheitter and Dr. Vera Regina Werner for revision of the last version of manuscript and useful comments and suggestions. I am indebted to biologist Haywood Dail Langhinghouse IV for his correction of the English version of the manuscript.

REFERENCES

AZEVEDO, A.M.G. 2000. **Habitats, associações vegetais e Fenologia das plantas das marismas da ilha da Pólvora estuário da Lagoa dos Patos (RS, Brasil)**. 115 p. Dissertação (Mestrado em Oceanografia Biológica) – Fundação Universidade de Rio Grande, Rio Grande.

BEREZINA, N.A., TYUREMNOV, S.I. 1973. Sokrannosti i razrushenie pyltsy kak vazhnyi faktor v obrazovanii sporovo-pyltsevykh spektrov (Conservation and destruction of pollen as important factors in forming of palynological spectra). Methods of study in Palynology. Moscow: Nauka. p. 5-7. In Russian.

BRUSH, G.S., BRUSH, L.M. 1994. Transport and deposition of pollen in an estuary: Signature of the landscape. In: TRAVERSE A. (Ed.): **Sedimentation of organic matter**. Cambridge: Cambridge Press. p. 33-46.

BRYANT JR., V.M. 1978. Palynology: A useful method for determination palaeoenvironments. **Texas Journal of Science**, Dallas, v. 45, p. 1- 45.

BRYANT, V.M., HOLLOWAY, R.G., JONES, J.G., CARLSON, D.L. 1994. Pollen preservation in alkaline soils of the American Southwest. In A.Traverse (Ed.): **Sedimentation of organic matter**. Cambridge: Cambridge Press. p. 47-58.

BUSK, J. G. H. 1997. The distribution of pollen in the surface sediments of Lake Malavi, Africa and the transport of pollen in large lake. **Review of Palaeobotany and Palynology**, Amsterdam, v. 97, p. 123-153.

CANTER-LUND, H.; LUND, J.W.G. 1995. **Freshwater Algae. Their microscopic world explored**. London: Biopress. 360 p.

CHAPMAN, V.J. 1974. **Salt marshes and deserts of the world**. 2 ed. New York: Interscience Press. 392 p.

CLEROT, L.C.P.; MEDEANIC, S.; TORGAN, L.C.; DILLENBURG S. R.; TOMAZELLI, L.J. 2003. Evolução da barreira IV na região do Cassino, RS durante o Holoceno. In: CONGRESSO DA ASSOCIAÇÃO BRASILEIRA DE ESTUDOS DO QUATERNÁRIO E II CONGRESSO DO QUATERNÁRIO DOS PAÍSES DE LINGUA IBÉRICAS, 2., 2003, Recife. **Anais...** Recife, 2003. p. 149.

CORDAZZO, C.V.; SEELIGER, U. 1995. **Guia ilustrado da vegetação costeira no extremo Sul do Brasil**. Rio Grande: Ed. da FURG. 275 p.

CORDEIRO, S.H.; LORSCHEITTER, M.L. 1994. Palynology of Lagoa dos Patos sediments, Rio Grande do Sul, Brasil. **Journal of Paleolimnology**, Dordrecht, v. 10, p. 35-42.

COSTA, C.S.B. 1992. Tidal marsh and wetland plants. In: SEELIGER, U.; ODEBRECHT, C.; CASTELO, J.P. (Ed.). **Subtropical Convergent Environments. The Coast and Sea in the Southwestern Atlantic**. Berlin: Springer-Verlag. p. 24-26.

COSTA, C.S.B.; DAVY, A.J. 1992. Coastal Salt march communities of Latin America. In: COASTAL PLANT COMMUNITIES OF LATIN AMERICA. Rio Grande: Ed. da FURG. p. 179-199.

COSTA, C.S.B.; SEELIGER, U.; OLIVEIRA, C.P.L.; MAZO, A.M.M. 1997. Distribuição, funções e valores das marismas e pradarias submersas no estuário da lagoa dos Patos (RS, Brasil). **Atlântica**, Rio Grande, v. 19, p. 67-85.

COUTINHO, R.; SEELIGER, U. 1984. The horizontal distribution of the benthic algal flora in the Patos Lagoon estuary, Brazil, in relation to salinity substratum and wave Exposure. **Journal of Experimental Marine Biology and Ecology**, Amsterdam, v. 80, p. 247-257.

CROSS, A.T., THOMPSON, G.G., ZAITZEFF, J.B. 1966. Source and distribution of palynomorphs in bottom sediments, southern part of the Gulf of California. **Marine Geology**, Amsterdam, v. 4, p. 467-524.

DAVY, A.J.; COSTA, C.S. B. 1992. Development and organization of salt march Communities. In: COASTAL PLANT COMMUNITIES OF LATIN AMERICA. Rio Grande: Ed. da FURG. p. 157-177.

DIMBLEBY, G.W. 1967. Soil pollen analysis. **Journal of Soil Sciences**, Oxford, v. 12, n. 1, p. 1-25.

DRUSTCHITS, V.V.; RYBAKOVA, N.O.; SHESHINA, O.N. 1986. Palinotsenozy raznofatsialnych osadkov i rekonstruktsia rastitelinosti. (Palynocoenozes from various sedimentary facies and vegetation reconstruction). **Vestnik Moskovskogo Universiteta**. Serie Geology, Moscow, v. 4, n. 1, p. 18-24. In Russian.

FAEGRI, K.; IVERSEN, J. 1989. **Text-book of pollen analyses**. New York: Hafner Press. 295 p.

GARCIA, M.J. 1997. Palinologia de turfeiras quaternárias do médio vale do rio Paraná do Estado de São Paulo, Brasil. Parte I: Fungos, Algas, Briófitas e Pteridófitas. **Revista Universidade Guarulhos-Geociências**, Guarulhos, v. 2, n. esp., p. 148-165.

GRAHAM, A. 1971. The role of Myxomyceta spores in palynology (with a brief note on the morphology of certain algal zygospores). **Review of Palaeobotany and Palynology**, Amsterdam, v. 11, n. 2, p. 89-99.

GRITCHIUK, V.P., ZAKLINSKAYA, E.N. 1948. **Analiz iskopaemych pyltsy i spor i ego primenenie v paleogeografii**. (Analysis of fossil pollen and spores its utility in palaeogeography). Moscow: Nauka. 222 p. In Russian.

GRILL, S.; GUERSTEIN, R. 1995. Estudio palinológico de sedimentos superficiales en el estuario de Bahia Blanca, Provincia de Buenos Aires, Argentina. **Polen**, Madrid, v. 7, p. 41-49.

GRIMM, E.C. 1987. CONISS: A Tortran 77 Program for stratigraphically constrained cluster analysis by the method of the incremental sum of square. **Pergamon Journal**, Amsterdam, v. 13, p. 13-35.

HJELL, K.L. 1997. Relationship between pollen and plants in human-influenced vegetation types using presence-absence data in western Norway. **Review of Palaeobotany and Palynology**, Amsterdam, v. 99, p. 1-16.

JACKSON, S.T. 1994. Pollen and spores in Quaternary lake sediments as sensors of vegetation composition: Theoretical models and empirical evidence. In: TRAVERSE, A. (Ed.): **Sedimentation of organic matter**. London: Cambridge Press. p. 47-58.

LORSCHEITTER, M.L. 1983. Evidences of sea oscillations of Late Quaternary in Rio Grande do Sul, Brazil, provided by palynological studies. **Quaternary of South America and Antarctic Peninsula**, Rotterdam, v. 1, p. 53-60.

MEDEANIC, S. 2003. Registros palinológicos nos sedimentos superficiais nas marismas atuais na parte Estuarina da Laguna dos Patos: Contribuição nas reconstruções paleoambientais. In: CONGRESSO DA ASSOCIAÇÃO BRASILEIRA DE ESTUDOS DO QUATERNÁRIO E II CONGRESSO DO QUATERNÁRIO DOS PAÍSES DE LINGUA IBÉRICAS, 2., 2003, Recife. **Anais...** Recife: 2003. p. 10.

MEDEANIC S.; DILLENBURG S.R.; TOLDO JUNIOR, E.E. 2001. Novos dados palinológicos da transgressão marinha pós-glacial em sedimentos da Laguna dos Patos. **Revista Universidade de Guarulhos-Geociências**, Guarulhos, v. 6, p. 64-76.

MEDEANIC, S.; JANKOVSKA, V.; DILLENBURG, S.R. 2003. The implication of green algae (Chlorophyta) for palaeoecological reconstruction of the Holocene lagoon system in the Tramandaí Lagoon region, Rio Grande do Sul, Brazil. **Acta Palaeobotanica**, Krakow, v**.** 43, n. 1, p. 113-123.

MULDER, C., JANSSEN, C.R. 1999. Occurrence of pollen and spores in relation to present day vegetation in a Dutch peat land area. **Journal of Vegetation Science**, Uppsala, v. 10, p. 87-100.

PAEZ, M.M., VILLAGRAN, C., STUTZ, S., HINOJ, F., VILLA, R. 1997. Vegetation and pollen dispersal in the subtropical-temperate climatic transition of Chile and Argentina. **Review of Palaeobotany and Palynology**, Amsterdam, v. 96, p. 169-181.

PALS, J.P.; VAN GEEL, B.; DELFOS, A. 1980. Palaeoecological studies in the Klokkeweel bog near Hoogkarspel (Prov. of Noord-Holland). **Review of Palaeobotany and Palynology**, Amsterdam, v. 30, p. 371-418.

RAMPINO, M.R.; SANDERS, J.E. 1981. Episodic growth of Holocene tidal marches in the northeastern United States: a possible indicador of eustatic sea level fluctuations. **Geology**, New York, v. 9, p. 63-67.

REITZ, R.; KLEIN, R.M.; REIS, A. 1988. **Madeira do Rio Grande do Sul**. Porto Alegre. 525 p.

RULL, V.; VEGAS-VILARRUBIA, T.; PERNIA, N.E. 1999. Palynological record of Early-Mid Holocene Mangrove in Eastern Venezuela. Implications for Sea-level rise and Disturbance history. **Journal of Coastal Research**, Florida, v. 15, n. 2, p. 496-504.

RIELEY, J.O.; PAGE, S.E. 1990. **Ecology of plant communities. A phytosociological account of the British vegetation**. London: Logman. 178 p.

SHESHINA, O.N. 1980. O stepeni shodstva palino-i-fitocenozov i restavratsia paleotafocenozov. (Comparison between pollen-and spores assemblages and plant cover and restauration of palaeotafocoenozes). **Vestnik Moskovskogo Universiteta**, Ser. Geologia*,* Moscow, v. 4, n. 4, p. 85-91. In Russian.

TAUK, S.M. 1990. Biodegradação de resíduous orgânicos no solo. **Revista Brasiléira de Geociências**, São Paulo, v. 20*,* n. 1-4, p. 299-301.

TOMAS, C.R. 1997. **Identifying Marine Phytoplankton**. New York: Academic. Press. 858 p.

TORGAN, L.C.; BARREDA, K.A.; FORTES, D.F. 2001. Catálogo das algas de águas continentais e marinhas do estado do Rio Grande do Sul, Brasil. **Iheringia**, Série Botânica, Porto Alegre, n. 56, p. 147-183.

TRAVERSE, A. 1988. **Paleopalynology**. London: Unwin Hyman Ltd. 600 p.

VAN GEEL, B. 1976. Fossil spores of Zygnemataceae in ditches of a prehistoric settlement in Hoogkarspel (The Netherlands). **Review of Palaeobotany and Palynology**, Amsterdam, v. 22, n. 4, p. 337-344.

VAN GEEL, B.; BOHNCKE, S.J.P.; DEE, H. 1980/81. A palaeoecological study of the Upper Late Glacial and Holocene sequence from "de Borchert" the Netherlands. **Review of Palaeobotany and Palynology**, Amsterdam, v. 31, n. 3, 4, p. 367-448.

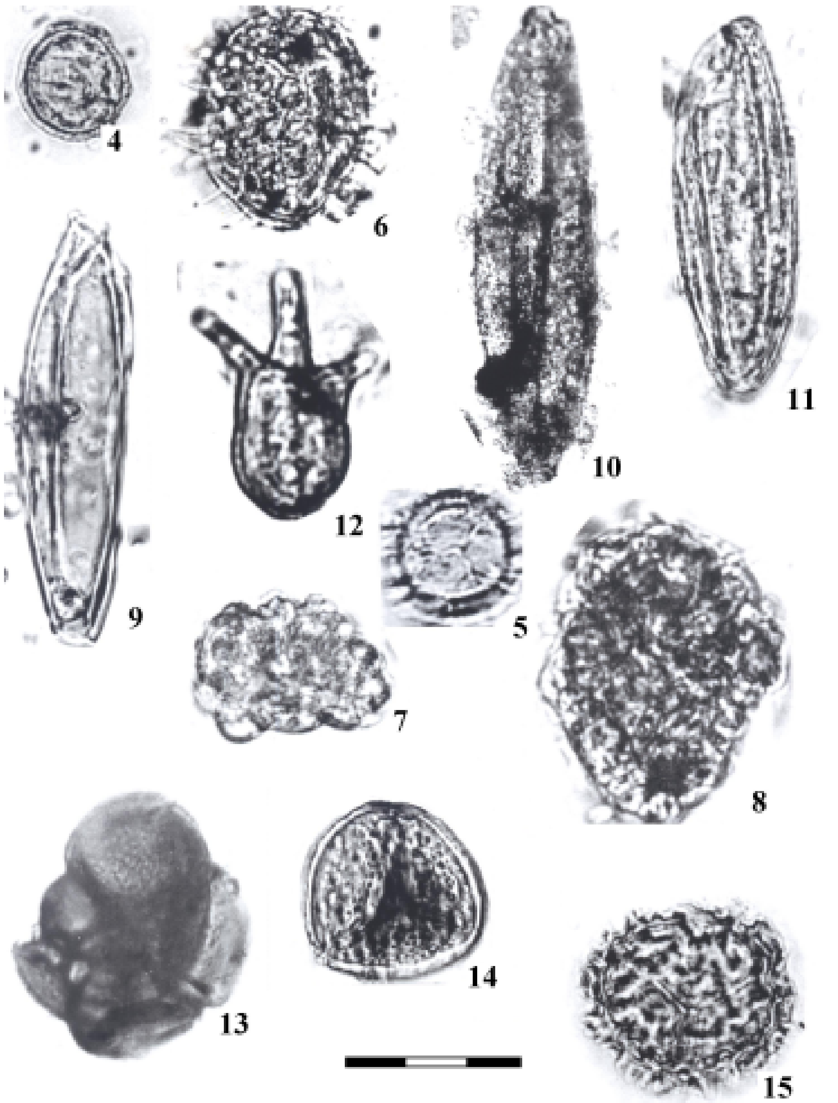
VAN GEEL, B.; KLINK, A.G.; PALS, J.P.; WILGERS, J. 1986. Upper Eemian Lake deposits from Twente, Eastern Netherlands. **Review of Palaeobotany and Palynology**, Amsterdam, v. 47, p. 31-61.

VAN GELL, B.; HAMMEN, T. Van der 1978. Zygnemataceae in Quaternary Colombian sediments. **Review of Palaeobotany and Palynology**, Amsterdam, v. 25, n. 5, p. 377-392.

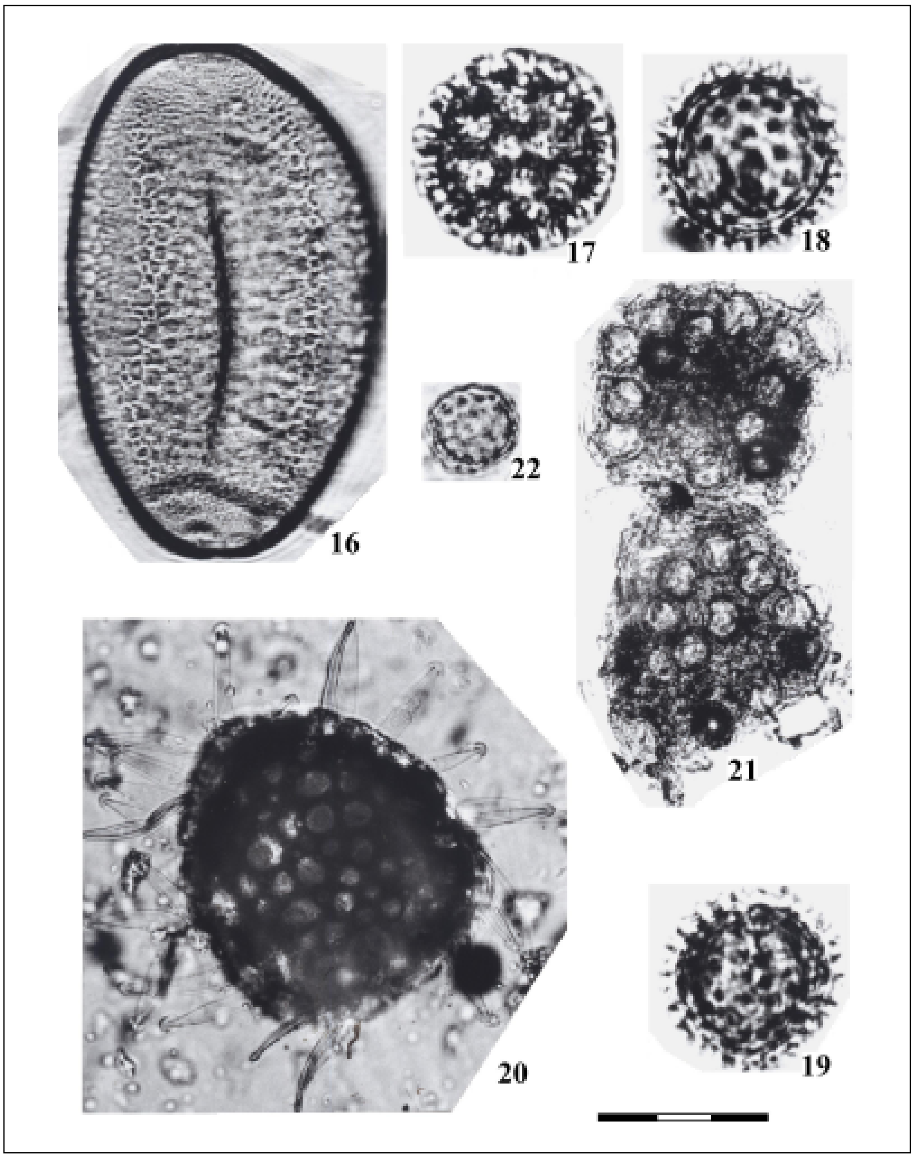
VIEIRA, J.P.; RANGEL, S.R.S. 1988. **Planície Costeira do Rio Grande do Sul: Geografia física, vegetação e dinâmica sociodemográfica**. Porto Alegre: Sagra. 256 p.

WOO, H.J.; OERTEL, G.F.; KEORNEY, M.S. 1998. Distribution of pollen in surface sediments of a barrier-lagoon system, Virginia, USA. **Review of Palaeobotany and Palynology**, Amsterdam, v. 102, p. 289-303.

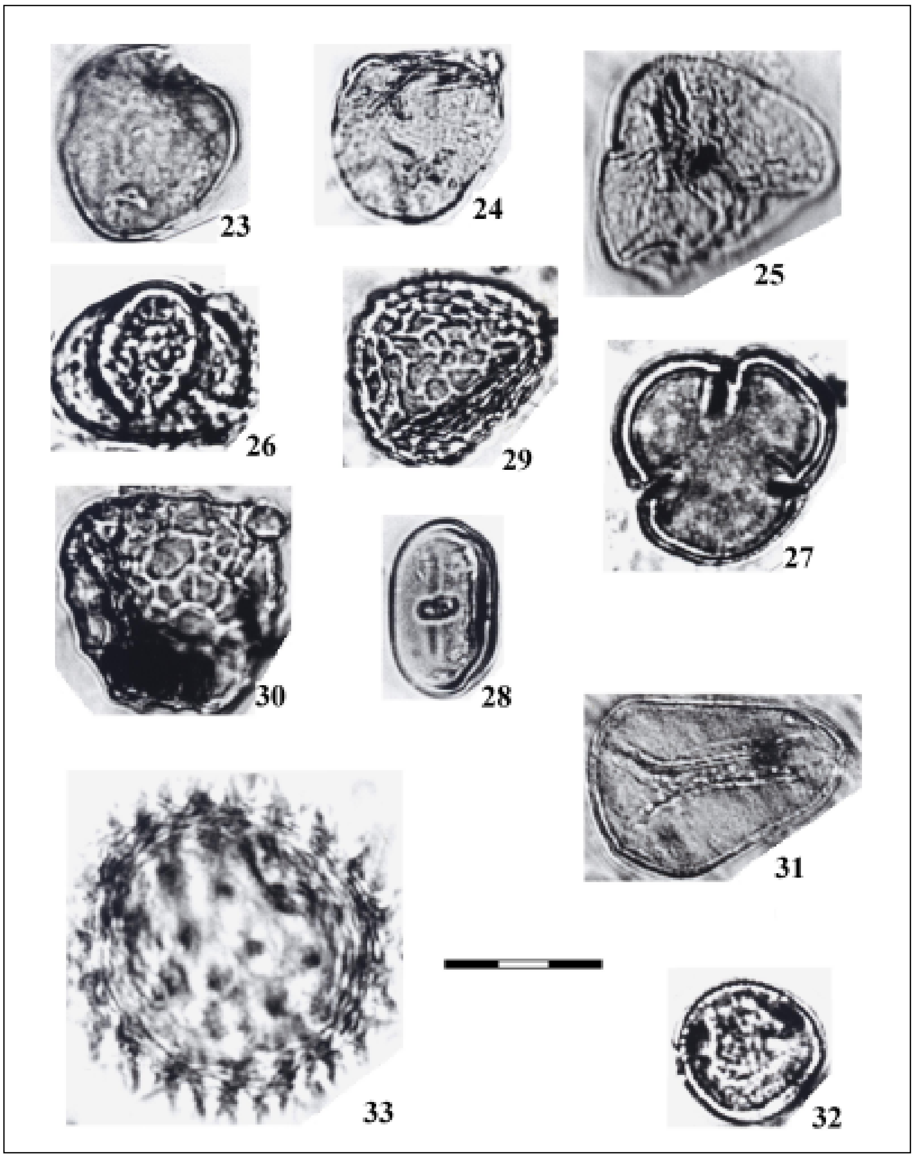
Trabalho recebido em 17.V.2004. Aceito para publicação em 30.VII.2006.



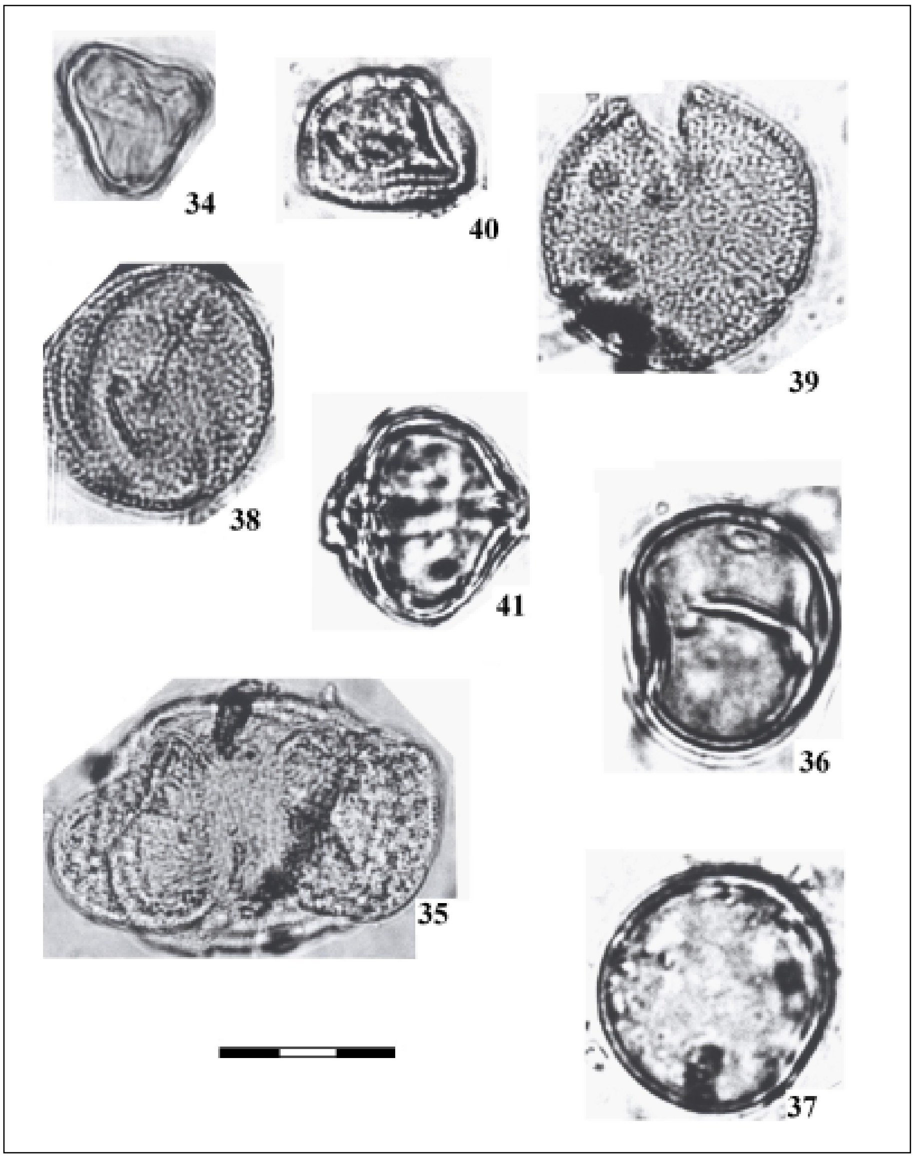
Figs. 4-15. LM. **4.** Acritarcha (*Micrhystridium* type). **5.** Acritarcha (*Cymatiosphaera* type). **6.** Dinophyta (*Operculodinium* type). **7, 8.** Chlorophyta (*Botryococcus* type). **9-11.** Chlorophyta (*Spirogyra* type). **12.** Fungi (*Tetraploa* type). **13.** Microforaminifera lining. **14.** Bryophyta (*Phaeoceros* type). **15.** Bryophyta (*Anthoceros* type*)*. Bar: 10 mm.



Figs. 16-22. LM. **16.** Amarillidaceae (*Crinum* type). **17.** Amaranthaceae (*Blutaporon* type). **18, 19.** Asteraceae (*Senecio* type). **20, 21**. Azollaceae (*Azolla filiculoides* type). **22.** Chenopodiaceae (*Chenopodium* type). Bar: 10 mm.



Figs. 23-33. LM. **23-25, 31.** Cyperaceae. **26, 27.** Gunneraceae (*Gunnera* type). **28.** Fabaceae. **29, 30.** Fabaceae (*Vigna luteola* type). **32.** Juncaginaceae (T*riglochin* type). **33.** Malvaceae (*Hibiscus* type). Bar: 10 mm.



Figs. 34-41. LM. **34.** Myrtaceae (*Eucalyptus* type). **35.** Pinaceae (*Pinus maritima* type). **36, 37.** Poaceae. **38, 39.** Polygonaceae (*Rumex* type). **40.** Typhaceae (*Typha* type). **41.** Verbenaceae (*Phyla* type). Bar: 10 mm.