Palynomorphs in Holocene sediments from a paleolagoon in the coastal plain of extreme southern Brazil

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ABSTRACT

This paper presents the results of a qualitative palynological analysis of a 140 cm-thick section of Holocene sediments from a paleolagoon, representing the last 2600 years, taken from an outcrop at Hermenegildo Beach (33°42’S; 53°18’W), located in the municipality of Santa Vitória do Palmar, in the state of Rio Grande do Sul, Brazil. Samples were treated with hydrochloric acid, hydrofluoric acid and potassium hydroxide, after which they were subjected to acetolysis and mounted on glycerin-coated slides for light microscopy analysis. Among the 48 palynomorphs identified were 25 fungi, eight algae, three bryophytes, and 12 pteridophytes. Brief descriptions and illustrations of each palynomorph are presented, together with ecological data from the organism of origin when possible. Our findings will serve as reference material for paleoenvironmental studies in the coastal plain of southern Brazil.

Key words: palynomorph descriptions, paleolagoon, Holocene, southern coastal plain, Rio Grande do Sul

Introduction

Little is known about sea-level oscillations and their effects on climate and vegetation dynamics in the southern coastal plain in the state of Rio Grande do Sul, Brazil, despite the contribution that such oscillations have made to shaping the current landscape of the region. Studies of plant succession can expand the understanding of the historic climate and vegetation dynamics responsible for the existing phytogeographic patterns. Palynological analysis of Quaternary sediment profiles with the associated chronological context is of great importance to plant succession studies because it elucidates vegetation changes over time. Archived catalogs are fundamental to the correct identification of palynomorphs in sediments. Few palynomorph descriptions exist for use in paleoenvironmental studies of the > 600 km-long coastal plain of Rio Grande do Sul, the southernmost Brazilian state (Lorscheitter 1988, 1989; Neves & Lorscheitter 1992, 1995a; Neves & Bauermann 2003, 2004; Roth & Lorscheitter 2013), and there are no palynological references for the extreme southern portion of the region.

The purpose of the present study was to document the palynology of coastal plain sediments from the extreme south of Rio Grande do Sul, representing the last 2600 years, as reference material for paleoenvironmental research. We provide taxonomic descriptions and photomicrographs, as well as ecological information about the organism of origin when possible.

Materials and methods

A 140 cm-thick sediment profile of a paleolagoon was obtained from a Holocene outcrop at Hermenegildo Beach (33°42’S; 53°18’W), located in the municipality of Santa Vitória do Palmar, in the state of Rio Grande do Sul, in the coastal plain in the extreme south of Brazil (Fig. 1). Twenty-eight samples were taken at 5-cm intervals. Each was collected in an 8-cm³ box, directly from the vertical slope. The radiocarbon date at the base of the profile was determined by Beta Analytic Inc. (Miami, FL, USA).

The samples were treated by hydrochloric acid, hydrofluoric acid and potassium hydroxide, after which they were subjected to acetolysis and filtered through a net with a 250-μm mesh (Faegri & Iversen 1989). The samples were mounted on glycerin-coated slides (Salgado-Labouriau 1973; Faegri & Iversen 1989) and examined under light microscopy (DIA-PAN; Leica Microsystems, Wetzlar, Germany). We counted a minimum of 300 pollen grains per sample. In parallel counts, we identified spores and other palynomorphs, which were monitored by saturation curves. Photomicrographs were taken using a digital camera (DFC295; Leica Microsystems) connected to the microscope.

Botanical identification was based on the reference collection of the Palynology Laboratory of the Department of Botany at the Federal University of Rio Grande do Sul, located in the city of Porto Alegre, and on descriptions in the literature (Van Geel 1978; Hooghiemstra 1984; Barnett

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Figure 1. A. State of Rio Grande do Sul, in southern Brazil; B. Location of Hermenegildo Beach; C. Hermenegildo Beach and the Holocene paleolagoon outcrop studied, composed of dark-clay organic sediments covered by transgressive sands.

Results and discussion

The radiocarbon date at the base of the Hermenegildo Beach sediment profile was 2590 ± 60 years BP, indicating that the study sequence represented the last 2600 years. A total of 48 taxa were identified in the sequence: 25 fungi, eight algae, three bryophytes and 12 pteridophytes.

Fungi

Phylum: Glomeromycota
Class: Glomeromycetes
Order: Glomerales
Family: Glomeraceae


Fig. 2

Spheroidal, yellow and smooth-walled chlamydospore, always connected to coenocytic hyphae. Diameter: ca. 22 μm.
Note: The genus was reported for the Quaternary in Rio Grande do Sul under the former names Rhizophagites Rosendahl (Lorscheitter 1989) and Rhizophagus Dang (Neves & Lorscheitter 1992; Neves & Bauermann 2003).

Ecological data: Glomus is the most common genus of arbuscular fungi in mycorrhizal associations with the roots of many vascular plants (Schübler et al. 2001).

Phylum: Ascomycota
Class: Dothideomycetes
Order: Pleosporales
Family: Tetraplosphaeriaceae


Fig. 3

Conidia multicellular, elongated, dark brown, verrucate, with four divergent septate appendages. Long axis (without appendages): 37-43 μm. Short axis: 26-30 μm.

Note: The species has been cited as *Tetraploa aristata* Berk. & Brome (Van Geel 1978). The genus was reported for the Quaternary as *Tetraploa* (Barnett & Hunter 1987), and the species was reported as *Tetraploa aristata* Berk. & Brome for the Quaternary in Rio Grande do Sul (Neves & Lorscheitter 1992; Neves & Bauermann 2003; Leal & Lorscheitter 2006).

Ecological data: widespread fungi, generally found on leaf bases and stems just above the soil (Van Geel 1978).

Order: Microthyriales
Family: Microthyriaceae

3. *Microthyriaceae*

Fig. 4

Hyaline and smooth walled structure, approximately circular in frontal view, with irregular lobate margins. Diameter: 26-30 μm.

Ecological data: generally epiphyllous fungi with broad distribution in tropical regions (Dilcher 1965).

Class: Sordariomycetes
Order: Sordariales
Family: Sordariaceae

44. *Gelasinospora calospora* (Mouton) C. Moreau & Moreau type

Fig. 5 and 6


Ecological data: *Gelasinospora* species are mainly fimicolous but can also carbonicolous or lignicolous (Van Geel 1978).

Order: Magnaporthales
Family: Magnaporthaceae

55. *Gaeumannomyces* cf. *caricis* J. Walker type

Fig. 7

Hyphopodia smooth-walled, dark brown, approximately circular in frontal view, with irregular lobate margins. Prominent clear spot in central area, showing the point of host penetration. Long axis: 25-59 μm. Short axis: 21-40 μm.

Ecological data: parasite or saprophyte on Poaceae stems and roots (Von Arx 1974).

Phylum: Basidiomycota
Class: Agaricomycetes
Order: Atheliales
Family: Atheliaceae

6. *Athelia* Pers. type

Fig. 8

Bulbils more or less ellipsoidal in frontal view, dark brown, with a large number of densely distributed cells. Long axis: 24-39 μm. Short axis: 18-39 μm.

Ecological data: cosmopolitan distribution, including pathogenic species in lichens and algae (Kirk et al. 2008).

Other spores

7. Type 1

Fig. 9


8. Type 2

Fig. 10

Group of spores, elongate and slightly curved, dark brown, 3-septate, surface covered by a conspicuous hyaline undulating epispore. Middle septum constricted. Long axis: 34-35 μm. Short axis: 15-18 μm.

9. Type 3

Fig. 11


10. Type 4

Fig. 12-13


11. Type 5

Fig. 14

Spore fusiform, dark brown, smooth-walled, with a small pore at both end. Long axis: 30-35 μm. Short axis: 14-19 μm.
12. Type 6
Fig. 15

13. Type 7
Fig. 16
Group of spores elongate and slightly curved, dark brown, 1-septate, truncate extremities, smooth-walled. Long axis: ca. 32 μm. Short axis: ca. 15 μm.

14. Type 8
Fig. 17

15. Type 9
Fig. 18
Small spore, spherical, dark brown, with striate surface. Irregular parallel ridges cover the surface. Diameter: ca. 22 μm.

16. Type 10
Fig. 19 and 20
Small spore, fusiform, hyaline, with thick protruding extremities. Striate surface, striae parallel to the long axis. Long axis: ca. 24 μm. Short axis: ca. 12 μm.

17. Type 11
Fig. 21

18. Type 12
Fig. 22
Group of spores, elongate, hyaline, multicellular (regular distribution of cells), cells larger at one extremity (two-celled), with one-celled at the opposite tip, smooth-walled. Long axis: ca. 24 μm. Short axis: ca. 13 μm.

19. Type 13
Fig. 23
Small spore, ellipsoidal, dark brown. Extremities with conspicuously dark thicker areas. Striate, with fine parallel longitudinal projections. Long axis: ca. 15 μm. Short axis: ca. 8 μm.

20. Type 14
Fig. 24

21. Type 15
Fig. 25
Group of spores, elongate and fusiform, brown, 2-septate, covered by a fine hyaline epispore with irregular folds, largely detached from the surface. Long axis: 32-35 μm. Short axis: 7-9 μm.

22. Type 16
Fig. 26

23. Type 17
Fig. 27

24. Type 18
Fig. 28
Spore elongate and fusiform, brown, darker at both ends, covered by a fine epispore close to the surface. Epispore transversally striate, with dense and fine striae. Long axis: ca. 141 μm. Short axis: ca. 36 μm.

25. Type 19
Fig. 29
Group of spores, small, elongate and fusiform, dark brown, 1-septate, striate wall. Very fine parallel projections along the long axis. Long axis: ca. 31 μm. Short axis: ca. 8 μm.

Algae

Division: Chlorophyta
Class: Chlorophyceae
Order: Chlorococcales
Family: Dictyosphaeriaceae

26. Botryococcus Kützing
Fig. 30

Family: Hydrodictyaceae

27. Pediastrum boryanum (Turpin) Meneghini
Fig. 31-32
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Class: Zygnematophyceae
Order: Zygnematales
Family: Zygnemataceae

28. **Debarya** (De Bary) Wittrock

Fig. 33

Zygospore circular to lenticular in polar view, splitting along a sharp defined equatorial line of weakness into two symmetrical halves; each hemisphere divided into a polar and an equatorial zone by a low circumpolar (orbicular to oblong) ridge encircling the spore between the pole and the equator; irregular additional structure in the center of the polar zone; equatorial zone of the spores radially striate, with polar zones vaguely striate-reticulate. Diameter: 22-31 μm.

**Note:** zygospore generally found with only one half.

**Ecological data:** in water deposits with temporal stagnation (Van Geel & Van der Hammen 1978).

29. **Mougeotia** C. Agardh

Fig. 34-37

Zygospore quadrate to subtriangular in polar view, sides more or less straight, retuse angles, laevigate thin wall. Diameter: 19-67 μm.

**Ecological data:** in water deposits and humid soils (Joly 2002).

30. **Spirogyra** Link

Fig. 38-40

Zygospore generally ellipsoidal, flattened, hyaline or clear yellow. Laevigate to reticulate thin wall with irregular coarse reticulum. Long axis: 53-94 μm. Short axis: 52-64 μm.

**Ecological data:** as in Mougeotia.

31. **Zygnema** C. Agardh type

Fig. 41


**Note:** This zygospore type occurs in different genera of the Zygnemaceae and also in Oedogoniaceae (Van Geel & Van Der Hammen 1978).

**Ecological data:** as in Mougeotia.

Division: Dinophyta
Class: Dinophyceae

32. **Operculodinium centrocarpum** (Deflandre & Cookson) Wall

Fig. 42

Dinoflagellate cyst spheroidal, with delicate wall. Fine and elongate processes densely distributed over the entire surface. Capitate processes at the extremity. Diameter: ca. 35 μm.

**Ecological data:** marine dinocyst whose distribution is used as an index to ancient shoreline positions in the coastal plain of southern Brazil (Lorscheitter & Romero 1985; Cordeiro & Lorscheitter 1994; Neves & Lorscheitter 1995b; Lorscheitter & Dillenburg 1998; Lorscheitter 2003).

**Incertae sedis**

33. **Pseudoschizaea rubina** Rossignol ex Christopher

Fig. 43-44

Vesicle flattened and hyaline, circular in frontal view. Distinctive fine concentric marks on both hemispheres. Long axis: 37-44 μm.

**Note:** *Concentricystes rubinus* Rossignol is the former name of the species (Rossignol 1962).

**Ecological data:** acritarch, probably of algal origin, found in fresh water deposits (Rossignol 1962).

Bryophytes

Class: Embryopsida
Subclass: Bryidae
Order: Sphagnales
Family: Sphagnaceae

34. **Sphagnum** L.

Fig. 45-46

Radial, equatorial limb subtriangular-convex. Trilete, arms > 75% of the radius. Exospore laevigate on prominent proximal face, trilobate central thickness on distal face, lobes irregularly arranged. Equatorial axis: ca. 75 μm.

**Ecological data:** hygrophilous, cosmopolitan distribution in areas with high rainfall, forming small groups or extensive colonies on acid soils of bogs, marshes, or lake margins (Joly 2002; Baptista *et al.* 2012).

Subclass: Marchantiidae
Order: Anthocerotales
Family: Anthocerotaceae

35. **Aspiromitus punctatus** (L.) Schljakov

Fig. 47-48

Radial, equatorial limb circular to subtriangular-convex. Trilete, fine arms > 75% of the radius. Arms bifurcate at the extremity. Exospore laevigate on proximal face, reticulate on distal face. Coarse irregular reticulum, with developed echinate muri. Simple, bifurcate or trifurcate echinae. Equatorial axis: 52-54 μm.


**Ecological data:** humid environments in grassland and marshes, cosmopolitan distribution (Schultz 1980).

36. **Phaeoceros laevis** (L.) Prosk.

Fig. 49-52
Radial, equatorial limb circular to subtriangular-convex. Trilete, fine arms > 75% of the radius. Arms bifurcate at the extremities. Exospore laevigate on proximal face, laevigate to microechinate on distal face. Equatorial axis: ca. 49 μm.

**Ecological data:** humid soils of protected areas, common on the banks of streams and in grasslands (Menéndez 1962).

Pteridophytes

Class: Embryopsida
Subclass: Lycopodiidae
Order: Lycopodiales

Family: Lycopodiaceae

37. **Lycopodiella alopecuroides** (L.) Cranfill
Fig. 53–54

Radial, equatorial limb subtriangular-convex, with hyaline prominent cingulum. Trilete, the arms > 75% of the radius, with margo. Exospore tuberculate on proximal face between the arms. Rugulate on distal face, with coarse exospore ridges. Equatorial axis: 46-84 μm.

**Ecological data:** terrestrial, in flooded fields and bogs (Lorscheitter et al. 1998)

Order: Selaginellales
Family: Selaginellaceae

38. **Selaginella marginata** (Humb. & Bonpl. ex Willd.) Spring
Fig. 55–56

Microspore radial, equatorial limb subtriangular-convex to circular, proximal face depressed. Trilete, the arms > 75% of the radius. Exospore baculate, baculae smaller between and along arms. Equatorial axis: ca. 62 μm.

**Ecological data:** terricolous, in humid environments (Lorscheitter et al. 1998)

Order: Isoetales
Family: Isoetaceae

39. **Isoetes** L.
Fig. 57


**Ecological data:** generally aquatic, submersed or amphibious plants, in varied environments (Tryon & Tryon 1982).

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40. **Marattia laevis** Sm.
Fig. 58–59

Oblate, reniform, bilateral. Monolete, linear, 50-75% of the spore length, fine laesura. Exospore echinate. Echinae on all the surface. Polar axis: ca. 24 μm. Equatorial axis: ca. 26 μm.

**Ecological data:** somewhat rare, in forests (Lorscheitter et al. 1998).

Order: Cyatheales
Family: Cyatheaceae

42. **Cyatheaceae**
Fig. 62

Radial, equatorial limb triangular with prominent rounded angles and slightly convex sides. Trilete, long arms > 75% of the radius, with margo. Coarse exospore, papillate. Equatorial axis: 40-69 μm.

**Ecological data:** wide distribution, open or moderately shaded humid or swampy environments, common in forests (Lorscheitter et al. 1999).

Order: Cyatheales
Family: Cyatheaceae

43. **Blechnum imperiale** H. Chr.
Fig. 63


**Ecological data:** generally subarborescent, dispersed in marshes or humid soils, close to streams in grasslands, but on drier soil of forested areas. Common in bogs (Sehnem 1968).

Order: Polypodiales
Family: Blechnaceae

44. **Blechnum** L. type
Fig. 64

pl – plane; DF – distal face; PF – proximal face.
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pl – plane; DF – distal face; PF – proximal face; EQ – equatorial view.
Oblate, reniform, bilateral. Monolete, linear, > 75% of the spore length, with margo. Laevigate exospore. Polar axis: ca. 31 μm. Equatorial axis: ca. 53 μm. **Note:** differs from *Blechnum imperiale* by its smaller size and clear appearance.

**Ecological data:** terricolous or lithophytic, sometimes epiphytic. Common in tropical mountains and nebular forests, along streams, marshes, and bogs, as well as in grasslands (Sehnem 1968).

Family: Polypodiaceae

45. *Polypodium* L. 1 type

Fig. 65


46. *Polypodium* L. 2 type

Fig. 66

Oblate, reniform, bilateral. Monolete, linear, > 75% of the spore length. Small globules scattered over the entire surface. Polar axis: ca. 39 μm. Equatorial axis: ca. 55 μm. **Ecological data:** as in *Polypodium* 1 type.

Order: Salviniales
Family: Salviniacae

47. *Salvinia* Ség.

Fig. 67


**Ecological data:** floating on lakes and other water bodies, in marshes, generally at elevations lower than 100 m (Tryon & Tryon 1982).

48. *Azolla filiculoides* Lam.

Fig. 68


**Ecological data:** as in *Salvinia*.

**Conclusions**

In this study, we identified 48 taxa, including 25 fungi, eight algae, three bryophytes and 12 pteridophytes. The morphological study of these distinct palynomorphs showed a diversity of taxa, corresponding to a variety of habitats. As the first palynological sedimentary study of the extreme southern of Brazilian coastal plain, this work provides reference materials for paleoenvironmental research in this region focusing on the last millennia in this region.

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