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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-cm^3 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 (DIAPAN; 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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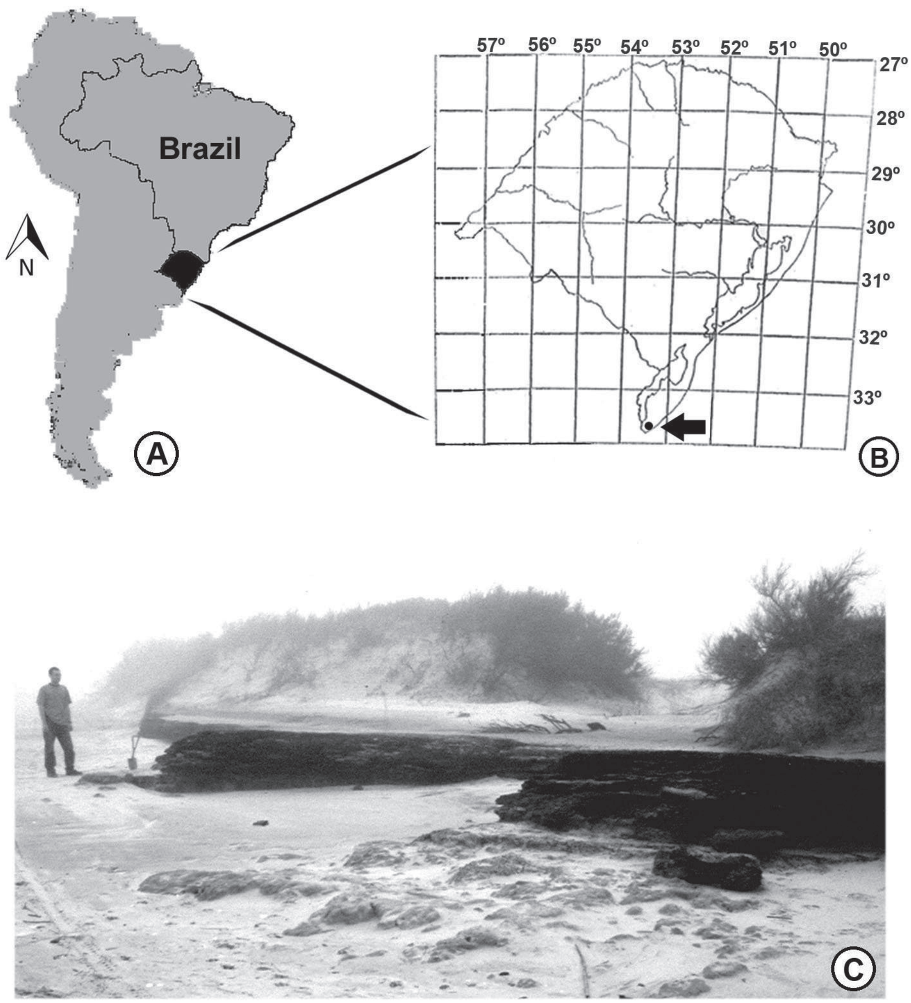


Figure 1. A. State of Rio Grande do Sul, in southern Brazil; B. Location of Hermenegildo Beach; C. Hermenegildo Beach and the Holocene paleolagoon outcrop studied, composed of dark-clay organic sediments covered by transgressive sands.

& Hunter 1987; Lorscheitter 1989; Tryon & Lugardon 1990; Neves & Lorscheitter 1992; Lorscheitter *et al*. 1998, 1999, 2005; Leal & Lorscheitter 2006; Leonhardt & Lorscheitter 2007; Roth & Lorscheitter 2008; Scherer & Lorscheitter 2008; Spalding & Lorscheitter 2009). Taxonomic treatment was based on Chase & Reveal (2009), Pirani & Prado (2012) and electronic databases: Index Fungorum (2013), Algaebase (2013) and MOBOT (2013). The word "type" was used when precise identification was not possible, following Berglund (1986). When identification was not possible, the material was separated by number to permit future identification.

The palynological description of each taxon is briefly presented, with nomenclature based on Punt *et al.* (2007) and Tryon & Lugardon (1990). In some cases, it was not possible to measure the polar axis of the grains due to their fixed position. Where possible, ecological data for the organisms of origin are included in order to facilitate future paleoenvironmental studies.

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

1. ***Glomus*** Tul. & C. Tul.
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

2. ***Tetraplosphaeria tetraploa*** (Scheuer) Kaz. Tanaka & K. Hiray.
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

Ascospore ellipsoidal, dark. Small pits distributed on all the surface. Long axis: 34-35 μm. Short axis: 24-27 μm.
Note: Species cited for the Quaternary in Rio Grande do Sul under its former name, *Gelasinospora adjuncta* Cain. (Neves & Bauermann 2003; Leal & Lorscheitter 2006; Leonhardt & Lorscheitter 2007; Scherer & Lorscheitter 2008).
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

Group of spores, fusiform, dark brown, 1-septate, slightly curved, with small constriction at the septum. Surface covered by a fine hyaline undulating epispore. Long axis: 33-35 μm. Short axis: 17-18 μm.

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

Group of spores, fusiform, dark brown, 1-septate, smooth-walled. Long axis: 28-34 μm. Short axis: 12-21 μm.

10. Type 4
Fig. 12-13

Spore spherical, dark brown, microverrucate, verrucae dense and regularly distributed. Diameter: 19-35 μm.

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
Group of spores globose, dark brown, 1-septate, truncate extremities. Surface microverrucate. Long axis: ca. 32 µm. Short axis: ca. 17 µm.

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
Large spore, ellipsoidal, dark brown, smooth-walled. Long axis: 43-52 µm. Short axis: 34-38 µm.

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
Small spore, characteristically curved, dark brown, smooth-walled. Long axis: 13-15 µm. Short axis: 11-13 µm.

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
Spore elongate, dark brown, truncate at one extremity, smooth-walled. Long axis: 23-25 µm. Short axis: ca. 13 µm.

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
Group of spores, globose, brown, 1-septate, constricted at the septum. Hyaline protruding extremities. Fine, delicate hyaline cover, almost invisible, with small folds irregularly distributed on the surface. Long axis: 36-40 µm. Short axis: 15-16 µm.

23. Type 17
Fig. 27
Small spore, fusiform, thin extremities, hyaline. Coarse, smooth wall. Long axis: 16-17 µm. Short axis: 7-9 µm.

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*** Kützling
Fig. 30
Colony irregularly lobate, of varying size, composed of many concentrically arranged smooth-walled cells. Colony diameter: 26-98 µm.
Ecological data: shallow freshwater environments (Erdtman 1969).

Family: Hydrodictyaceae
27. ***Pediastrum boryanum*** (Turpin) Meneghini
Fig. 31-32
Coenobial colony with a flattened star-like shape. Peripheral cells arranged in two hornlike projections, internal cells with distinct morphology. Laevigate to microverrucate cell walls. Colony diameter: 36-79 µm.
Ecological data: phytoplankton in lakes and in marshes (Rosa & Miranda-Kiesslich 1988).

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

Zygospore ellipsoidal to spheroidal, flattened, hyaline, laevigate. Cell wall pitted. Long axis: 33-47 μm. Short axis: 31-45 μm.

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

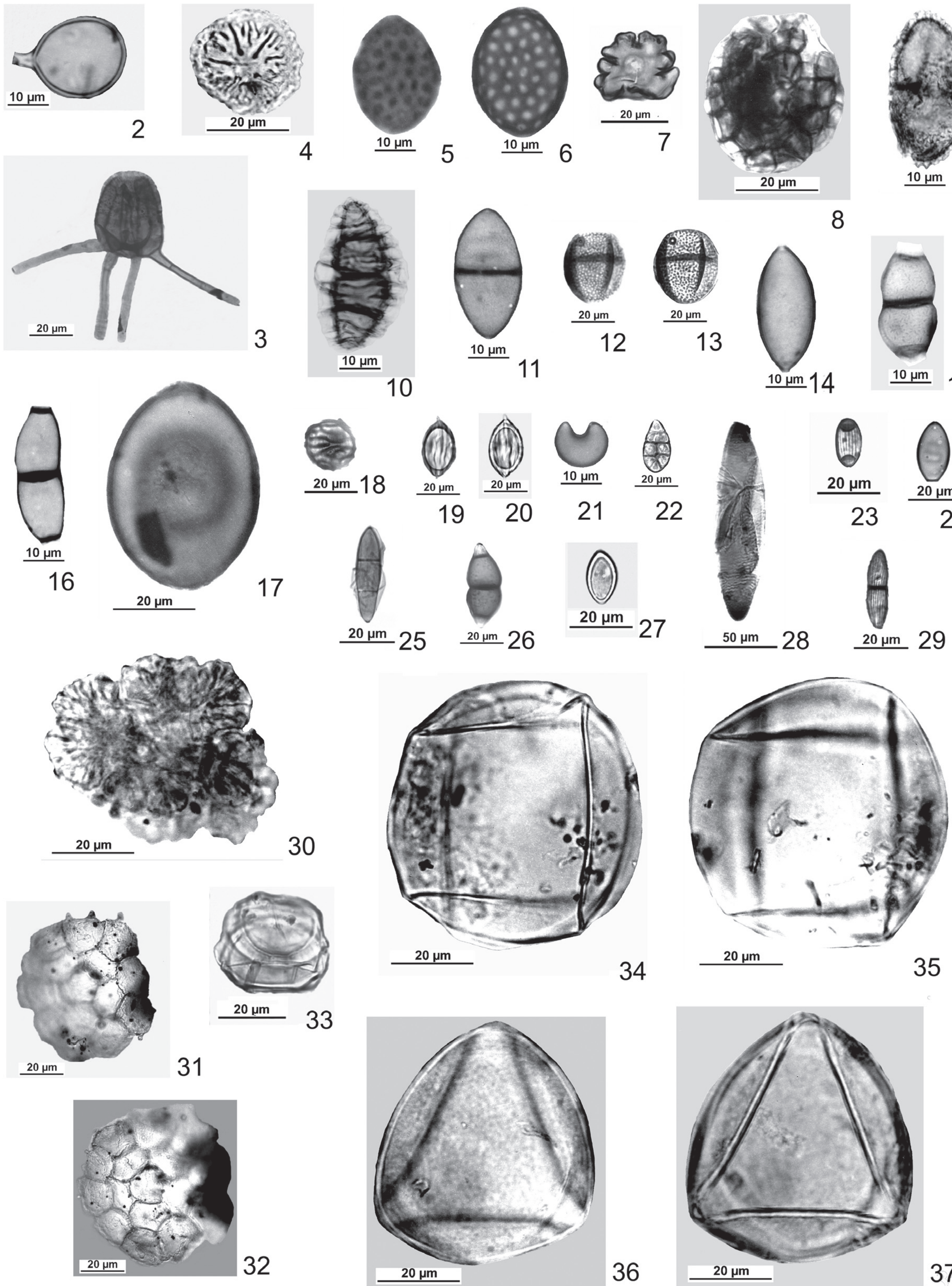
35. ***Aspiromitus punctatus*** (L.) Schljakov
Fig. 47-48

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.

Note: reported for the Quaternary in Rio Grande do Sul as *Anthoceros punctatus* L. (Lorscheitter 1989; Neves & Bauermann 2004; Leonhardt & Lorscheitter 2007), *Anthoceros* L. emend. Prosk. (Leal & Lorscheitter 2006).

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

36. ***Phaeoceros laevis*** (L.) Prosk.
Fig. 49-52



Figures 2-37. Fungi (2-29): 2. *Glomus* Tul. & C. Tul.; 3. *Tetraplosphaeria tetraploa* (Scheuer) Kaz. Tanaka & K. Hiray.; 4. Microthyriaceae; 5 and 6. *Gelasinospora calospora* (Mouton) C. Moreau & Moreau type: 1st-2nd pl; 7. *Gaeumannomyces* cf. *caricis* J. Walker type; 8. *Athelia* Pers. type; 9. Type 1; 10. Type 2; 11. Type 3; 12 and 13. Type 4: 1st-2nd pl; 14. Type 5; 15. Type 6; 16. Type 7; 17. Type 8; 18. Type 9; 19 and 20. Type 10: 1st-2nd pl; 21. Type 11; 22. Type 12; 23. Type 13; 24. Type 14; 25. Type 15; 26. Type 16; 27. Type 17; 28. Type 18; 29. Type 19. Algae (30-37): 30. *Botryococcus* Kützling; 31 and 32. *Pediastrum boryanum* (Turpin) Meneghini: 1st-2nd pl; 33. *Debarya* (De Bary) Wittrock; 34-37. *Mougeotia* C. Agardh: 34 and 35. 1st-2nd pl, zygospore quadrangular; 36 and 37. 1st-2nd pl., zygospore subtriangular.
pl – plane.

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

Microspore oblate, reniform, bilateral. Monolete, linear, generally a little shorter than the spore length. Paraexospore largely detached from exospore, connecting only on the proximal face. Paraexospore projected on laesura to form a thickening. Paraexospore wall laevigate, slightly thicker than the exospore. Size (including paraexospore): polar axis 16-27 µm; equatorial axis 25-31 µm. Size (without paraexospore): polar axis 12-16 µm; equatorial axis 20-28 µm.

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

Subclass: Marattiidae
Order: Marattiales
Family: Marattiaceae

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).

Subclass: Polypodiidae
Order: Osmundales
Family: Osmundaceae

41. ***Osmunda*** L.
Fig. 60-61

Globose, generally creased, radial. Equatorial limb circular. Trilete, long and fine arms, 75% of the radius or more, fine margo. Fine exospore wall, tuberculate. Small tubercles isolated or fused over the entire surface. Equatorial axis: ca. 105 µm.

Ecological data: terricolous, generally in marshes, bogs and humid slopes (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).

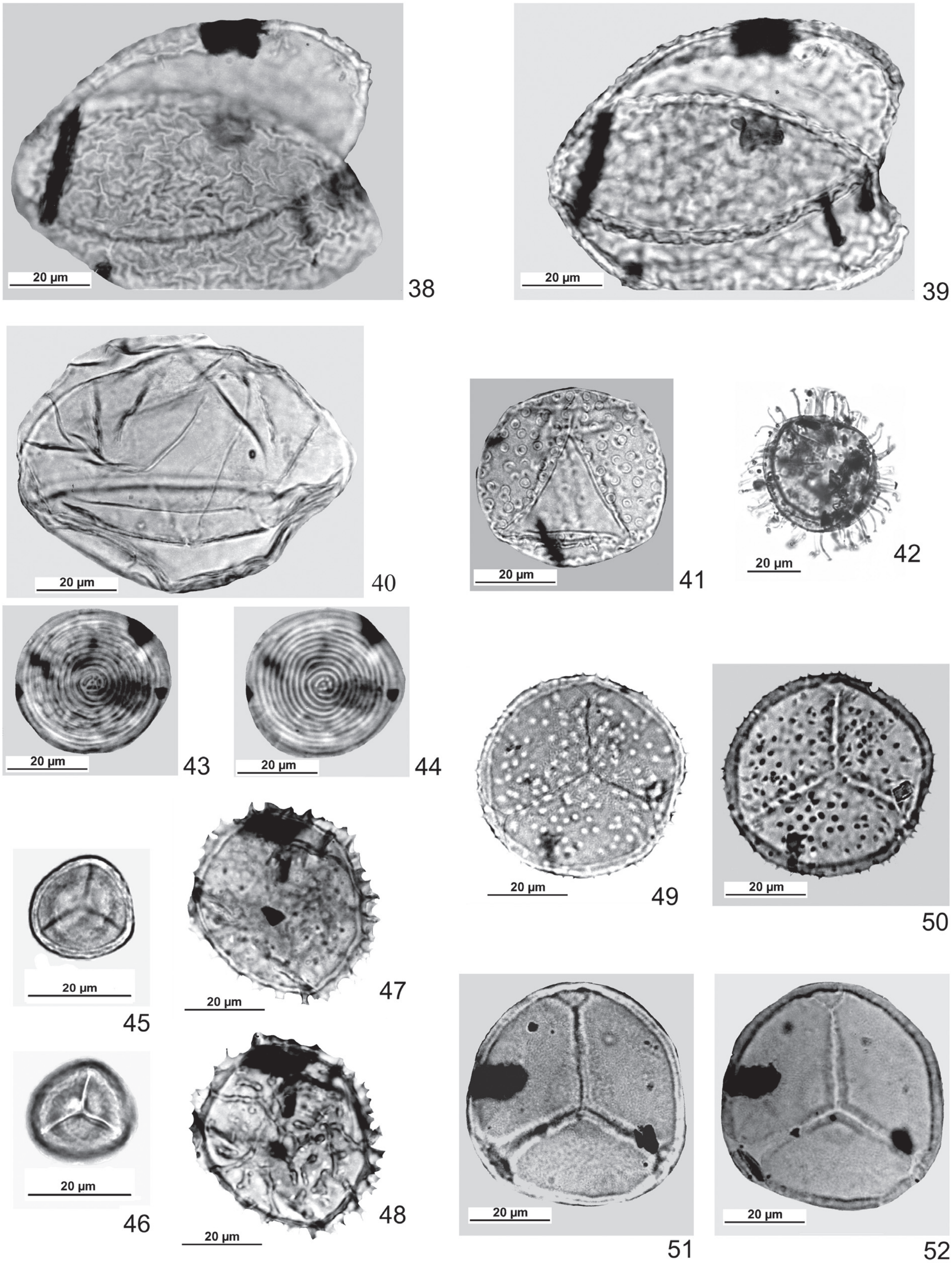
Order: Polypodiales
Family: Blechnaceae

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

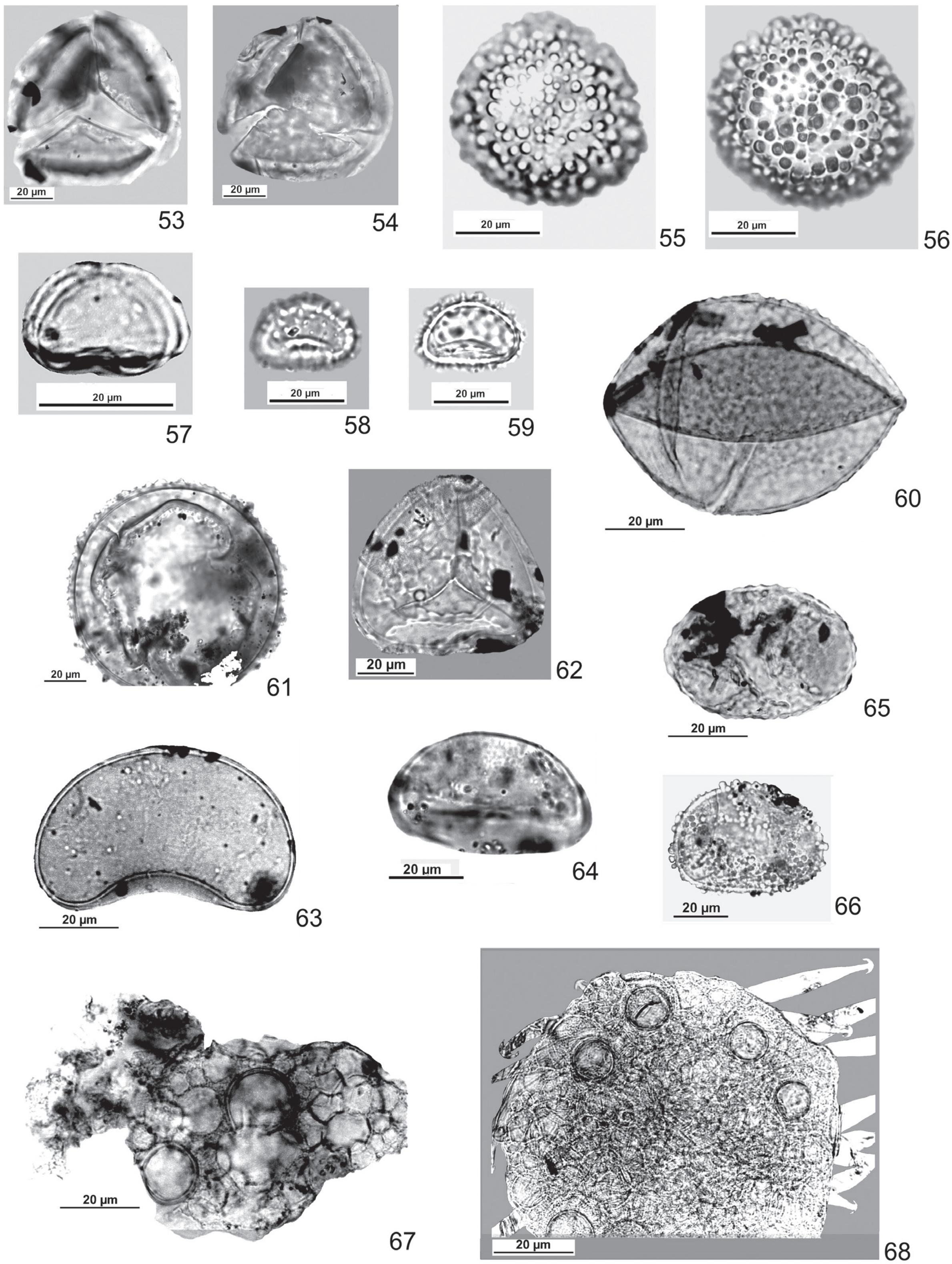
Oblate, reniform, bilateral. Monolete, linear, > 75% of the spore length, with margo. Coarse and laevigate exospore. Polar axis: 47-49 µm. Equatorial axis: 63-75 µm.

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).

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



Figures 38-52. Algae (8-44): 38-40. *Spirogyra* Link: 38 and 39. 1st-2nd pl, zygospore reticulate; 40. Zygospore psilate; 41. *Zygnema* C. Agardh type; 42. *Operculodinium centrocarpum* (Deflandre & Cookson) Wall; 43 and 44. *Pseudoschizaea rubina* Rossignol ex Christopher: 1st-2nd pl. Bryophytes (45-52): 45 and 46. *Sphagnum* L. (PF): 1st-2nd pl; 47 and 48. *Aspiromitus punctatus* (L.) Schljakov (DF): 1st-2nd pl; 49-52. *Phaeoceros laevis* (L.) Prosk.: 49 and 50. Echinate (DF): 1st-2nd pl (laesura seen due to transparency); 51 and 52. Psilate (PF): 1st-2nd pl.
pl – plane; DF – distal face; PF – proximal face.



Figures 53-68. Pteridophytes: 53 and 54. *Lycopodiella alopecuroides* (L.) Cranfill (PF): 1st-2nd pl; 55 and 56. *Selaginella marginata* (Humb. & Bonpl. ex Willd.) Spring (microspore, DF): 1st-2nd pl; 57. *Isoetes* L. (microspore, EQ), paraexospore detached from exospore; 58 and 59. *Marattia laevis* Sm. (EQ): 1st-2nd pl; 60 and 61. *Osmunda* L. (EQ and PF, respectively); 62. Cyatheaceae (PF); 63. *Blechnum imperiale* H. Chr. (EQ); 64. *Blechnum* L. type (PF); 65. *Polypodium* L. type 1 (PF); 66. *Polypodium* L. type 2 (EQ); 67. *Salvinia* Ség. Fragment of massulae, with microspores; 68. *Azolla filiculoides* Lam. Fragment of massulae, with microspores and glochidia.
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

Oblate, reniform, bilateral. Monolete, linear, > 75% of the spore length. Verrucate exospore. Small verrucae on all the surface. Polar axis: 32-38 μm. Equatorial axis: 51-55 μm.

Ecological data: genus of varied environments. Terricolous, lithophytic or epiphytic, in tropical mountains, nebular forests or grasslands areas with taller vegetation (Lorscheitter *et al.* 2005).

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: Salviniaceae

47. ***Salvinia*** Ség.
Fig. 67

Microspore globose, radial. Equatorial limb circular. Trilete, fine arms smaller than the radius. Laevigate to scabrate exospore. Spores suspended in an epispore matrix (massulae) irregularly vacuolate. Long axis of massulae: 108 μm. Short axis of massulae: 53 μm. Equatorial axis of microspore: 16-29 μm.

Note: generally fragmented massulae.

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

Microspore globose, radial. Equatorial limb circular. Trilete, fine arms smaller than the radius. Laevigate to scabrate exospore. Spores suspended in an epispore matrix (massulae) irregularly vacuolated, with many glochidia radiating from the surface. Glochidia single-celled, anchor-shaped. Long axis of massulae: 112-263 μm. Short axis of massulae: 69-224 μm. Equatorial axis of microspore: 20-63 μm.

Note: generally fragmented massulae.

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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