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PALYNOMORPHS FROM A 3,990 BP OLD SEDIMENT REVEAL THE LOCAL VEGETATION OF MARICÁ LAGOON, RIO DE JANEIRO STATE, SOUTHEAST BRAZIL

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Abstract: The Maricá-Guarapina Lagoon System is located approximately 50 km east of Rio de Janeiro city, in the municipality of Maricá, within a region of restinga vegetation characterized by significant botanical diversity. Palynological studies of sediment cores from this area can provide valuable insights into past vegetation and environmental changes. The present study focuses on the oldest sediment sample dated at 3,990 years BP of a core collected in the Maricá Lagoon (22º57' S, 42°50' W). This level was dated by radiocarbon-AMS at the Beta-Analytic Laboratory. The palynological analysis aims to reconstruct the local vegetation and confirmed the existence of a restinga phytophysiognomy at this time.
Keywords: palynological analysis; Southeast Brazil; Maricá Lagoon

INTRODUCTION

The municipality of Maricá, located approximately 50 km east of Rio de Janeiro city, Brazil, is home to the Maricá-Guarapina Lagoon System, a region characterized by restinga vegetation with significant botanical diversity. This vegetation plays a crucial role in understanding the dynamics of plant communities, contributing to environmental protection and the management of protected areas. Studies of restinga ecosystems are essential for identifying rare species and understanding effective colonization strategies in nutrient-poor soils, such as those found in restinga environments (Pereira et al., 2001).

During the Quaternary, the central coastal plain of Maricá underwent a complex geological evolution influenced by relative sea-level fluctuations (Silva, 2010). These variations shaped the deposition and erosion of sedimentary units, as well as the formation and migration of coastal barriers, resulting in successive processes of progradation and retrogradation (Silva, 2010). The restinga of Barra de Maricá consists of two sandy ridges separated by a depression containing a freshwater marsh, formed by the outcrop of the water table. The sandy barriers are the result of the movement of recent coastal ridges, generated after the last marine transgression (Perrin, 1984), in response to rising sea levels and reduced sediment supply (Muehe, 1984). The inner sandy barrier is linked to the formation of a Pleistocene coastal ridge, while the outer barrier is associated with the maximum Holocene transgression (Silva, 2010).

The Maricá Lagoon System (Figure 1) was formed through the accumulation of sediments transported by small rivers, which were redistributed by coastal currents and deposited along the shoreline, creating a natural barrier that isolated the lagoon from the ocean (Lamego, 1940, 1945). Palynological studies of sediment cores from this system provide valuable insights into past vegetation and environmental changes, offering a basis for the paleoenvironmental history of the region.

The present study aims to analyze pollen grains focused on angiosperm taxa and spores identified in a sediment of the Maricá Lagoon, dated to 3,990 years BP. The objective is to provide a palynological reference for the restinga vegetation of Maricá, contributing to paleoenvironmental reconstructions of the region during the late Quaternary. This catalog intends to support future research on the dynamics of vegetation and climate oscillations and changes in coastal environments of southeastern Brazil.

MATERIAL AND METHODS

The Maricá Lagoon, part of the Maricá--Guarapina Lagoon System, is located in the southeastern region of Brazil, on the coast of the state of Rio de Janeiro, in the municipality of Maricá. This lagoon system, which includes the Maricá, Barra, Padre, and Guarapina lagoons, covers a total area of 34 km². The Maricá Lagoon (Figure 1), delimited by the coor-

dinates 22°55' - 22°58' S and 42°49' - 42°53' W, occupies an extension of about 18.21 km² and with a depth of up to 2 meters, presents a predominantly flat and homogeneous bed, whose sediments are mostly composed of sandy mud, muddy sand, and sand (Silvestre, 2017).

Based on the results presented by Silvestre (2017), it is possible to infer that the sandy sediments concentrate near the barriers and in areas of high hydrodynamics. On the other hand, the muddy sediments predominate in areas close to the sources and in places of low hydrodynamics, such as at the mouths of rivers and in areas of greater depth. The vegetation of the study area, characterized by restinga clumps, is inserted in Quaternary coastal sandy deposits and presents a remarkable botanical diversity.

This diversity makes the region an ideal refuge for several species of fauna threatened with extinction. In recognition of this ecological importance, the area was designated as a target for environmental protection by state decree no. 7230 of 4/23/1984 (FEEMA, 1995). Among the great variety, the most numerous plant families include Asteraceae, Bromeliaceae, Cactaceae, Euphorbiaceae, Leguminosae, Myrtaceae, Orchidaceae and Rubiaceae. In addition, some families such as Anacardiaceae, Clusiaceae, Malpighiaceae and Palmae are particularly dominant due to the high number of individuals.

A sediment core (T2/MAR) was collected from the deepest part of Maricá Lagoon, Rio de Janeiro State, on March 23, 2009, using diving and percussion techniques with a PVC tube. After collection, the core was opened and subsampled for palynological analysis. Bruno (2012) provided a detailed description of the T2/MAR core, including its color, sedimentology, and conchiferous levels. Six samples from the core were previously collected at fixed depth intervals and dated by Accelerator Mass Spectrometry (AMS) at the Beta Analytic Inc. laboratory in Florida, USA. In this study, we focus on the analysis of a single subsample from the oldest level, dated to 3,990 years BP, to reconstruct the local vegetation and environmental conditions during this period.

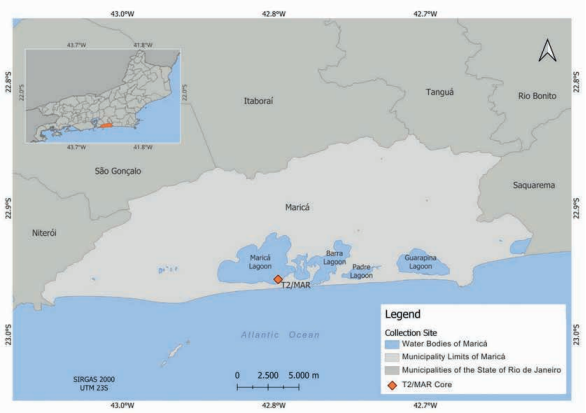

Figure 1: Location map of the sampling site where the core T2/MAR was collected for analysis. The orange mark indicates the sampling site, collected in Maricá Lagoon (Rio de Janeiro, Brazil). Base Map Source: QGis v.3.28; IBGE shapefiles (Bulla, A. M.).

The sediment sample, using a volume of 8 cm³, was chemically processed according to the classic parameters established by Ybert et al. (1992). This methodology comprises a sediment chemical treatment with acids (40% hydrofluoric acid, 10% hydrochloric acid) and the standard procedures of acetolysis according to Erdtman (1960). Two tablets of the exotic spore *Lycopodium clavatum* were added in order to determine the pollen concentration (Stockmarr, 1971). The material went through sieving in a 5 µm mesh with ultrasound. Permanent palynological slides were mounted with glycerinated gelatin and sealed with paraffin.

For the morphological description of the spores and pollen grains, the terminology of Punt et al. (2007) was adopted, considering the following aspects: dispersal unit (monads or tetrads); size; symmetry; polar-

ity; outline; shape in equatorial view; apertures; exine structure; and ornamentation. A comparative method with the palynotheca of the Palynology Laboratory (IGEO/UFRJ) was used. Consulted specific literature used Roubik & Moreno (1991), Gonçalves-Esteves et al. (1992), Persson (1993), Lorscheitter et al. (1999), Gonçalves-Esteves & Mendonça, (2001), Coelho & Barth (2002), Medeanic (2006), Leonhardt & Lorscheitter (2007), Luz et al. (2007), Macedo et al. (2009), Cancelli et al. (2010), Cancelli et al. (2012), Barreto et al. (2013), Gomez-Noguez et al. (2013), Ybert et al. (2016), Freitas et al. (2015), Lorente et al. (2017), Ybert et al. (2017a), Ybert et al. (2017b) and Ybert et al. (2018), Misumi et al. (2019), Barth & Misumi (2023).

After the description and identification of the pollen and spore taxa, the habit or main habits of the identified taxa are indicated, based on data from the aforementioned literature, and also Flora e Funga do Brasil (2020), Santos & Sylvestre (2001), Winter et al. (2007), Lorenzi (1992), Lorenzi (1998), Lorenzi (2000), Lorenzi (2009), Souza & Lorenzi (2005), Lorenzi & Matos (2002), Smith et al. (2004), Joly (1983) and Kissman & Groth (1999).

RESULTS

The palynological analysis of the sediment subsample dated to 3,990 years BP revealed a low diversity and concentration of palynomorphs. Despite the limited abundance pollen and spores from both aquatic and terrestrial vegetation were identified. Evidence of corrosion and degradation was observed on the palynomorphs, likely due to taphonomic processes during deposition and preservation. The pollen types identified in this sediment subsample were described following the botanical classification of Flora e Funga do Brasil (2020).

SPORES

Cyatheaceae Kaulf.

Cyathea J. Sm. (Plate 1/C, D)

Trilete spores, medium to large sized, heteropolar, subtriangular in polar view, verrucate surface, laesura with thin, long commissures lacking margo (Lorscheitter et al., 1999).

Ecological data: arborescent habit, occurring in humid areas of nearly all vegetation formations (Flora e Funga do Brasil 2020; Lorscheitter et al., 1999).

Lycopodiaceae Mirb.

Lycopodium L. (Plate 1/E)

Trilete spore, monads, medium-sized, radially symmetrical, heteropolar, subtriangular in polar view, exospore reticulate (Medeanic, 2006; Leonhardt & Lorscheitter, 2007).

Ecological data: terrestrial or rupicolous herb commonly found in Atlantic Forest associated with semi-open areas (Tryon & Tryon, 1982, apud Leonhardt & Lorscheitter 2007)

Polypodiaceae J. Presl.

Microgramma C. Presl. (Plate 1/B)

Trilete spores, monads, medium-large size, bilateral, triangular shape, exospore verrucate to reticulate, perine present (Roubik & Moreno, 1991).

Ecological data: herbaceous or epiphytic species from lowland and montane Atlantic Forest and restinga vegetation (Santos & Sylvestre 2001).

Polypodium L. (Plate 1/G)

Monolete spores, monads, medium to large size, heteropolar and bilaterally symmetrical, concave-convex shape, exospore verrucose (Roubik & Moreno, 1991).

Ecological data: herbaceous species found in Amazon rainforest, riparian forest, lowland Atlantic Forest, restinga, Araucaria forest and secondary vegetation (Santos & Sylvestre, 2001).

Pteridaceae E.D.M. Kirchn.

Adiantum L. (Plate 1/A)

Trilete spores, monads, medium-sized, radially symmetrical, isopolar, exospore verrucate to reticulate, perine absent (Roubik & Moreno, 1991; Gomez-Noguez et al., 2013).

Ecological data: herbaceous species present in forests, humid and shaded places, or exposed rocks (Winter et al., 2007).

Pityrogramma Link. (Plate 1/F)

Trilete spores, monads, large-sized, radially symmetrical, with subtriangular ambit, fossulate exosporium, type of ornamentation variable, perine absent (Roubik & Moreno, 1991; Freitas et al., 2015).

Ecological data: herbaceous habit, occurring in humid soils with direct sun exposure (Flora e Funga do Brasil, 2020).

GYMNOSPERMS

Podocarpaceae Endl.

Podocarpus lambertii Klotzsch ex Endl. (Plate 1/H)

Pollen grain in monad, bisaccate, with medium-sized body, monocolpate, bilateral symmetry, surface ornamented with minute tortuous microreticulate ridges, air sacs internally irregularly reticulate; non-orbiculate pollen grain (Barreto et al., 2013).

Ecological data: Podocarpus is a genus of heliophyte conifers that grow in montane and high-montane forests and in semideciduous forests, in soils of various types and in areas with variable moisture contents. P. lambertii is the species common to the areas from Rio de Janeiro to Rio Grande do Sul (Lorenzi, 1992).

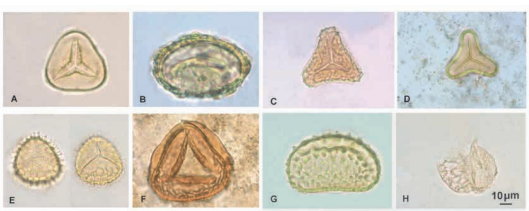

Plate 1: A. *Adiantum* v.p. **B.** *Microgamma* c.o. **C-D.** *Cytathea* v.p. **E.** *Lycopodium* v.d., v.p. **F.** *Pityrograma* v.p. **G.** *Polypodium* v.e. **H.** *Podocarpus lambertii* v.e.

ANGIOSPERMS

Amaranthaceae A. Juss.

Alternanthera Forssk. (Plate 2/A)

Small to medium-sized pollen grain, apolar, sub-spheroidal; pantoporate; surface reticulate with supratectal spinules. The pollen has 8 to 12 pores, located within the lumina. These pores are broad, circular, and separated by high muri, forming pentagonal or hexagonal shapes, which give the pollen grain a polyhedral appearance (Gonçalves-Esteves et al., 1992; Ybert et al., 2016).

Ecological data: herbaceous habit, ruderal, common in open environments (Souza & Lorenzi, 2005).

Amaranthaceae (Plate 2/C)

Small-sized pollen grain, apolar, subspheroidal, pantoporate, with slightly granulate surface; approximately 30 circular pores, each with a granule (Misumi et al., 2019).

Ecological data: herbaceous habit; ruderal, common in open environments (Souza & Lorenzi, 2005).

Amaranthus L./Chenopodiaceae (Plate 2/D)

Medium-sized pollen grain, apolar, subspheroidal; pantoporate; psilate surface. Approximately 50 circular pores, each with an annulus (Gonçalves-Esteves et al., 1992).

Ecological data: herbaceous habit; ruderal, common in open environments (Souza & Lorenzi, 2005).

Gomphrena L. (Plate 2/B)

Small-sized pollen grain, apolar, spheroidal shape, apertures indistinct, homoreticulate, lumina variable in shape, muri undulate, narrow, and high, columellae straight and short, forming cones at the junctions of the muri (Ybert et al., 2016).

Ecological data: herb; subshrub (Flora e Funga do Brasil, 2020).

Anacardiaceae R. Br.

Schinus L. (Plate 2/E)

Medium-sized pollen grain, isopolar, subprolate, 3-colporate, with a striate-reticulate surface, longicolpate, with narrow colpi and lalongate endoapertures (Gonçalves-Esteves & Ferreira, 1994; Ybert et al., 2016).

Ecological data: shrubby or arboreal habit, heliophyte, pioneer species, common in moist areas, but also found in dry soils, rainforests and seasonal forests, cerrado, mangroves, and restinga vegetation (Flora e Funga do Brasil, 2020; Lorenzi, 1992).

Apiaceae Lindl. (Plate 2/F)

Medium-sized pollen grain, isopolar, with circular amb, perprolate, showing a constriction along the equatorial axis, 3-colporate, with a psilate surface (Barreto et al., 2013).

Ecological data: herbaceous habit. The family Apiaceae has a cosmopolitan distribution and constitutes one of the largest families of angiosperms (Souza & Lorenzi, 2005).

Aquifoliaceae Bercht. & J.Presl

Type *Ilex* L. (Plate 2/G)

Medium-sized pollen grain, isopolar, prolate, 3-colporate, pilate surface, longicolpate, broad colpi, endoapertures slightly evident, surface pilate (Ybert et al., 2016).

Ecological data: Shrub or tree habit; selective hygrophyte, heliophyte to sciophyte, with a wide distribution along the Atlantic coast and in the restingas (sandy coastal plains) of the South and Southeast regions, as well as in rainforests, seasonal forests, and grassland areas (Flora e Funga do Brasil, 2020; Lorenzi, 1992, 1998).

Arecaceae Schultz Sch. (Plate 2/H)

Medium-sized pollen grain, heteropolar, bilateral symmetry, elliptical (in polar view), with one more tapered end, monosulcate, and psilate to scabrate ornamentation. Sulci narrow and as long as the grains (Macedo et al., 2009).

Ecological data: herbaceous or palm habit; rainforests and seasonal forests, grasslands, anthropic areas, cerrado, caatinga, restinga, and on rocky outcrops (Flora e Funga do Brasil, 2020; Souza & Lorenzi, 2005).

Asteraceae Bercht. & J.Presl. (Plate 2/K)

Medium-sized pollen grain, isopolar, spheroidal, 3-colporate, spiculate surface, endoapertures scarcely visible, caveate exine, multiple spiculae regularly distributed over the entire surface (Cancelli et al., 2010).

Ecological data: herbaceous or subshrub habit; ruderal, also found in rainforests and restinga vegetation (Lorenzi, 2000).

Vernonia Schreb. (Plate 2/J)

Medium-sized pollen grain, apolar, spheroidal, fenestrate, echinate surface, narrow and acute spines (Roubik & Moreno, 1991).

Ecological data: subshrub to shrub habit; ruderal, occurring in cerrado, grasslands and coastal plains, in both moist and dry soils (Lorenzi, 2000).

Tilesia G. Mey. (Plate 2/I)

Medium-sized pollen grain, isopolar, 3-colporate, medium-wide colpi, oval to rounded-rectangular lalongate endoapertures, large apocolpus, ordered sculpture, small spines with non-contiguous bases (some with foramina), infra-microreticulate exine, distinct columellae, meridional outline and subcircular ambit, subspheroidal shape (Ybert et al., 2016).

Ecological data: shrub or liana (Flora e Funga do Brasil, 2020).

Bignoniaceae Juss.

Tabebuia Gomes ex DC. (Plate 2/L)

Medium-sized pollen grain, isopolar, suboblate to oblate spheroidal, 3-colporate, microreticulate surface, longicolpate, wide colpi, lalongate endoapertures (Ybert et al., 2016).

Ecological data: tree habit, heliophyte, hygrophyte, characteristic of permanently wet or

flooded areas in coastal plains and rainforests of southeastern Brazil (Flora e Funga do Brasil, 2020; Lorenzi, 1992).

Calophyllaceae J. Agardh

Calophyllum L. (Plate 2/M)

Medium-sized pollen grain, isopolar, oblate spheroidal, 3-colporate, microreticulate surface, longicolpate, narrow colpi with slight margo, lalongate endoapertures (Gonçalves-Esteves & Mendonça, 2001; Ybert et al., 2017a).

Ecological data: tree habit, occurring in moist and swampy soils of rainforests, seasonal forests, and restinga vegetation (Flora e Funga do Brasil, 2020; Lorenzi, 1992).

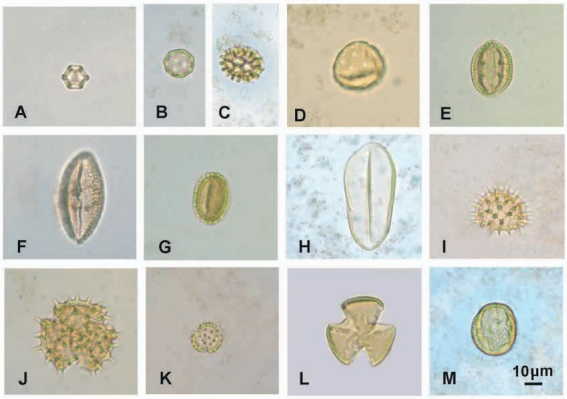

Plate 2: A. *Althernantera* **B.** *Gomphrena* **C.** Amaranthaceae **D.** *Amaranthus* / Chenopodiaceae **E.** *Schinus* **F.** Apiaceae **G.** *Ilex* **H.** Arecaceae **I.** *Tilesia (Wulfia)* **J.** *Vernonia* **K.** Asteraceae **L.** *Tabebuia* **M.** *Calophyllum*

Cannabaceae Martinov

Celtis L. (Plate 3/A)

Medium-sized pollen grain, isopolar, spheroidal, 3-porate, psilate surface. Annulate pores (Lorente et al., 2017).

Ecological data: shrub, tree and subshrub habit, pioneer, heliophyte, occurring in open areas and semideciduous, rainforest and gallery forests (Flora e Funga do Brasil, 2020; Lorenzi, 1998, 2009).

Trema Lour. (Plate 3/B)

Small pollen grain, bilateral symetry, spheroidal; 2-porate; scabrate surface. Pores with thickening (Ybert et al., 2018).

Ecological data: shrub or tree habit; pioneer, heliophyte, occurring in all types of formations except very humid locations (Lorenzi, 1992).

Chloranthaceae R.Br. ex Sims

Hedyosmum Sw. (Plate 3/C)

Medium-sized pollen grain, heteropolar, monoaperturate, with distal opening corresponding to a branched area, showing sexine with granulations, finely reticulate surface, homobrochate, subspheroidal shape (Barreto et al., 2013).

Ecological data: Chloranthaceae species are mostly selective hygrophytes occurring as shrubs in forest interiors, both in upland and floodable areas (Lorenzi & Matos, 2002; Smith et al., 2004; Souza & Lorenzi, 2005).

Convolvulaceae Juss.

Ipomoea L. (Plate 3/D)

Very large pollen grain size; apolar; pantoporate; circular to ellipsoidal pores, numerous; ordered ornamentation; tall spines with broad base and pointed to rounded apex, frequently curved; exine granulose to rugulate between spines; straight columellae, taller beneath spines; spheroidal shape (Ybert et al., 2017a).

Ecological data: Creeping herb, halophyte; restinga vegetation, in sandy soils (Ybert et al., 2017a).

Euphorbiaceae Juss.

Alchornea Sw. (Plate 3/E)

Small pollen grain, isopolar, oblate spheroidal, circular ambit; 3-colporate, scabrate surface, colpi without margo, with opercula (Coelho & Barth, 2002; Ybert et al., 2017a).

Ecological data: shrub or tree habit; pioneer, characteristic of Atlantic rainforest (Lorenzi, 1992).

Sapium Jacq. (Plate 3/G)

Medium to large size pollen grain; isopolar; pleuroaperturate; 3-colporate; long and very narrow colpi; wide endocingulate endoapertures with narrow costa; small apocolpus; microreticulate exine; columellae taller in interapertural areas; elliptical meridional outline; triangular ambit with straight sides; subprolate to prolate shape (Ybert et al., 2017a).

Ecological data: Tree; Atlantic Forest, Riparian Forest, Subtropical Forest, Cerrado (Ybert et al., 2017a).

Sebastiania Spreng. (Plate 3/F)

Medium-sized pollen grain, isopolar, subprolate, 3-colporate, microreticulate surface, longicolpate, narrow colpi, lalongate endoapertures with slight thickening (Ybert et al., 2017a).

Ecological data: tree habit; heliophyte, hygrophyte, pioneer, in open environments, moist to swampy areas, in gallery and montane forests (Lorenzi, 1992, 1998).

Fabaceae Lindl.

Inga Mill. (Plate 3/H)

Polyads acalymmate, 16 monads, coaperturate, pores poorly distinct, scabrate exine, medium to large size, polyad subcircular when viewed along minor axis, ellipsoidal when viewed along major axis (Ybert et al., 2017b).

Ecological data: Shrub, Tree; Atlantic Forest, Restinga (Ybert et al., 2017b).

Parapiptadenia Brenan (Plate 3/I)

Pollen grains in polyads, composed of small grains (16 grains) irregularly arranged, heteropolar, radiosymmetric, suboblate, ellipsoidal, with psilate ornamentation. Apertures not evident (Macedo et al., 2009).

Ecological data: shrub or tree habit (Flora e Funga do Brasil 2020).

Piptadenia biuncifera Benth. (Plate 3/J)

Medium-sized polyad, elongated, porate, psilate surface composed of 16 grains with each grain bearing 4 pores (Ybert et al., 2017b).

Ecological data: shrub, tree or liana habit; occurring in rainforests, seasonal forests, riparian forests, cerrado, caatinga, restinga and anthropic areas (Flora e Funga do Brasil, 2020).

Vigna Savi (Plate 3/K)

Medium-sized pollen grain, isopolar, oblate spheroidal; 3-porate; reticulate surface. Large pores with annulus; heteroreticulate with high muri forming ridges (Ybert et al., 2017b).

Ecological data: herbaceous or liana habit; in anthropic areas, seasonal and floodplain forests, cerrado and caatinga grassland formations, and restinga vegetation (Flora e Funga do Brasil, 2020).

Gentianaceae Juss.

Schultesia Mart. (Plate 3/L)

Pollen grains in tetrahedral or tetragonal tetrads; coaperturate; circular annulate apertures located at distal pole and junction between monads; retipilate exine, pili taller in distal areas; medium to large tetrad size; triangular or rhomboid shape (Cancelli et al., 2012).

Ecological data: Herb; Grassland, Riparian Forest, Restinga, Rocky Outcrops (Ybert et al., 2017a).

Plate 3: A. *Celtis* **B.** *Trema* **C.** *Hedyosmum* **D.** *Ipomoea* **E.** *Alchornea* **F.** *Sebastiania* **G.** *Sapium* **H.** *Inga* (snippet) **I.** *Parapiptadenia* **J.** *Piptadenia* **K.** *Vigna* **L.** *Schultesia*

Haloragaceae R. Br.

Myriophyllum L. (Plate 4/A)

Medium-sized pollen grain, radial symmetry, polygonal ambit, 4-porate, protruding pores, scabrate surface (Barreto et al., 2013).

Ecological data: Aquatic herb species occurring in flooded areas of the Rio de Janeiro coast (Lorenzi, 2000; Souza & Lorenzi, 2005).

Loranthaceae Juss.

Struthanthus Mart. (Plate 4/B)

Medium-sized pollen grain, isopolar, radial symmetry, oblate, 3-colporate, syncolporate, psilate surface (Barreto et al., 2013).

Ecological data: Epiphytic and hemiparasitic (mistletoe) habit species, present in various Brazilian vegetation formations, predominantly in central regions (Souza & Lorenzi, 2005).

Malpighiaceae Juss.

Heteropterys Kunth. (Plate 4/C)

Large-sized pollen grains; isopolar; 3 syncolpate colpi, wide at equatorial region; 6 elliptical lalongate endoapertures; two endoapertures per colpus, located midway between poles and equator; microreticulate exine; thick nexine; straight, very short columellae;; spheroidal shape (Ybert et al., 2018).

Ecological data: Liana; Rainforest, Restinga (Ybert et al., 2018).

Tetrapterys Cav. (Plate 4/D)

Medium-sized pollen grain, apolar, spheroidal, 4-porate, psilate surface, circular pores with associated colpoids, thick nexine 1 (Gonçalves-Esteves et al., 2007; Ybert et al., 2018).

Ecological data: shrub, subshrub or climbing habit; common throughout the country, particularly in forest edges (Souza & Lorenzi, 2005).

Malvaceae Juss.

Sida L. (Plate 4/E)

Large-sized pollen grain, apolar, circular ambit, spheroidal, pantoporate, pores covered by sexine with nexine thickening (annulus), surface with numerous mammiform spines (broad-based with tall columellae), tectum perforate with short columellae, nexine 1 very thick, nexine 2 thin (Barth and Misumi, 2023).

Ecological data: shrub, herb, subshrub; preferentially occurring in sunny, disturbed vegetation areas, rarely in forest understory. In Brazil, found throughout the territory, thriving in diverse environments (Flora e Funga do Brasil, 2020).

Melastomataceae Juss.

Tibouchina Aubl. (Plate 4/F)

Small to medium-sized pollen grains; isopolar; heterocolpate; narrow and very long colpi and pseudocolpi; lalongate elliptical endoapertures; high costae; very small apocolpus; scabrate to granulose exine; indistinct columellae; elliptical meridional outline; lobed subtriangular ambit; subprolate to prolate shape (Ybert et al., 2018).

Ecological data: shrub, tree or subshrub habit (Flora e Funga do Brasil, 2020).

Myrtaceae Juss. (Plate 4/G)

Small-sized pollen grain, isopolar, radial symmetry, triangular ambit, syncolporate, scabrate surface (Barreto et al., 2013).

Ecological data: Family representatives include heliophytic to sciophytic, hygrophytic to xerophytic shrubs or trees. Common in the Atlantic Forest (Souza & Lorenzi, 2005).

Onagraceae Juss.

Ludwigia L. (Plate 4/H)

Large-sized pollen grain, isopolar, radial symmetry, subtriangular ambit, 3-colporate, brevissimocolpate, colpi only distinct in equatorial view, poroid-like endoapertures with strongly protruding vestibules, sexine projecting over them, scabrate to verrucate surface (Barreto et al., 2013).

Ecological data: Species of this genus are shrubs occurring in swamps and waterlogged areas of lowland Atlantic rainforest (Joly, 1983).

Phyllanthaceae Martinov

Phyllanthus L. (Plate 4/I, J)

Medium-sized pollen grain, isopolar, prolate; 3-colporate; reticulate surface; longicolpate, narrow colpi with margo and slight constriction; lalongate endoapertures (Roubik & Moreno, 1991).

Ecological data: herbaceous, shrub, subshrub, tree or liana habit; occurring in both fertile and poor soils of open or shaded areas, in rainforests and gallery forests, grasslands, cerrado, caatinga, restinga, and rocky outcrops, as aquatic or ruderal vegetation (Flora e Funga do Brasil, 2020; Kissman & Groth, 1999; Souza & Lorenzi, 2005).

Phytolaccaceae R. Br.

Phytolacca dioica L. (Plate 4/K)

Small to medium-sized pollen grain (27.5 x 13.5 µm), isopolar, radial symmetry, circular ambit, perprolate, 3-colpate, long and wide colpi showing isolated sexine elements; perforate spiculate surface, supratectal spiculae, exine thicker at apocolpi, nexine 1 not detected; nexine 2 of constant thickness (Barth and Misumi, 2023).

Ecological data: tree habit (Flora e Funga do Brasil 2020).

Poaceae Barnhart (Plate 4/M, N, O)

Large to small-sized pollen grain, heteropolar, spheroidal; 2-porate; slightly scabrate psilate surface. Non-equidistant pores with annulus (Roubik & Moreno, 1991).

Ecological data: herbaceous habit (sometimes woody, as in bamboos); herbaceous forms are main constituents of grasslands but may occur in rainforests, seasonal forests, coastal formations (restinga, mangroves), and even as aquatic vegetation (Flora e Funga do Brasil, 2020; Souza & Lorenzi, 2005).

Polygonaceae A. Juss.

Polygonum L. (Plate 4/P)

Medium-sized pollen grain, spheroidal, pantoporate, pores with irregular outline, difficult to visualize; surface reticulate, heterobrochate, muri simple to duplicolumellate, with granules within lumina (Barreto et al., 2013).

Ecological Data: species of this genus are herbs or subshrubs, frequently found in waterlogged habitats (Souza & Lorenzi, 2005).

Primulaceae Batsch ex Borkh

Myrsine L. (Plate 4/L)

Small to medium-sized pollen grain, isopolar, oblate-spheroidal to subprolate, quadrangular ambit; 4-colpate; psilate surface; brevicolpate (Ybert et al., 2018).

Ecological data: shrub or tree habit; heliophyte (hygrophytic or not), pioneer species occurring throughout Atlantic rainforest areas (including open terrains and restinga), as well as grasslands and cerrado vegetation (Flora e Funga do Brasil, 2020; Lorenzi, 1992, 1998, 2009).

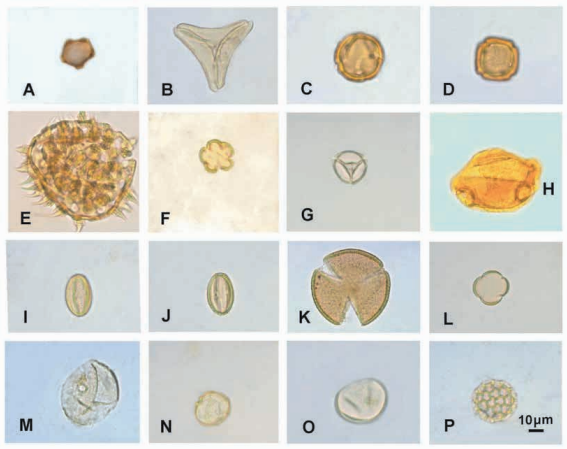

Plate 4. A. *Myriophyllum* **B.** *Struthanthus* **C.** *Heteropterys* **D.** *Tetrapterys* **E.** *Sida* **F.** *Tibouchina* **G.** Myrtaceae **H.** *Ludwigia* **I.** *Phyllanthus* surface **J.** *Phyllanthus* optical section **K.** *Portulacca dioica* **L.** *Myrsine* **M-O.** Poaceae **P.** *Polygonum*

Proteaceae Juss.

Roupala Aubl. (Plate 5/A)

Medium-sized pollen grains, isopolar, radiosymmetric, triangular with straight interangular zones, triporate, tectate exine, columellate, with psilate to finely reticulate ornamentation (Cancelli et al., 2012).

Ecological data: shrub or tree habit; an exclusively neotropical genus with wide distribution (Flora e Funga do Brasil, 2020).

Rubiaceae Juss.

Borreria G. Mey. (Plate 5/B)

Medium-sized pollen grain; isopolar; colpate; 8 short, fusiform colpi; very large apocolpus; microreticulate to scrobiculate exine; circular lumina; muri with thickness approximately equal to lumina diameter; straight to digitate columellae, taller at equator and poles; circular to slightly elliptical meridional outline; circular ambit; oblate-spheroidal to prolate-spheroidal shape (Ybert et al., 2018).

Ecological data: shrub, herb, liana or subshrub (Flora e Funga do Brasil, 2020).

Oldenlandia L. (Plate 5/C)

Small to medium-sized pollen grain; isopolar; zonocolporate; 4-5 long, narrow colpi; lalongate elliptical endoapertures; distinct costae; large apocolpus; microreticulate exine; straight columellae; elliptical meridional outline; subcircular to polygonal ambit; suboblate to prolate-spheroidal shape (Ybert et al., 2018).

Ecological data: Herb; Aquatic, Terrestrial; Riparian Forest, Restinga (Ybert et al., 2018).

Posoqueria Aubl. (Plate 5/D)

Medium-sized pollen grain, spheroidal (or oblate), tricolporate with acute ectocolpi at both ends. Exine reticulate with lumina gradually decreasing in size toward the poles, lacking supratectal processes. Size: 34-57 x 40-59 µm (Persson, 1993).

Ecological data: shrub or tree habit (Flora e Funga do Brasil, 2020).

Sapindaceae Juss.

Serjania Mill. (Plate 5/E, F)

Medium-sized pollen grain, heteropolar, oblate, triangular ambit with rounded vertices; 3-colporate; microreticulate surface. Angulaperturate; syncolpate (colpi united at one pole only); lalongate endoapertures; heteroreticulate with lumina decreasing toward colpi (Roubik & Moreno, 1991; Ybert et al., 2018).

Ecological data: shrub or liana habit; frequent as lianas along forest edges, also found in grasslands, anthropic areas, restinga, and rocky outcrops (Flora e Funga do Brasil, 2020; Souza & Lorenzi, 2005).

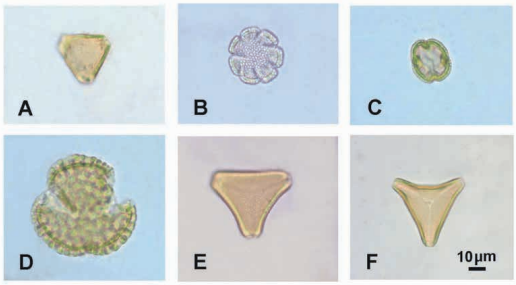

Plate 5: A. *Roupala* **B.** *Borreria* **C.** *Oldenlandia* **D.** *Posoqueria* **E.** *Serjania* apertural opposite site **F.** *Serjania* aperture

FINAL CONSIDERATIONS

The plant taxa detected and identified in an old sediment sample inform that at 3,990 years BP the local vegetation around the Maricá lagoon belonged to typical restinga plant associations, between the taxa of Arecaceae, *Calophyllum*, *Heteropterys, Ilex*, *Inga*, *Ipomoea, Microgramma*, *Myrsine*, *Oldenlandia*, *Piptadenia*, *Schinus*, *Schultesia* and *Serjania*. No human influence could be detected.

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