Acta Botanica Brasilica 27(4): 761-772. 2013.

Pollen grains in quaternary sediments from the Campos Basin, state of Rio de Janeiro, Brazil: Core BU-91-GL-05

Aline Gonçalves de Freitas[1,2,4], Marcelo de Araujo Carvalho[2],
Claudia Barbieri Ferreira Mendonça[3] and Vania Gonçalves-Esteves[3]

Received: 16 August, 2012. Accepted: 1 August, 2013

ABSTRACT

Here, we describe pollen grains extracted from a Pleistocene-Holocene sediment core (BU-91-GL-05; 22°48'45"S; 41°54'13"W) taken from the Albacora Slope (22°48'45"S; 41°54'13"W), located in the Campos Basin of the northern region of the state of Rio de Janeiro, Brazil. The analysis resulted in the identification and morphological description of 46 types of pollen: one of a gymnosperm genus (*Podocarpus*); and 45 of angiosperm taxa across 27 families—one family of monocotyledons (Poaceae) and 26 families (30 types) of dicotyledons. The most common angiosperm families were Amaranthaceae (*Chenopodium*, *Amaranthus* and *Gomphrena*); Fabaceae (Fabaceae type, *Bauhinia*, *Inga* and *Canavalia*); Malpighiaceae (*Tetrapteris*, *Heteropteris* and *Peixotoa*); Malvaceae (*Sida*, *Abutilon*, *Hibiscus* and *Pseudobombax*); Rubiaceae (*Faramea*, *Borreria* and *Psychotria*); Asteraceae (*Eupatorium* and tribe Vernonieae); Bignoniaceae (Bignoniaceae type, *Adenocalymma* and *Tabebuia*); and Onagraceae (*Fuchsia* and *Ludwigia*). The palynoflora in this study are associated with dense montane and submontane Atlantic Forest, semideciduous forest and *restinga* (coastal woodland), all of which are present in the state of Rio de Janeiro. Palynological analysis can provide important data about paleovegetation and paleoclimatic changes in the studied area during the Quaternary, specifically in the last 145,000 years.

Key words: palynology; pollen descriptions; paleovegetation; Quaternary; Campos Basin

Introduction

Morphological descriptions and taxonomic identification of quaternary pollen grains form marine sediments can allow inferences to be made about the paleovegetation, paleoclimate and paleoenvironment during the Upper Pleistocene-Holocene in coastal areas of southeastern Brazil. Fossil pollen grains and spores are morphologically similar to those produced by modern plants. Although the palynological records collected to date for southern and southeastern Brazil are relatively specific, these data constitute an important tool for the understanding of vegetation dynamics and paleoclimate, as well as for and paleoenvironmental reconstruction of the Pleistocene-Holocene (Behling *et al*. 2002; Freitas 2005; Luz *et al*. 2006; Medeanic *et al*. 2006; Freitas *et al*. 2007; Toledo *et al*. 2009).

Based on palynological analysis of sediment from the Campos Basin, located in the northern region of the state of Rio de Janeiro, Brazil, Behling *et al*. (2002) observed changes in paleovegetation with a predominance of grasses in glacial cycles and increases in arboreal and semideciduous forests during interglacial cycles. Undertaking Pleistocene-Holocene palynological analysis of the BU-91-GL-05 core, taken from the same basin, Freitas (2005) registered continental palynomorphs (cryptogamic spores, phanerogamic pollen grains, fresh water microalgae and microfungi). Vegetation types included taxa associated with Atlantic Forest (montane and lowland), semideciduous forest and *restinga* (coastal woodland), as well as herbs and hydrophytes. The percentage variations in the terrestrial palynomorphs indicated paleoenvironmental changes occurred during glacial and interglacial cycles over the past 145,000-150,000 years based on foraminiferal biozones. The morphological descriptions of spore and pollen types reveal a richness and diversity, in the same core, of pteridophyte and hydrophyte spores (Freitas *et al*. 2007) of periodically or totally flooded environments such as inundated brackish swamps, lagoon systems and flooded areas of pioneer formations of *restinga*, salt marshes and mangrove.

---

[1] Based on the Master's dissertation of the first author

[2] Universidade Federal do Rio de Janeiro, Museu Nacional, Departamento de Geologia e Paleontologia, Laboratório de Paleoecologia Vegetal, Rio de Janeiro, RJ, Brazil

[3] Universidade Federal do Rio de Janeiro, Museu Nacional, Departamento de Botânica, Laboratório de Palinologia, Rio de Janeiro, RJ, Brazil

[4] Author for correspondence: tuttyfreitas@gmail.com

Palynological analyses coastal plain in northern part of the state of Rio de Janeiro indicate climatic oscillations from ca. 6,100 ^{14}C yr BP to the present. Luz & Barth (2002) studied sediments from the nearby Lagoa de Cima, in the city of Campos dos Goytacazes, and registered spore-pollen indicators of Atlantic Forest, *restinga*, field vegetation, salt marshes and lagoon shores. The Holocene lacustrine sediment cores showed the expansion of the coastal plain with establishment of field vegetation between 6,500 and ca. 4,000 ^{14}C yr BP. These changes were probably mediated by relative sea level oscillations in the region during the Holocene (Luz *et al.* 2011).

In a paleoenvironmental reconstruction of the Lagoa Salgada, in the city of Macaé (state of Rio de Janeiro), Toledo *et al.* (2009) used multivariate statistical analyses in order to compare pollen records between surface and subsurface sediments. The authors determined that the recent vegetation became established in the region at ca. 2,500 ^{14}C yr BP.

As can be seen in Fig. 1, the current vegetation formations in the northern region of the state of Rio de Janeiro include the following (Radambrasil 1983; IBGE 1992): Atlantic Forest; semideciduous forest; and pioneer formations with fluvial and marine influence (*restinga*, mangrove and salt marshes).

This work presents morphological descriptions of pollen grains recovered from quaternary marine sediments (Fig. 1). These data were associated with recent vegetation in the northern region of the state of Rio de Janeiro and constitute the first records of terrestrial palynomorphs on the slope portion of the Campos Basin in southeastern Brazil.

Study Area

The Campos Basin is located in the southeastern portion of the Brazilian continental margin in an area between the states of Espírito Santo (21°S, the Vitória ridge) and Rio de Janeiro (23°S, the Cabo Frio upwelling) (Fig. 1). The studied region has a warm climate with seasonal humidity in lowland regions, with rainy summers and dry winters. The average monthly rainfall ranges from 650 mm to 1000 mm, the dry season lasting 3-4 months (Nimer 1979). The average annual temperature in the largest city of the region (Campos dos Goytacazes) is 23°C. The coastal plain, including the Paraiba do Sul river delta, is extensive. It gradually decreases between positions 21°30'S and 22°15'S and receives fluvial and marine influence (Nimer 1979; Radambrasil 1983).

The recent vegetation in the northern state of Rio de Janeiro comprises plant formations associated with Atlantic Forest (lowland and montane), semideciduous forest, mangrove and *restinga* (Radambrasil 1983; IBGE 1992). Phytosociological data for northern Rio de Janeiro (Assumpção & Nascimento 2000; Costa & Dias 2001; Moreno *et al.* 2003; Pessoa & Oliveira 2006; Pimentel *et al.* 2007; Silva & Nascimento 2001) suggest that the region encompasses the so-called *tabuleiro* forests (coastal lowland forests on Tertiary deposits) in the lowlands and xeromorphic (*restinga*) vegetation in the coastal areas.

In the north of the state of Rio de Janeiro, there is a major protected area (Jurubatiba Coastal Woodlands National Park), managed by the Chico Mendes Institute for

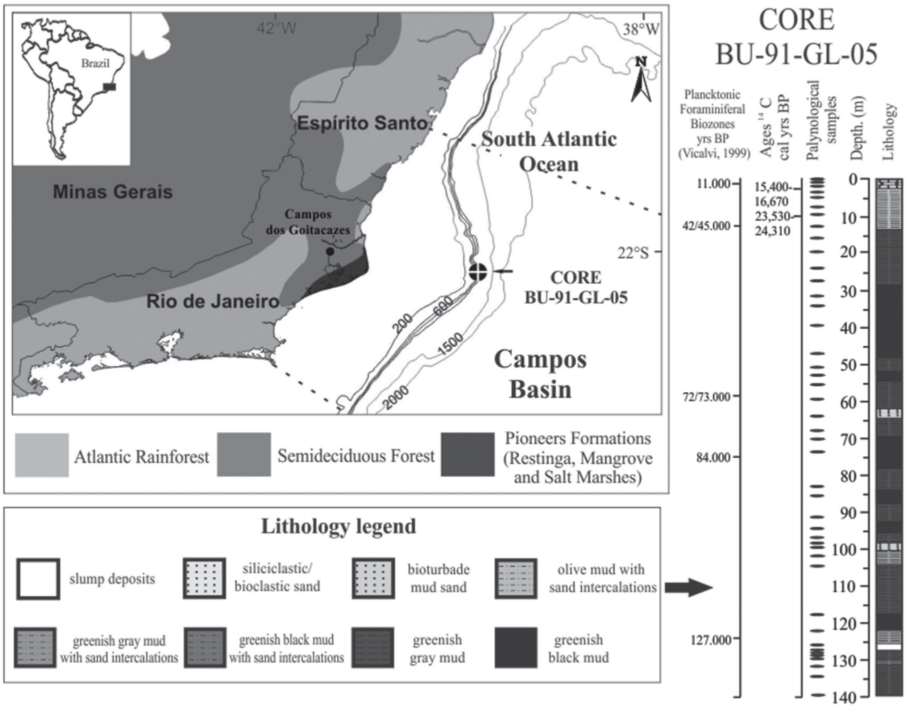

Figure 1. Map showing the location of core BU-91-GL-05, Albacora Slope, Campos Basin, state of Rio de Janeiro, Brazil, as well as the current distribution of vegetation in southeastern Brazil.

the Conservation of Biodiversity, encompassing multiple *restinga* ecosystems (Costa & Dias 2001; Pereira *et al.* 2004; Montezuma & Araujo 2007).

Material and methods

The marine core BU-91-GL-05 (22°08'12"S; 39°54'53"W) is 149.5 m long and was collected at a depth of 650 m, on the Albacora Slope, northern Campos Basin, located 150 km east of the city of Campos dos Goytacazes, in the northern part of the state of Rio de Janeiro (Fig. 1). The core sediments are composed mainly of organic muds. Sandy intercalations occur near the top of the core, at 63-65 m and 97-100 m. Slump or turbidite deposits also occur between 126.70-127.85 m (Caddah *et al.* 1998) (Fig. 1). Using planktonic foraminiferal biostratigraphy, Vicalvi (1997; 1999) calculated the estimated age of deposition of the sediments in the core in the last 145,000-150,000 years. Two sediment samples from the top of the core were submitted to ^{14}C-dating (Beta Analytic Inc., Miami, FL, USA). The ages derived were 13,210 ± 70 ^{14}C yr BP for the 1.3-1.5 m interval and 20,020 ± 100 ^{14}C yr BP for the 10.2-10.4 m interval (Fig. 1; Tab. 1). Dates were calibrated using the IntCal09 curve (Ramsey *et al.* 2009) in the Calib 6.1.1 program (Stuiver & Reimer 1993).

For pollen analysis, we selected 43 samples of core BU-91-GL-05 (10-20 g each). Samples were treated using the standard techniques employed in palynofacies analysis (Tyson 1995; Mendonça Filho *et al.* 2002), which consist of removing the mineral fraction, with hydrochloric and hydrofluoric acids, and concentrating the resulting organic residue with a dense liquid ($ZnCl_2$; D=2.0 g/cm^3), in this case without oxidation. The samples were stored in the Laboratory of Plant Paleoecology at the National Museum of the Federal University of Rio de Janeiro.

We made standard morphological descriptions of pollen grains using characters such as polarity; symmetry; number, position and character of apertures; exine ornamentation; shape; and size (Punt *et al.* 2007) (Tab. 2). These characteristics provide a sound basis for correlations between fossil and modern pollen grains, permitting their taxonomic classification. The identification of pollen grains was made on the basis of data obtained from the following bibliographic sources: Moreira *et al.* (2004), Souza *et al.* (2004), Carrijo *et al.* (2005), Gonçalves-Esteves *et al.* (2007), Mendonça *et al.* (2007a; 2007b; 2009; 2010), Aguiar *et al.* (2008), Peçanha *et al.* (2008), Loueuille *et al.* (2012) and Milward-Azevedo *et al.* (2010; 2012). This was in addition to consulting the reference collection of the Álvaro Xavier Moreira Laboratory of Palynology in the Botany Department of the National Museum of the Federal University of Rio de Janeiro. The pollen type was characterized by establishing the proximity between the material analyzed and the taxonomic group (Salgado-Labouriau 1973; Lorscheitter 1989). The photomicrographs shown in Fig. 2 and Fig. 3 were obtained with a Zeiss light microscope in conjunction with the AxioVision software, version 6.0 (Carl Zeiss, Oberkochen, Germany).

Table 1. ^{14}C dating of core BU-91-GL-05, Albacora Slope, Campos Basin, state of Rio de Janeiro, Brazil.

Lab code	Depth (m)	^{14}C yrs BP	Calibrated age* (cal yr BP)	δ^{13}C
Beta-270653	1.3	13,220 ± 70	15,400-16,670	−25,4
Beta-270652	10.2	20,020 ± 100	23,530-24,310	−22,7

*Ages were calibrated based on Stuiver & Reimer (1993) and Ramsey *et al.* (2009), with the IntCal09 calibration curve.

Pollen descriptions (Tab. 2) follow the classification system established in the Angiosperm Phylogeny Group III guidelines (Souza & Lorenzi 2008; , APG III 2009). The pollen types identified in core BU-91-GL-05 correspond to recent vegetation reported for Atlantic Forest (lowland and montane), semideciduous forest and *restinga*, as well as to the hygrophytes, herbs and other vegetation currently occurring in flooded coastal plain environments. These correlations were based on floristic and phytosociological surveys carried out on the northern of the Rio de Janeiro State (Tab. 3).

Results and discussion

In the 43 samples taken from core BU-91-GL-05, we identified 46 pollen types (Fig. 2 and 3). These were distributed as follows (Tab. 2 and 3): one gymnosperm genus (*Podocarpus*); and 45 angiosperm types belonging to 27 families—15 types of a single family of monocotyledons (Poaceae) and 30 types across 26 families of dicotyledons. The families of angiosperms that were most representative in terms of the number of pollen types were Fabaceae, with four (Fabaceae type , *Bauhinia*, *Inga* and *Canavalia*), Amaranthaceae, with three (*Chenopodium*, *Amaranthus* and *Gomphrena*), Malpighiaceae, with three (*Tetrapteris*, *Heteropteris* and *Peixotoa*), Malvaceae, with three (*Sida*, *Abutilon*, *Hibiscus* and *Pseudobombax*), Rubiaceae, with three (*Faramea*, *Borreria* and *Psychotria*), Bignoniaceae, with three (Bignoniaceae type, *Adenocalymma* and *Tabebuia*), Asteraceae, with two (*Eupatorium* and tribe Vernonieae), and Onagraceae, with two (*Fuchsia* and *Ludwigia*). The wide spectrum of pollen types points to a dynamic paleovegetation environment throughout the Upper Pleistocene-Holocene in southeastern Brazil, especially in the north of the state of Rio de Janeiro.

Relationships between fossil pollen records and recent vegetation

The pollen types identified are associated with Atlantic Forest (lowland and montane), semideciduous forest and pioneer formations (*restinga*, mangrove and salt marshes)

Table 2. Morphological descriptions of pollen grains recorded from core BU-91-GL-05, Albacora Slope, Campos Basin, state of Rio de Janeiro, Brazil.

Pollen grain distribution CLASS-SUBCLASS Family Type	Pollen unit	Polarity/ Symmetry	Size (µm)	NPC apertures	Exine	Shape	Observations
GYMNOSPERMAE							
Podocarpaceae							
Type 1 *Podocarpus* L'Her. ex Pers. [Fig. 2; 1]	monad	apolar-asymmetric	62.0 × 33.0	bisaccate	reticulate		
ANGIOSPERMAE-MONOCOTYLEDONES							
Poaceae							
Type 2 Poaceae [Fig. 2; 2]	monad	heteropolar-radiosymmetric	42.0 × 38.0	monoporate	psilate to scabrate	spheroidal	pore with conspicuous annulus
ANGIOSPERMAE-DICOTYLEDONES							
Acanthaceae							
Type 3 Acanthaceae [Fig. 2; 3]	monad	isopolar-radiosymmetric	45.8 × 34.0	3-zonoporate	reticulate-baculate	prolate	
Amaranthaceae							
Type 4 *Chenopodium* L. [Fig. 2; 4]	monad	apolar-asymmetric	20.0 × 20.0	pantoporate (42 pores)	microreticulate	spheroidal	
Type 5 *Amaranthus* L. [Fig. 2; 5]	monad	apolar-asymmetric	26.0 × 26.0	pantoporate (7 pores)	granulate	spheroidal	
Type 6 *Gomphrena* [Fig. 2; 6-7]	monad	apolar-asymmetric	44.0 × 44.0; 33.3 × 33.3	pantoporate (12 pores)	lophate	spheroidal	
Apocynaceae							
Type 7 Apocynaceae [Fig. 2; 8]	monad	isopolar-radiosymmetric	52.0 × 50.0	3-zonoporate	scabrate to rugulate	oblate spheroidal	
Aquifoliaceae							
Type 8 *Ilex* L. [Fig. 2; 9]	monad	isopolar-radiosymmetric	32.2 × 28.6	tricolporate	clavate	prolate spheroidal	
Asteraceae							
Type 9 *Eupatorium* [Fig. 2; 10]	monad	isopolar-radiosymmetric	32.0 × 30.0	tricolporate	echinate	oblate spheroidal	
Type 10 Tribe Vernonieae [Fig. 2; 11]	monad	isopolar-radiosymmetric	50.0 × 47.0	tricolporate	subechinolophate	oblate spheroidal to prolate	
Bignoniaceae							
Type 11 Bignoniaceae [Fig. 2; 13]	monad	isopolar-radiosymmetric	40.0 × 27.2	tricolporate	reticulate-homobrochate	prolate	
Type 12 *Adenocalymma* Mart.ex Meisn. [Fig. 2; 14]	monad	apolar-asymmetric	45.0 × 42.0	inaperturate	rugulate	spheroidal	
Type 13 *Tabebuia* Gomes ex. DC. [Fig. 2; 15]	monad	isopolar-radiosymmetric	36.6 × 34.8	tricolporate	reticulate-homobrochate	prolate	
Boraginaceae							
Type 14 *Tournefortia* L. [Fig. 2; 16]	monad	isopolar	20.0 × 18.0	tricolporate	gemmate-verrucate		
Clusiaceae							
Type 15 *Garcinia* L. [Fig. 2; 18]	monad	isopolar-radiosymmetric	41.4 × 14.8	tricolporate	rugulate	prolate spheroidal	
Convolvulaceae							
Type 16 *Merremia* [Fig. 2; 17]	monad	isopolar-radiosymmetric	60.0 × 58.4	tricolpate	reticulate with granula	oblate spheroidal	
Ericaceae							
Type 17 Ericaceae [Fig. 2; 19]	tetrad	isopolar-radiosymmetric	29.6 × 29.6	tricolporate demicolpate	reticulate		
Euphorbiaceae							
Type 18 *Sebastiania* [Fig. 2; 20]	monad	isopolar-radiosymmetric		tricolporate	microreticulate	prolate spheroidal	
Type 19 *Alchornea* Sw. [Fig. 2; 21]	monad	isopolar-radiosymmetric	28.0 × 27.7	tricolporate	reticulate	suboblate to oblate spheroidal	
Type 20 *Croton* L. [Fig. 2; 22]	monad	apolar	40.0 × 40.0	inaperturate	croton pattern	spheroidal	

Continues

Table 2. Continuation.

Pollen grain distribution CLASS-SUBCLASS Family Type	Pollen unit	Polarity/ Symmetry	Size (μm)	NPC apertures	Exine	Shape	Observations
Fabaceae							
Type 21 Fabaceae [Fig. 2; 23]	monad	isopolar-radiosymmetric	37.0 × 34.1	tricolpate	scabrate	spheroidal	equatorial view
Type 22 *Bauhinia* L. [Fig. 2; 24]	monad	isopolar-radiosymmetric	34.7 × 33.0	tricolporate	reticulate with supratectal gemmae	subprolate	
Type 23 *Inga* Scop. [Fig. 2; 25]	polyad	apolar-asymmetric	60.0 × 57.0	triporate	psilate		16 pollen grains
Type 24 *Canavalia* DC. [Fig. 2; 26]	monad	isopolar-radiosymmetric	46.0 × 42.0	tricolporate	rugulate-perforate	suboblate	
Lentibulariaceae							
Type 25 *Utricularia* L. [Fig. 2; 27]	monad	isopolar-radiosymmetric	53.0 × 43.5	14-17-colporate	psilate	oblate spheroidal to suboblate	
Loranthaceae							
Type 26 *Struthanthus* Mart. [Fig. 3; 1]	monad	isopolar-radiosymmetric	27.5 × 27.2	syncolporate	scabrate	peroblate to suboblate	
Malpighiaceae							
Type 27 *Tetrapteris* Cav. [Fig. 3; 2]	monad	apolar-asymmetric	27.0-35.0 × 23.0-33.0	porate (6 pores)	rugulate to microreticulate	spheroidal	
Type 28 *Heteropteris* Fee. [Fig. 3; 3]	monad	apolar-radiosymmetric	27.0-31.0 × 27.0-28.0	zonoporate (6-8 pores)	scabrate/ rugulate/ perforate	spheroidal	
Type 29 *Peixotoa* Juss. [Fig. 3; 4]	monad	apolar-radiosymmetric	27.0 × 26.0	zonoporate (8 pores)	perforate	spheroidal	
Malvaceae							
Type 30 *Sida* [Fig. 3; 6]	monad	apolar-asymmetric	42.8-48.5 × 40.9-44.2	pantoporate (30 pores)	echinate	spheroidal	
Type 31 *Abutilon* Mill. [Fig. 3; 5]	monad	apolar-asymmetric	42.7-56.6 × 42.7-57.8	tricolporate	echinate	spheroidal	
Type 32 *Hibiscus* L. [Fig. 3; 7]	monad	apolar-asymmetric	50.0-69.3 × 50.0-73.3	pantoporate	echinate	spheroidal	
Type 33 *Pseudobombax* Dugand [Fig. 3; 8]	monad	isopolar-radiosymmetric	60.0 × 55.5	brevitricolporate	reticulate-heterobrochate	oblate	
Meliaceae							
Type 34 Meliaceae [Fig. 3; 9]	monad	isopolar-radiosymmetric	34.5 × 34.5	zonocolporate (4-colporate)	reticulate	spheroidal	
Myrtaceae							
Type 35 Myrtaceae [Fig. 3; 10]	monad	isopolar-radiosymmetric	21.8 – 23.0	tricolporate	psilate	peroblate to oblate spheroidal	
Onagraceae							
Type 36 *Fuchsia* L. [Fig. 3; 11]	monad	heteropolar-radiosymmetric	60.0-70.0 × 50.0-68.0	triporate	psilate to scabrate	suboblate to oblate	
Type 37 *Ludwigia* L. [Fig. 3; 12]	monad	heteropolar-radiosymmetric	44.7-56.6 × 44.4-59.0	tricolporate	rugulate	suboblate to oblate	
Passifloraceae							
Type 38 *Passiflora* L. [Fig. 3; 13]	monad	isopolar-radiosymmetric	43.2-45.7 × 32.8-37.1	zonocolpate	reticulate-homobrochate	oblate to subprolate	
Polygalaceae							
Type 39 *Polygala* L. [Fig. 3; 15]	monad	isopolar-radiosymmetric	37.8 × 32.8	zonocolporate (8-10 colpori)	rugulate	subprolate	
Polygonaceae							
Type 40 *Polygonum* L. [Fig. 3; 14]	monad	apolar	39.0-47.0 × 35.2-40.0	pantoporate	reticulate-heterobrochate	spheroidal	

Continues

Table 2. Continuation.

Pollen grain distribution CLASS-SUBCLASS Family Type	Pollen unit	Polarity/ Symmetry	Size (μm)	NPC apertures	Exine	Shape	Observations
Rubiaceae							
Type 41 *Faramea* [Fig. 3; 16]	monad	isopolar-radiosymmetric	34.0 × 30.0	triporate	rugulate	oblate-spheroidal	
Type 42 *Borreria* Mey. [Fig. 3; 17]	monad	isopolar-radiosymmetric	44.0 × 40.0	zonocolporate (10-colporate)	spiculate-baculate	suboblate	
Type 43 *Psychotria* L. [Fig. 3; 18]	monad	apolar	37.0 × 36.0	inaperturate	reticulate	spheroidal to subprolate	
Sapindaceae							
Type 44 Sapindaceae [Fig. 3; 19]	monad	isopolar-radiosymmetric	58.8 × 34.4	triporate	scabrate	suboblate to peroblate	
Solanaceae							
Type 45 Solanaceae [Fig. 3; 20]	monad	isopolar-radiosymmetric	27.6 × 28.0	tricolporate	rugulate	prolate-spheroidal	
Symplocaceae							
Type 46 *Symplocos* [Fig. 2; 12]	monad	isopolar-radiosymmetric	32.5 × 32.5	triporate	scabrate	circular	

NPC – number, position and character.

Table 3. Pollen types registered in core BU-91-GL-05 and their associated ecosystems. According with: Garcia (1994); Rizzini (1997); Assumpção & Nascimento (2000); Kurtz & Araujo (2000); Pereira & Araujo (2000); Costa & Dias (2001); Silva & Nascimento (2001); Bove *et al.* (2003); Moreno *et al.* (2003); Pessoa & Oliveira (2006); Pimentel *et al.* (2007); Souza & Lorenzi (2008).

Ecosystems	Family - Pollen type	Ecosystems	Family - Pollen type
	Podocarpaceae - *Podocarpus*	*Restinga*	Ericaceae - Ericaceae Type
Montane forest	Symplocaceae - *Symplocos*		Fabaceae - *Canavalia*
	Onagraceae - *Fuchsia*		Malvaceae - *Abutilon*
Lowland formations			Malvaceae - cf. *Hibiscus*
Atlantic Forest and semideciduous forest	Acanthaceae - Acanthaceae Type		Polygalaceae - *Polygala*
	Apocynaceae - Apocynaceae Type		
	Bignoniaceae - Bignoniaceae Type	Aquatics	Lentibulariaceae - *Utricularia*
	Meliaceae- Meliaceae Type		Onagraceae - *Ludwigia*
	Sapindaceae- Sapindaceae Type		Polygonaceae *Polygonum*
	Solanaceae - Solanaceae Type		
		Herbs	Asteraceae - Eupatorieae
Atlantic Forest and semideciduous forest/*Restinga*	Aquifoliaceae - *Ilex*		Asteraceae - Vernonieae
	Clusiaceae- *Garcinia*		Poaceae - Poaceae Type
	Euphorbiaceae - *Alchornea*		Rubiaceae - *Borreria*
	Euphorbiaceae - Euphorbiaceae Type		Rubiaceae - *Faramea*
	Fabaceae - *Inga*		
	Fabaceae - Fabaceae Type	Flooded coastal plain environments	Poaceae - Poaceae Type
	Malpighiaceae - *Tetrapteris*		Aquifoliaceae - *Ilex*
	Malpighiaceae - *Heteropteris*		Asteraceae - *Eupatorium*
	Malvaceae - *Pseudobombax*		Clusiaceae - *Garcinia*
	Malvaceae - *Sida*		Euphorbiaceae - *Alchornea*
	Myrtaceae - Myrtaceae Type		Fabaceae - *Inga*
	Passifloraceae - *Passiflora*		Lentibulariaceae - *Utricularia*
	Rubiaceae- *Psychotria*		Malvaceae - *Hibiscus*
			Onagraceae - *Ludwigia*
Restinga	Amaranthaceae - *Amaranthus*		Passifloraceae - *Passiflora*
	Amaranthaceae - *Chenopodium*		Polygalaceae - *Polygala*
	Amaranthaceae - *Gomphrena*		Polygonaceae - *Polygonum*
	Boraginaceae *Tournefortia*		Rubiaceae - *Borreria*
	Convolvulaceae Convolvulaceae Type		

*Montane and lowland formations comprise the Atlantic Forest.

distributed at different elevations in the north of the state of Rio de Janeiro (Radambrasil 1983). To make those associations, we consulted floristic studies undertaken in montane and submontane areas (Kurtz & Araujo 2000; Moreno *et al*. 2003; Pessoa & Oliveira 2006); dense lowland forest and semideciduous forest (Silva & Nascimento 2001; Kurtz *et al*. 2009); *restinga* (Costa & Dias 2001; Pimentel *et al*. 2007); and herbaceous and hygrophytic coastal vegetation ecosystems (IBGE 1992; Costa & Dias 2001; Bove *et al*. 2003).

Atlantic Forest

Arboreal taxa (*Podocarpus* and *Ilex*), as classified by the Brazilian Institute of Geography and Statistics (IBGE 1992) and Radambrasil (1983), are tree layer components derived from mixed and montane/upper montane Araucaria forest, at 400-2,000 m of elevation. Arboreal taxa of lowland tropical rain forest do occur, as represented by Euphorbiaceae (*Alchornea* and *Croton*), Myrtaceae and Rubiaceae, which occupy the slopes of coastal and inland mountains (Radambrasil 1983; IBGE 1992). According to Carauta & Rocha (1988), the Podocarpaceae arboreal family consists of high latitude woodlands along the length of the Paraíba do Sul River, in the state of Rio de Janeiro.

Moreno *et al*. (2003) undertook a phytosociological survey in two areas of dense, submontane forest, at 50-250 m of elevation, in the foothills of the Imbé mountain range, near Campos dos Goytacazes, in the state of Rio de Janeiro (Fig. 1). The families Fabaceae, Myrtaceae, Euphorbiaceae and Rubiaceae were found to be quite species-rich in the area. The taxa most commonly found in the marine sediment examined in the present study (*Tabebuia*, *Alchornea*, *Inga*, Meliaceae, *Trichilia*, Myrtaceae, *Psychotria* and *Symplocos*) were also recorded for the Imbé region, on the coastal plain of the northern part of the state of Rio de Janeiro. Phytosociological studies of the shrub-arboreal component of a submontane forest in the Poço das Antas Biological Preserve (state of Rio de Janeiro) have shown that the most common botanical families are Euphorbiaceae, Fabaceae, Myrtaceae, Bignoniaceae, Sapindaceae, Boraginaceae, Meliaceae and Rubiaceae (Pessoa & Oliveira 2006). Our pollen data fit with the *Garcinia*, *Inga*, *Myrtaceae*, *Alchornea*, Asteraceae and *Psychotria* taxa. Some of the arboreal taxa recorded for the Atlantic Forest in the Paradise State Ecological Reserve, near the town of Cachoeira de Macacu, in the state of Rio de Janeiro (*Tabebuia*, *Garcinia*, Meliaceae, Myrtaceae and *Psychotria*) (Kurtz & Araujo 2000) were also seen in marine sediments of the Campos Basin.

The shrub-herbaceous component of the lowland Atlantic Forest is composed of *Adenocalymma*, *Arrabidaea*, *Cordia*, *Vernonia*, *Alchornea*, Poaceae, *Desmodium*, *Inga*, *Hibiscus*, *Guarea*, Myrtaceae, *Polygonum* and *Psychotria* (Vieira & Pessoa, 2001). Occurring on flood plains, hills and coastal plains, the pollen types of these taxa are similar to those recorded in core BU-91-GL-05, characteristic of dense submontane forest vegetation.

Semideciduous forest

In floristic surveys of the Mata do Carvão forest, a remnant of the Mata Tabuleiros forest, located near Campos dos Goytacazes, Silva & Nascimento (2001) noted the species richness of the arboreal families Fabaceae, Euphorbiaceae, Bignoniaceae, Meliaceae, Myrtaceae, Sapindaceae and Rubiaceae. In sediment from the Albacora Slope, we found *Tabebuia*, *Pseudobombax*, Myrtaceae, Meliaceae, *Polygala* and Rubiaceae. Phytosociological data from the Pau Brasil Environmentally Protected Area, in the Emerenças Hills, near the city of Armação dos Búzios, which is in the lakes region of the state of Rio de Janeiro, indicate the dominance of Myrtaceae, Fabaceae and Euphorbiaceae (Kurtz *et al*. 2009).

Some of the taxa recorded in the present study (*Tabebuia*, *Garcinia*, *Heteropteris*, *Pseudobombax*, Meliaceae and Myrtaceae) belong to the shrub-arboreal component of semideciduous forests in coastal regions of the state of Rio de Janeiro. *Bauhinia* (Fabaceae) was also recorded by Kurtz *et al*. (2009) and is present in the lowland forest arboreal layer occupying the hills and coastal plains (Costa & Dias 2001).

Restinga

Considering the diversity of pollen types identified and registered, as well as the proximity to the *restingas* in the study area, those pollen types have strong relationships with arboreal taxa of shrub and herbaceous vegetation, *restinga* and other pioneer formations. According to Rizzini (1997), *restingas* are found in regions with direct marine influence and consequently exhibit an enormous variety of vegetation types. Coastal area vegetation communities are directly affected by tidal fluctuations. The families (genera) commonly found near beaches and dunes include the following (IBGE 1992; Radambrasil 1983): Fabaceae (*Canavalia*), Poaceae (*Paspalum*), Apiaceae (*Hydrocotyle*), Erythroxylaceae (*Erythroxylum*), and Myrtaceae.

In a floristic analysis of *restingas* in the state of Rio de Janeiro, Pereira & Araujo (2000) showed that the most representative families are Fabaceae, Myrtaceae, Orchidaceae, Bromeliaceae, Rubiaceae, Cyperaceae, Asteraceae, Poaceae, Melastomataceae and Euphorbiaceae. The taxa identified in our study have also been reported in floristic and phytosociological studies of the *restingas* of Rio de Janeiro, especially along its northern coast. Among the plant communities in Jurubatiba Coastal Woodlands National Park, the following related herbaceous types have been recorded (Costa & Dias 2001): Amaranthaceae (*Alternanthera*, *Blutaparon* and *Gomphrena*); Apocynaceae; *Ilex*; Asteraceae (*Eupatorium* and *Vernonia*); Bignoniaceae (*Adenocalymma*, *Arrabidaea* and *Tabebuia*); Malvaceae (*Pseudobombax*, *Abutilon* and *Hibiscus*); Boraginaceae (*Tournefortia*); Clusiaceae (*Garcinia*); Ericaceae; Euphorbiaceae (*Alchornea* and *Croton*); Fabaceae (*Bauhinia*, *Canavalia* and *Inga*); Lentibulariaceae (*Utricula-*

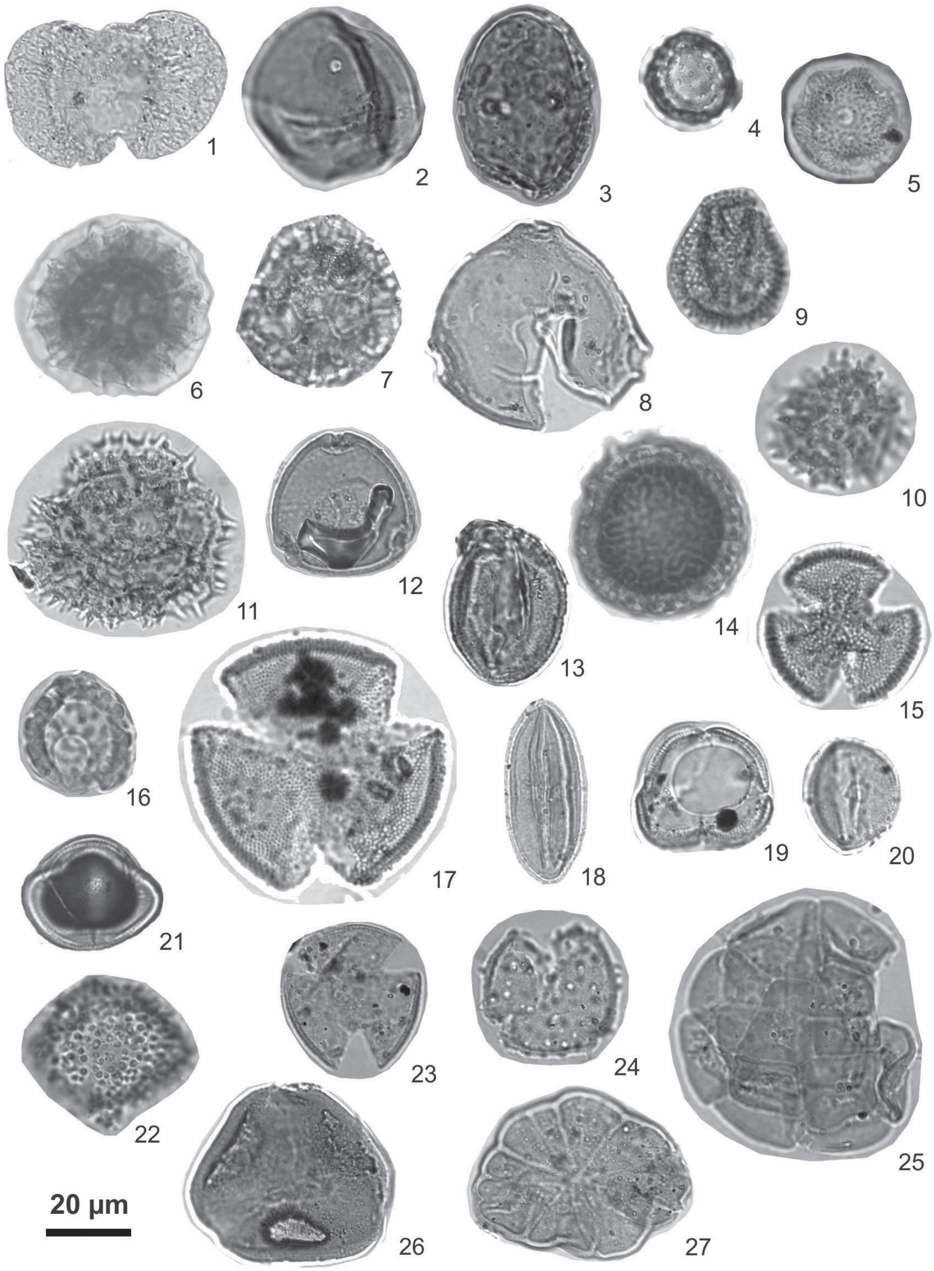

Figure 2. Photomicrographs of gymnosperm and angiosperm pollen grains registered in core BU-91-GL-05 (magnification, ≥ 1000×): 1—Type 1 *Podocarpus*; 2—Type 2 Poaceae; 3—Type 3 Acanthaceae; 4—Type 4 *Chenopodium*; 5—Type 5 *Amaranthus*; 6,7—Type 6 *Gomphrena*; 8—Type 7 Apocynaceae; 9—Type 8 *Ilex*; 10—Type 9 *Eupatorium*; 11—Type 10 *Vernonia*; 12—Type 11 *Symplocos*; 13—Type 12 Bignoniaceae; 14—Type 13 *Adenocalymma*; 15—Type 14 *Tabebuia*; 16—Type 15 *Tournefortia*; 17—Type 16 *Merremia*; 18—Type 17 *Garcinia*; 19—Type 18 Ericaceae; 20—Type 19 *Sebastiania*; 21—Type 20 *Alchornea*; 22—Type 21 *Croton*; 23—Type 22 Fabaceae; 24—Type 23 *Bauhinia*; 25—Type 24 *Inga*; 26—Type 25 *Canavalia*; 27—Type 26 *Utricularia*. Scale: 20 µm.

ria); Malpighiaceae (*Heteropteris*, *Tetrapteris* and *Peixotoa*); Meliaceae; Myrtaceae; Onagraceae (*Ludwigia*); Passifloraceae (*Passiflora*); Poaceae; Polygala (*Polygala*); Rubiaceae (*Faramea*, *Borreria* and *Psychotria*); and Sapindaceae. According to Araujo (2000), *restinga* is compartmentalized into various vegetation formations. The taxa identified in the Campos Basin marine sediments were similar to those occurring in such formations: herbaceous formations on sandbanks (Poaceae, *Blutaparon*, *Alternanthera*, *Gomphrena* and *Canavalia*); dense shrubby backshore formations (Poaceae, *Vernonia* and *Erythroxylum*); sparse shrubby Clusia-dominated formations (Poaceae, *Lepidaploa*, *Vernonia*, *Peixotoa*, *Croton*, *Faramea*, *Ilex* and *Paullinia*); sparse shrubby Ericaceae-dominated formations (Ericaceae, Poaceae, *Vernonia*, *Peixotoa*, *Croton* and *Ilex*); *restingas sensu stricto* (*Alternanthera*, Myrtaceae, *Garcinia*, *Alchornea*, *Croton*,

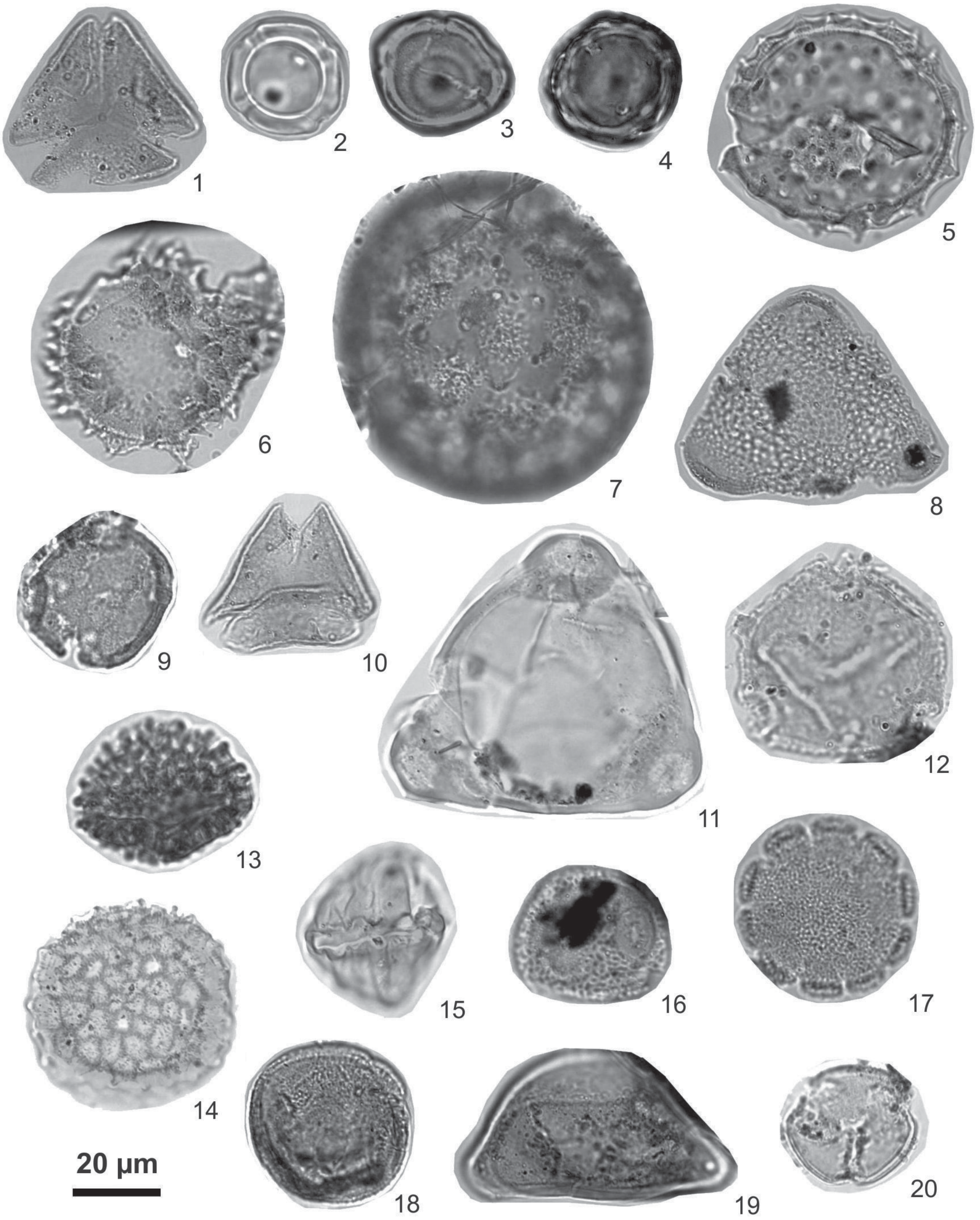

Figure 3. Photomicrographs of gymnosperm and angiosperm pollen grains registered in core BU-91-GL-05 (magnification, ≥ 1000×): 1—Type 27 *Struthanthus*; 2—Type 28 *Tetrapteris*; 3—Type 29 *Heteropteris*; 4—Type 30 *Peixotoa*; 5—Type 31 *Abutilon*; 6—Type 32 *Sida*; 7—Type 33 *Hibiscus*; 8—Type 34 *Pseudobombax*; 9—Type 35 Meliaceae; 10—Type 36 Myrtaceae; 11—Type 37 *Fuchsia*; 12—Type 38 *Ludwigia*; 13—Type 39 *Passiflora*; 14—Type 40 *Polygonum*; 15—Type 41 *Polygala*; 16—Type 42 *Faramea*; 17—Type 43 *Borreria*; 18—Type 44 *Psychotria*; 19—Type 45 Sapindaceae; 20—Type 46 Solanaceae. Scale: 20 µm.

Bauhinia, *Pseudobombax*, *Abutilon*, *Faramea*, Apocynaceae, *Tabebuia*, *Ilex*, *Tetrapteris*, *Psychotria*, *Adenocalymma* and Convolvulaceae); and periodically flooded areas, including some *restingas*, marshes, river banks and lakeshores (Poaceae, Myrtacae, *Hibiscus*, *Adenocalymma*, *Arrabidaea*, *Ludwigia*, *Utricularia*, *Peixotoa*, *Desmodium* and *Inga*).

The identity of the pollen grains from the one Poaceae family described in this paper was verified through assessment of their morphological features. However, it is not yet possible to distinguish all taxa down to the genus level. Coincidentally, a flora identified in *restingas* of the northern coast of Rio de Janeiro indicate that genera belonging to Poaceae occur in coastal environments, such as sandbanks (*Andropogon*, *Eragrostis*, *Gymnopogon*, *Rhynchelytrum* and *Sporobolus*); in flooded areas and in the transition between sandbanks and marshlands (*Dac-*

tyloctenium and *Paspalum*); and in *restinga* (*Stenotaphrum* and *Streptochaeta*).

In floristic studies of the areas surrounding the lagoons in the Grussaí-Iquipari drainage basin, near the municipality of São de João Barra, in northern Rio de Janeiro, Assumpção & Nascimento (2000) recorded four vegetation formations that also correspond to pollen types deposited in the Campos Basin during the Pleistocene-Holocene: beach grass/marsh grass formation (Poaceae, *Alternanthera*, *Blutaparon* and *Borreria*); beach grass with shrubs (Myrtaceae, Poaceae, *Desmodium*, *Polygala* and *Borreria*); Clusia-dominated formations (Myrtaceae, Meliaceae, *Tournefortia*, Poaceae, *Inga* and Sapindaceae); and *restinga* (Bignoniaceae, *Arrabidaea*, *Pseudobombax*, *Garcinia*, *Inga*, *Heteropteris*, Myrtaceae and Sapindaceae). The pollen grains described are also related to the shrub-arboreal component in Coastal Woodlands National Park, near Lake Comprida and Lake Cabiúnas, along the northern coast of Rio de Janeiro. Pimentel *et al.* (2007) analyzed the taxa richness and diversity among beaches, dunes and Clusia-dominated formations. The taxa found were: *Croton*, *Garcinia*, *Heteropteris*, *Ilex*, *Inga*, Meliaceae, Tribe Vernonieae (*Vernonia*) and Myrtaceae.

Herbaceous vegetation

The Poaceae pollen grains identified in the present study are also related to *restinga* vegetation in open upper montane areas (Rizzini 1997) or grassy woodlands that occupy wetlands, near rivers and lakes and in association with Asteraceae and Cyperaceae (IBGE 1992). Taxa commonly associated with herbaceous vegetation include Poaceae, *Amaranthus*, *Alternanthera*, *Gomphrena*, *Chenopodium*, *Borreria*, *Polygala*, *Utricularia*, Asteraceae, *Peixotoa*, *Desmodium*, Ericaceae, *Adenocalymma* and Convolvulaceae. This association is characteristic of xerophytic and hygrophytic vegetation, reflecting grassland or open areas with some riparian or lacustrine influence.

The results of a palynological analysis carried out by Behling *et al.* (2002) in the Campos Basin suggest that grass-dominated ecosystems composed most of the landscape during glacial cycles in southeastern Brazil, thus reflecting a colder, drier climate in northern Rio de Janeiro. Palynological data from the Albacora Slope sediments, in the same basin, indicate the presence of grasses in the glacial and interglacial cycles (Freitas 2005). The low frequency of grasses in the samples analyzed (<10%) is more likely to be due to changes in sea level than to be a response to significant climatic changes in the northern region of the state of Rio de Janeiro during the Pleistocene-Holocene.

Flooded coastal plain environments

Coastal plain environments are home to a variety of habitats, including wetlands; fresh water lakes;, brackish and salt water lagoons; flood plains; and partially or periodically flooded forests (MMA 2002). Taxa observed in the present study—herbaceous (Poaceae, *Polygonum*, *Ludwigia*, *Borreria*, *Polygala* and *Utricularia*); shrub-arboreal (*Vernonia*, *Stigmaphyllon*, *Garcinia*, *Alchornea*, *Croton*, *Inga*, *Desmodium*, *Pseudobombax*, Meliaceae, *Tabebuia* and *Ilex*); and lianas (*Passiflora*, Sapindaceae, *Psychotria*)—also correspond to vegetation occurring in periodically or permanently flooded areas of the Jurubatiba Coastal Woodlands National Park. These exist in lakes, salt marshes and flooded coastal plains in the northern part of the state of Rio de Janeiro (Costa & Dias 2001; Bove *et al.* 2003).

Conclusions

On the basis of the morphological descriptions and taxonomic identification of pollen grains, we can make some inferences regarding the paleovegetation of continental areas adjacent to the Campos Basin during the Pleistocene-Holocene, thus contributing to the current body of research in the area. The pollen types identified in this study are attributed to the following, as currently found in the north of the state of Rio de Janeiro: dense lowland and montane rain forest; seasonal semideciduous forest, *restinga*; herbaceous vegetation; and hygrophytes common to wetland environments.

Acknowledgments

This study received financial support from *Petróleo Brasileiro* (Petrobras, Brazilian Petroleum; Research Grant no. RH-UC-63.011/2003 to AGF), from the *Fundação de Amparo a Pesquisa do Estado do Rio de Janeiro* (FAPERJ, Foundation for the Support of Research in the State of Rio de Janeiro; laboratory supplies) and from the Brazilian *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq, National Council for Scientific and Technological Development; research grant to VG-E). We are grateful to Dr. João Graciano Mendonça Filho, of the Geology Department of the *Universidade Federal do Rio de Janeiro* (UFRJ, Federal University of Rio de Janeiro), for providing the core to be analyzed; to the geochemist Taíssa R. Menezes, of the Petrobras Center for Research, for the chemical processing of samples; and to Dr. Elizabete P. Ferreira, of the Biostratigraphy and Applied Paleoecology Sector of the Petrobras Center for Research, and Dr. Mauro B. de Toledo, of the Laboratory of Marine Geology at Fluminense Federal University, for the valuable palynological discussions.

References

Aguiar, A.C.A.; Gonçalves, V.M.; Gonçalves-Esteves, V.L; Yamamoto, K. 2008. Palynotaxonomy of Brazilian species of *Polygala*. **Botanical Journal of the Linnean Society 157**: 609-619.

APG III. Angiosperm Phylogeny Group. 2009. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. 161: 105-121.

Araujo, D.S.D. 2000. **Análise florística e fitogeográfica das restingas do Estado do Rio de Janeiro**. Tese de Doutorado. Programa de Pós-Graduação em Ecologia, Universidade Federal do Rio de Janeiro, Rio de Janeiro.

Asssumpção, J. & Nascimento, M.T. 2000. Estrutura e composição florística de quatro formações vegetais de Restinga no complexo lagunar Grussaí/Iquipari, São João da Barra, RJ, Brasil. **Acta Botanica Brasilica 14**(3): 301-315.

Behling, H.; Arz, H.W.; Pätzold, J.; Wefer, G. 2002. Late Quaternary and Climate dynamics in Southeastern Brazil, inferences from marine slope cores GeoB 3229-2 and GeoB 3202-1. **Palaeogeography, Palaeoclimatology, Palaeoecology 179**: 227-243.

Bove, C.P.; Gil, A.S.B.; Moreira, C.B. & Anjos, R.F.B. 2003. Higrófitas fanerogâmicas de ecossistemas aquáticos temporários de planície costeira do Estado do Rio de Janeiro, Brasil. **Acta Botanica Brasilica 17**(1): 119-135.

Caddah, L.F.G.; Kowsmann, R.O. & Viana, A.R. 1998. Slope sedimentary facies associated with Pleistocene and Holocene sea-level changes, Campos basin, southeast Brazilian Margin. **Sedimentary Geology 115**: 159-174.

Carauta, J.P.P. & Rocha, E.S.F. 1988. Conservação da flora do trecho fluminense da bacia hidrográfica do rio Paraíba do Sul. **Albertoa 11**(1): 86-135.

Carrijo, T.T.; Mendonça, C.B.F.; Esteves, R.L.; Gonçalves-Esteves, V.L. 2005. Palinotaxonomia de espécies de *Stilpnopappus* Mart. Ex DC. e *Strophopappus* DC. (Compositae). **Hoehnea 32**(2): 259-268.

Costa, A.F. & Dias, I.C.A. 2001. **Flora do Parque Nacional da Restinga de Jurubatiba e arredores; Rio de Janeiro, Brasil: listagem, florística e fitogeografia: angiospermas, pteridófitas, algas continentais**. Rio de Janeiro, Museu Nacional - Série Livros.

Freitas, A.G. 2005. **Reconstrução paleoclimática com base na análise de palinomorfos continentais em sedimentos pleistocênicos-holocênicos do talude continental brasileiro de Bacia de Campos, RJ**. M.Sc. Dissertation, Universidade Federal do Rio de Janeiro, Rio de Janiero.

Freitas, A.G.; Carvalho, M.A. & Mendonça Filho, J.G. 2007. **Description of bryophyte and fern spores and fresh-water algae of Pleistocene-Holocene sediments of Albacora Slope, Campos Basin, RJ, Brazil**. Pp. 457-470. In: Carvalho, I.S.; Cassab, R.T.; Schwanke, C.; Carvalho, M.A.; Fernandes, A.C.S.; Rodrigues, M.A.C.; Carvalho, M.S.S.; Arai, M.; Oliveira, M.E.Q. (Eds.) Paleontologia: Cenários de Vida, vol 2. Rio de Janeiro, Interciência.

Garcia, M.J. 1994. **Palinologia de turfeiras quaternárias do médio vale do Rio Paraíba do Sul, Estado de São Paulo**. Tese de doutorado, Programa de Pós-Graduação submetida ao Instituto de Geociências da Universidade de São Paulo. 3 vols.

Gonçalves-Esteves, V.; Junior, E.F.S. & Mendonça, C.B.F. 2007. Palinologia de espécies de Malpighiaceae Juss. ocorrentes nas restingas do Estado do Rio de Janeiro. **Hoehnea 34**(4): 519-529.

Instituto Brasileiro de Geografia e Estatística (IBGE). 1992. **Manual técnico da vegetação brasileira**. Rio de Janeiro: Fundação Instituto Brasileiro de Geografia e Estatística - IBGE.

Kurtz, B.C. & Araujo, D.S.D. 2000. Composição florística e estrutura do componente arbóreo de um trecho de Mata Atlântica na Estação Ecológica Estadual do Paraíso, Cachoeiras de Macacu, Rio de Janeiro, Brasil. **Rodriguésia 51**(78/79): 69-111.

Kurtz, B.C.; Sá, C.F.C. & Silva, D.O. 2009. Fitossociologia do componente arbustivo-arbóreo de florestas semidecíduas costeiras da região de Emerenças, área de proteção ambiental do Pau Brasil, Armação dos Búzios, Rio de Janeiro, Brasil. **Rodriguésia 60**(1): 129-146.

Lorscheitter, M.L. 1989. Palinologia de sedimentos quaternários do testemunho T15, Cone do Rio Grande, Atlântico Sul, Brasil. Descrições taxonômicas - parte II. **Pesquisas 22**: 89-127.

Loueuille, B. Souza-Souza, R.M.B; Abreu, V.H.R.; Mendonça. C.B.F.; Gonçalves-Esteves, V.L. 2012. Pollen morphology of the genus *Eremanthus* Less. (Vernonieae, Asteraceae). **Acta Botanica Brasilica 26**: 46-57.

Luz, C.F.P. & Barth, O.M. 2002. Palinomorfos indicadores de tipos de vegetação em sedimentos holocênicos da Lagoa de Cima, Norte do Estado do Rio de Janeiro, Brasil - Dicotyledoneae. **Leandra 15**: 11-34.

Luz, C.F.P.; Barth, O.M. & Silva, C.G. 2006. Dinâmica temporal na lagoa do Campelo, região norte do Estado do Rio de Janeiro baseada em estudos palinológicos. **Revista Brasileira de Paleontologia 9**: 127-136.

Luz, C.F.P.; Barth, O.M.; Martin, L.; Silva, C.G. & Turcq, J. 2011. Palynological evidence of the replacement of the hygrophilous Forest by Field vegetation during the last 7,000 years B.P. in the northern coast of Rio de Janeiro, Brazil. **Anais da Academia Brasileira de Ciências 83**: 939-951.

Medeanic, S.; Costa César, S.B. & Corrêa, I.C.S. 2006. Os palinomorfos nas reconstruções paleoambientais: *Azolla filiculoides* Lam. Nos sedimentos holocênicos da planície costeira do Rio Grande do Sul. **Gravel 4**: 49-61.

Mendonça, C.B. F.; Gonçalves-Esteves, V.L & Esteves, R.L. 2007a. Palinotaxonomia de espécies de *Lepidaploa* (Cass.) Cass. (Vernoniinae-Compositae) ocorrentes no Sudeste do Brasil. **Revista Brasileira de Botânica 30**: 69-86.

Mendonça, C.B.F.; Gonçalves-Esteves, V.L.; Souza, M.A.; Esteves, R.L. 2007b. Estudio polínico de *Albertinia brasiliensis* Spreng., de espécies de *Cololobus* H. Rob., *Cyrtocymura* H. Rob. y *Dasyanthina serrata* (Less.) H. Rob. (Vernoniinae-Compositae) que ocurren el sureste del Brasil. **Polibotánica 23**: 77-92.

Mendonça, C.B.F.; Gonçalves-Esteves, V.L & Nunes, A. D. 2009. Palynotaxonomy of *Vernonanthura* H. Rob. (Vernonieae-Compositae) species from southeast, Brazil. **Revista Brasileira de Botânica 32**: 625-640.

Mendonça, C.B.F.; Carrijo, T.T. & Gonçalves-Esteves, V.L. 2010. *Lessigianthus* H. Rob. (Vernonieae-Asteraceae): generic and infrageneric relationships based oh pollen morphology. **Nordic Journal of Botany 28**: 1-10.

Mendonça-Filho, J.G.; Carvalho, M.A. & Menezes, T.R. 2002. Palinofacies. Pp. 20-24. In: **Técnicas de procedimentos de trabalho com fósseis e formas modernas comparativas**. São Leopoldo, UNISINOS.

Milward-Azevedo, M.A.; Souza, F.C.; Baumgratz, J.F.A.; Gonçalves-Esteves, V.L. 2010. Palinotaxonomia de *Passiflora* L. subg. *Decaloba* (DC.) Rchb. (Passifloraceae) no Brasil. **Acta Botanica Brasilica 24**: 133-145.

Milward-Azevedo, M.A.; Gonçalves-Esteves, V.L. & Baumgratz, J.F.A. 2012. Taxonomic revision of *Passiflora* L. subgenus *Decaloba* (DC.) Rchb. (Passifloraceae) in Brazil. **Phylotaxa 53**: 1-68.

Ministério do Meio Ambiente (MMA). 2002. **Avaliações e Ações Prioritárias para a Conservação da Biodiversidade das Zonas Costeira e Marinha**. Brasília, Fundação Bio-Rio, SECTAM/PA, IDEMA, SNE, SMA/SP, FEPA H.L.

Montezuma, R.C.M. & Araujo, D.S.D. 2007. Estrutura da vegetação de uma restinga arbustiva inundável no Parque Nacional da Restinga de Jurubatiba, Rio de Janeiro. **Pesquisas, Botânica 58**: 157-176.

Moreira, F.F.; Mendonça, C.B.F.; Pereira, J.F. & Gonçalves-Esteves, V. 2004. Palinotaxonomia de espécies de Apocynaceae ocorrentes na Restinga de Carapebus, Carapebus, RJ. **Acta Botanica Brasilica 18**(4): 711-721.

Moreno, M.R.; Nascimento, MT. & Kurtz, B. 2003. Estrutura e composição florística do estrato arbóreo em duas zonas altitudinais na mata atlântica de encosta da região do Imbé, RJ. **Acta Botanica Brasilica 17**: 371-386.

Nimer, E. 1979. **Climatologia do Brasil**. V. 4. Rio de Janeiro, Secretaria de Planejamento da Presidência da República. IBGE. Série Recursos Naturais e Meio Ambiente.

Peçanha, A.F.; Esteves, R.L. & Gonçalves-Esteves, V.L. 2008. Palinotaxonomia de *Albertinia brasiliensis* Spreng., *Eremanthus bicolor* (DC.) Baker e *Vanillosmopsis erythropappa* (DC.) Sch. Bip. (Compositae-Vernonieae). **Acta Botanica Brasilica 22**: 313-321.

Pereira, O.J. & Araujo, D.S.D. 2000. **Análise florística das restingas dos Estados do Rio de Janeiro e Espírito Santo**. Pp. 25-63. In: Esteves, F.A. & Lacerda, L.D. (Eds.) Ecologia de Restingas e Lagoas Costeiras. Macaé, NUPEM/UFRJ.

Pereira, M.C.A.; Cordeiro, S.Z. & Araujo, D.S.D. 2004. Estrutura do estrato herbáceo na formação aberta de *Clusia* do Parque Nacional da Restinga de Jurubatiba, RJ, Brasil. **Acta Botanica Brasilica 18**(3): 677-687.

Pessoa, S.V.A. & Oliveira, R.R. 2006. Análise estrutural da vegetação arbórea em três fragmentos florestais na reserva biológica de Poço das Antas, Rio de Janeiro, Brasil. **Rodriguésia 57**(3): 391-411.

Pimentel, M.C.P.; Barros, M.J.; Cirne, P.; Mattos, E.A.; Oliveira, R.C.; Pereira, M.C.A.; Scarano, F.R.; Zaluar, H.L.T. & Araujo, D.S.D. 2007. Spatial variation in the structure and floristic composition of "restinga" vegetation in southeastern Brazil.**Revista brasileira de Botânica 30**(3): 543-551.

Punt, W.; Blackmore, S.; Nilsson, S. & Thomas, A. 2007. **Glossary of pollen and spore terminology**. **Review of Palealeobotany and Palynology 143**: 1-81.

RADAMBRASIL. 1983. **Levantamento de Recursos Naturais**. Folhas Rio de Janeiro/Vitória (SF.23 / 24).

Ramsey, C.; Buck C.E.; Burr, G.S.; Edwards, R.L.; Friedrich, M.; Grootes, P.M.; Guilderson, T.P.; Hajdas, I.; Heaton, T.J.; Hogg, A.G.; Hughen, K.A.; Kaiser, K.F.; Kromer, B.; McCormac, F.G.; Manning, S.W.; Reimer, R.W.; Richards, D.A.; Southon, J.R.; Talamo, S.; Turney, C.S.M.; Van Der Plicht, J. & Weyhenmeyer, C.E. 2009. IntCal09 and Marine09 radiocarbon age calibration curves, 0 - 50,000 years cal BP. **Radiocarbon 51**: 1111-1050.

Rizzini, C.T. 1997. **Tratado de Fitogeografia do Brasil: Aspectos sociológicos e florísticos**. 2. ed. Rio de Janeiro, Âmbito Cultural Edições Ltda.

Salgado-Labouriau, M.L. 1973. **Contribuição à Palinologia dos Cerrados**. Rio de Janeiro, Academia Brasileira de Ciências.

Silva, G.C. & Nascimento, M.T. 2001. Fitossociologia de um remanescente de mata sobre tabuleiros no norte do estado do Rio de Janeiro (Mata do Carvão). **Revista Brasileira de Botânica 24**(1): 51-62.

Souza, V.C. & Lorenzi, H. 2008. **Botânica Sistemática: guia ilustrado para identificação das famílias de fanerógamas nativas e exóticas no Brasil, baseado na APG II**. 2.ed. Nova Odessa, Instituto Plantarum.

Souza, F.C.; Souza, M.A.; Mendonça, C.B.F. & Gonçalves-Esteves, V.L. 2004. Estudo polínico de espécies de Aeschynomeneae e Phaseoleae (Papilionoideae-Leguminosae Juss.) ocorrentes nas restingas do Estado do Rio de Janeiro. **Arquivos do Museu Nacional 62**: 357-366.

Stuiver, M. & Reimer, P.J. 1993. Extended ^{14}C data base and revised CALIB 3.0 ^{14}C age calibration program. **Radiocarbon 35**: 215-230.

Toledo, M.B.; Barth, O.M.; Silva, C.G. & Barros, M.A. 2009. Testing multivariate analysis in paleoenvironmental reconstructions using pollen records from lagoa Salgada, NE, Rio de Janeiro State, Brazil. **Anais da Academia Brasileira de Ciências 81**: 757-768.

Tyson, R.V. 1995. **Sedimentary organic matter. Organic fácies and palynofacies**. Londres, Chapman & Hall.

Vicalvi, M.A. 1997. Zoneamento bioestratigráfico e paleoclimático dos sedimentos do Quaternário superior do talude da Bacia de Campos, RJ, Brasil. **Boletim de Geociências da Petrobras 11**: 132-165.

Vicalvi, M.A. 1999. **Zoneamento bioestratigráfico e paleoclimático do Quaternário Superior do Talude da Bacia de Campos e do Platô de São Paulo adjacente, com base em foraminíferos planctônicos**. Tese de Doutorado, Instituto de Geociências, Universidade Federal do Rio de Janeiro, Rio de Janeiro.

Online version: www.scielo.br/abb and http://www.botanica.org.br/acta/ojs