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Palynological analysis of a sediment core obtained in Guanabara Bay, Rio de Janeiro, Brazil

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ABSTRACT

The sediment of a core collected about 2 km north of Paquetá Island, Guanabara Bay, was submitted to pollen analysis, in order to recognize the dynamics of the regional vegetation, and the anthropic influence. Radiocarbon dating of a sample next to the bottom of the core indicates an age of 4.210 ± 40 ^{14}C yrs B.P (calibrated age). It was possible to establish four palynological zones. Starting at the bottom of the core, a decrease in palynomorph concentration, the presence of degraded pollen grains and spores, and the predominance of ombrophilous forest pollen grains were observed in the basal portion of Zone I. These data may indicate the presence of an exuberant Atlantic Forest, dominated by a marine regressive event. The concentration of well-preserved palynomorphs increased in Zone II, with the predominance of the ombrophilous forest vegetation also, and an expressive increase of hygrophytes, indicating more humid environmental conditions. Palynomorph concentration decreased again toward the top of Zone III, and the field vegetation was predominant. In the upper Zone IV occurred a strong decrease in pollen and spore concentration, with predominance of field vegetation also, and the appearance of exotic pollen grains, showing the anthropic influence at this time.

Key words: pollen, Quaternary Palynology, Guanabara Bay, paleoenvironment.

INTRODUCTION

Guanabara Bay is located in the coastal area of the Rio de Janeiro state (Lat. $22°40' - 23°00'$S and Long. $043°00' - 043°20'$W), between the cities of Rio de Janeiro and Niterói (Figure 1). It is inserted in a depressed and prolongated tectonic band of Tertiary age, called the "Baixada Fluminense" or Guanabara Rift, of the half-graben type (Ruellan 1974, Ferrari 1990, Amador 1997). Its origin is related to climatic and sea level changes, that occurred during the Quaternary along the Brazilian coast (Amador and Ponzi 1974, Amador 1992, 1997, Ireland 1987, Martin et al. 1997). Guanabara Bay represents an important ecosystem that has been drastically destroyed, beginning in 1500 AD by human occupation activity.

The prehistoric occupation around Guanabara Bay

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dates from the last 8,000 years, given by archaeological records known as "sambaquis" (Kneip and Pallestrini 1984). Fisher, collector and hunter indian groups started to occupy the complex ecosystem around the bay during the main Holocene transgressive sea event (Kneip et al. 1981).

The region of the basin, at the time the Europeans arrived, was practically all covered with a continuous, exuberant forest, which comprises the Atlantic Forest domain (Kurtz and Araújo 2000). However, currently, the ombrophilous forest remains mainly located on mountain slopes, unsuitable for agricultural activities and forest management (Veloso et al. 1991).

The numerous lagoons and lakes occurring in the coastal areas of the state of Rio de Janeiro lack palynological studies. Data obtained from Quaternary sediments of southeastern Brazil supplied, in the last years, important information about environmental and natural vegetation changes, related to intensive human activities (Amador 1997, Kneip et al. 1981), and also about variations in sea level during the Holocene (Ireland 1987, Suguio et al. 1985). In Northern Rio de Janeiro, Luz et al. (1999) and Barth et al. (2001) demonstrated by means of palynological analyses of two lake cores (Lagoa de Cima and Lagoa do Campelo), that, since circa 7,000 years BP, sea level oscillation influenced significantly the succession of vegetation types. Humid and drought phases occurred during that time, and this was also observed in the Lagoa Salgada by Barth et al. (2001), since about 3,000 years BP The palynological analyses of two cores obtained in the Bay of Sepetiba (Coelho et al. 1999, Santos et al. 2000), dated at 6,300 years B.P., showed several environmental phases also. Barth et al. (2004) dated a sample in Guanabara Bay in about 4,200 years BP, corresponding to an exuberant vegetation of the Atlantic Forest type. Bartholomeu et al. (2001) recognized changes between "restinga" and swampy vegetation in a peat bog sediment that was outcropped in a beach site at the entrance to Guanabara Bay.

In order to supply data for multidisciplinary studies carried out in Guanabara Bay and along the coastal region of Rio de Janeiro state, the present study intends to recognize and to explain the environmental history in this region during the Holocene, as well as to identify the anthropic influence using palynological data.

MATERIALS AND METHODS

The core reached 240 cm in length, and was collected by the method of percussion, using PVC pipes, with the assistance of divers. The coring was carried out in November 2001 in the eastern portion of Guanabara Bay (coordinates: Lat. 22°44, 466' S and Long. 43°06, 757' W), approximately 2 km north of Paquetá Island (Figure 1).

The palynological analysis comprised 14 sediment samples, selected according to the core lithology and stratigraphy. The chemical treatment of the samples followed the standard methodology for Quaternary sediments proposed by Ybert et al. (1992). It includes chemical attacks with 10% HCL for elimination of carbonates, of 40% HF for elimination of silicates, acetolysis and the recovering of palynomorphs using a CL_2 Zn gradient (density = 2). To get the absolute concentration of palynomorphs per volume of sediment, two tablets of *Lycopodium clavatum* were introduced into each sample (Stockmarr 1971). The counting of a minimum of 300 pollen grains was established for each level of sediment. Pollen catalogues (Barth 1962, 1964, 1972, 1976, Barth and Barbosa 1972a, b, 1975a, b, Bove and Barth 1992, Barth and Costa 1993, Barros et al. 1999, Luz and Barth 2000, Hooghiemstra 1984, Roubik and Moreno 1991), and specific papers (Behling 1995, Garcia 1997, 1998, Lorscheitter et al. 1998, 1999), were used for palynomorph identification.

The softwares Tilia, Tilia-graph and Coniss (Grimm 1987) were used for statistical analyses of the palynological data obtained. The identified palynomorphs in the samples were grouped according to the respective types of vegetation, and the classification of vegetation by Veloso et al. (1991).

One sample was selected next to the basis of the core, at 222 cm of depth, for radiocarbon ^{14}C dating in the Beta Analytic Inc., USA.

RESULTS

The lithology of the analyzed core consists of silt, clay and mud sediments (N.R. Silva, unpublished data). The bottom layer is a light-gray mud. Near the base of the core (230–235 cm) occurs a discordance (or an erosive surface), constituted of gray-bluish silt. In the 230–120 cm interval there is a gray-bluish silt also. In the 120–60 cm interval the sediments change to a green-bluish-gray

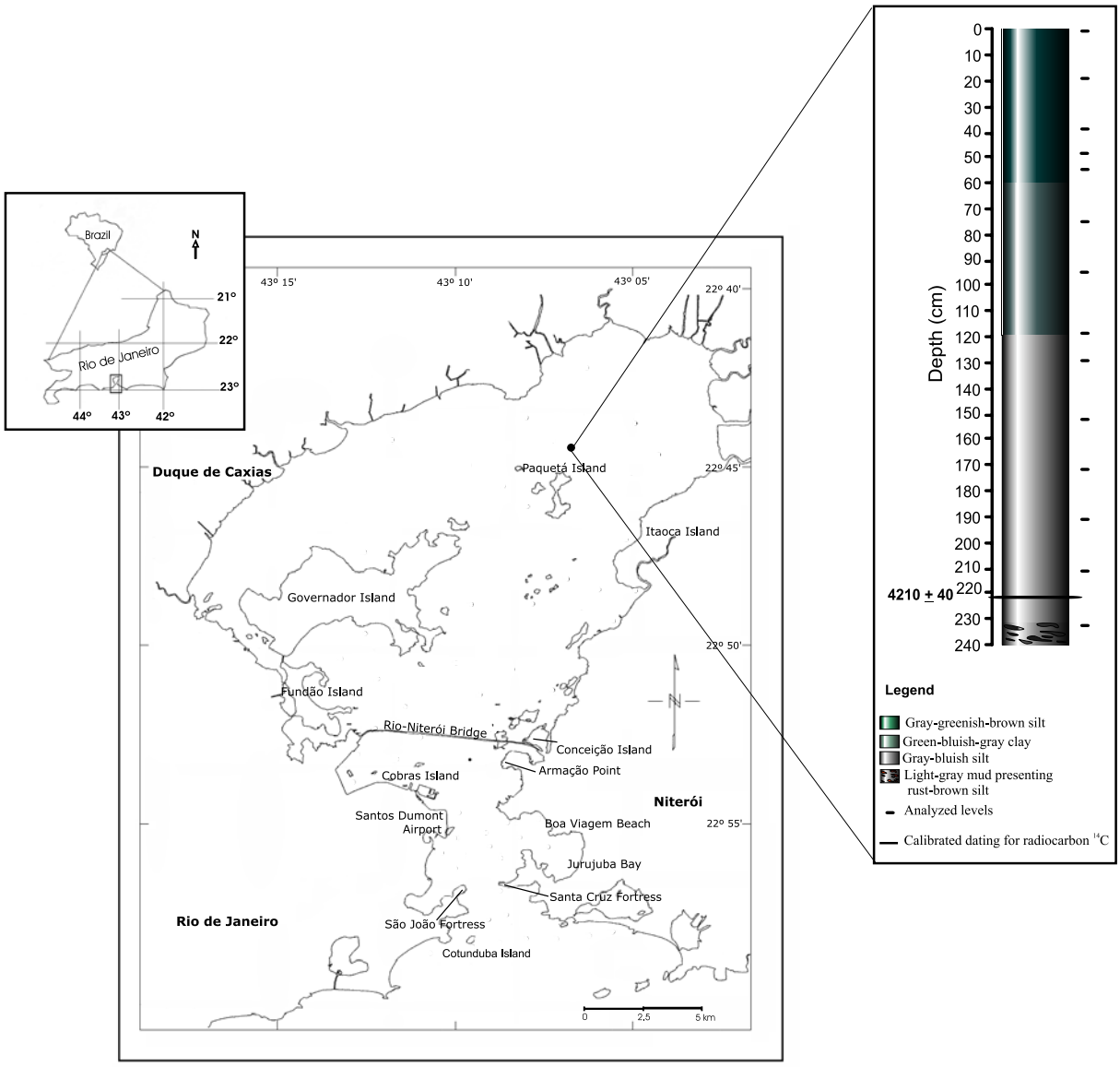

Fig. 1 – Map of the study area, showing the core in detail.

clay. The upper layer (60–0 cm), corresponding to the top of the core, and is composed of a gray-greenish-brown silt (Figure 2).

The ecological grouping of the identified taxa was carried out in accordance with types of vegetation that occur today in the region of Guanabara Bay (Veloso et al. 1991). The list of the identified taxa, as well as the corresponding types of vegetation, is presented in Table I.

It was possible to determine four palynological zones in the studied core, based upon the integrated curves of palynomorph percentage and concentration diagrams, the group analysis of Coniss, and the correlation with the sedimentological data.

Zone I (232–192 cm interval; the level 222 cm was ^{14}C dated in 4.210 ± 40 years B.P. – calibrated age).

This zone includes the erosive surface described above. A decrease of palynomorph concentration was noticed in direction to the top of this zone (Figure 7).

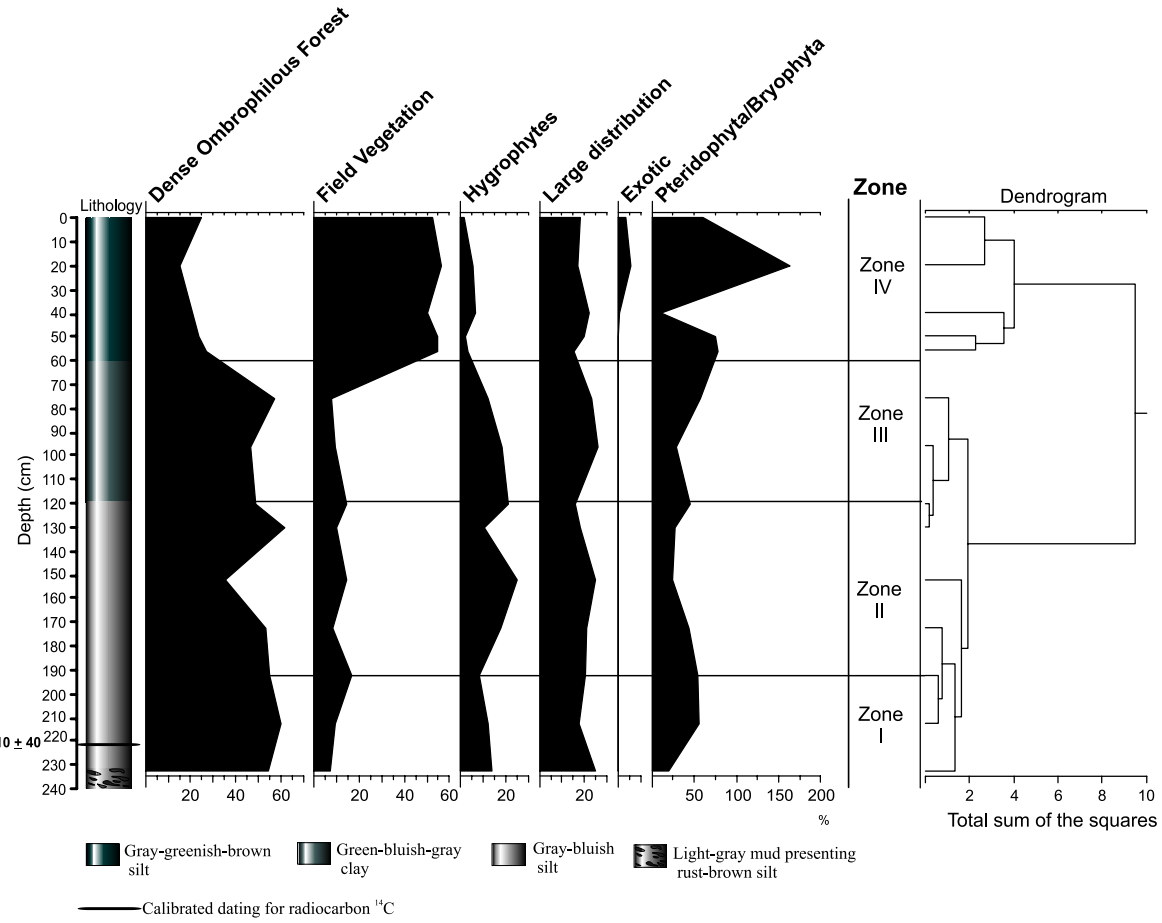

Fig. 2 – Percentage palynodiagram of the ecological groups recognized.

The pollen grains and spores were degraded by exposition to the air or corroded by microorganisms. The taxa of the ombrophilous forest presented its highest percentages and a great richness of pollen types, outstanding *Alchornea*, *Banara*, *Cecropia*, *Celtis*, *Lecythis*, Meliaceae, Piperaceae and *Trichilia* (Figures 3, 4 and 5).

Zone II (192–120 cm interval).

This zone is characterized by a strong increase of the total concentration of palynomorphs, and by the highest richness of taxa identified in the core (Figure 7). The ombrophilous forest predominated (dominant pollen types are *Alchornea*, Arecaceae, *Banara*, *Ilex*, Meliaceae and *Myrcia*). The hygrophytes presented increased percentages of pollen types of Scrophulariaceae, in special of *Bacopa*, *Lindernia* and *Scoparia*. There was a high incidence of spores (Figures 2 to 6). A decrease of pollen grain and spore concentration was observed next to the top of this zone (Figure 7).

Zone III (120–50 cm interval).

This zone is marked by a decrease of the total concentration of palynomorphs toward the top of this zone (Figure 7). The pollen types of the ombrophilous forest experience an expressive reduction, mainly of *Alchornea*, *Banara*, *Cecropia*, Meliaceae and Piperaceae (Figures 3 and 4). Increasing of Amaranthaceae/Chenopodiaceae and *Borreria* pollen percentages at the end of this zone characterizes the open-land vegetation (Figure 5). The taxa of the hygrophytes show a strong reduction of concentration in the top direction also (Figure 7).

Zone IV (60–0 cm interval, top of the core).

The sediment of this zone has a semi-fluid muddy

TABLE I

Botanical taxa identified using pollen morphology and classification according to the vegetal formations occurring in the region of the Guanabara Bay (Veloso et al. 1991, Radambrasil 1983).

Dense Ombrophilous Forest	*Alchornea* (Euphorbiaceae), *Alibertia* (Rubiaceae), Arecaceae, *Astronium* (Anacardiaceae), *Banara* (Flacourtiaceae), *Bauhinia* (Caesalpiniaceae), Bombacaceae, *Bowdichia* (Fabaceae), Bromeliaceae, *Casearia* (Flacourtiaceae), *Cecropia* (Moraceae), *Celtis* (Ulmaceae), *Cestrum* (Solanaceae), *Clusia* (Clusiaceae), *Cordia* (Boraginaceae), *Cupania* (Sapindaceae), *Derris* (Fabaceae), *Didymopanax* (Araliaceae), *Doliocarpus* (Dilleniaceae), *Euplassa* (Proteaceae), *Gaylussacia* (Ericaceae), *Guapira* (Nyctaginaceae), *Hedyosmum* (Chloranthaceae), *Heisteria* (Olacaceae), *Hoffmannia* (Rubiaceae), *Humiria* (Humiriaceae), *Hyeronima* (Euphorbiaceae), *Ilex* (Aquifoliaceae), Lecythidaceae, *Lecythis* (Lecythidaceae), Loranthaceae, *Mabea* (Euphorbiaceae), *Marcgravia* (Marcgraviaceae), *Matayba* (Sapindaceae), Meliaceae, Menispermaceae, *Myrsine* (Myrsinaceae), Ochnaceae, *Paullinia* (Sapindaceae), *Physalis* (Solanaceae), Piperaceae, *Podocarpus* (Podocarpaceae), *Podocarpus lamberti* (Podocarpaceae), *Podocarpus sellowii* (Podocarpaceae), *Pouteria* (Sapotaceae), *Prestonia* (Apocynaceae), *Psychotria* (Rubiaceae), *Rheedia* (Clusiaceae), *Rinorea* (Violaceae), Sapotaceae, *Sebastiana* (Euphorbiaceae), *Symplocos* (Symplocaceae), *Tabebuia* (Bignoniaceae), *Tapirira* (Anacardiaceae), *Tovomita* (Clusiaceae), *Trema* (Ulmaceae), *Trichilia* (Meliaceae), *Weinmannia* (Cunoniaceae)
Open land Vegetation	*Alternanthera* (Amaranthaceae), Amaranthus/Chenopodiaceae, *Borreria* (Rubiaceae), Brassicaceae, *Chamaesyce* (Euphorbiaceae), *Desmodium* (Fabaceae), *Diodia* (Rubiaceae), *Geranium* (Geraniaceae), *Heteropteris* (Malpighiaceae), *Hyptis* (Lamiaceae), *Phyllanthus* (Euphorbiaceae), Poaceae
Hygrophytes	*Bacopa* (Scrophulariaceae), Cyperaceae, *Lindernia* (Scrophulariaceae), *Myriophyllum* (Haloragaceae), *Oxalis* (Oxalidaceae), *Pachira aquatica* (Bombacaceae), *Scoparia* (Scrophulariaceae), Scrophulariaceae, *Typha* (Typhaceae)
Large Distribution	Anacardiaceae, *Anacardium* (Anacardiaceae), Apiaceae/Umbelliferae, Apocynaceae, Asteraceae, Bignoniaceae, *Cassia* (Caesalpiniodeae), Combretaceae/Melastomataceae, Convolvulaceae, Euphorbiaceae, Fabaceae, Flacourtiaceae, Malpighiaceae, Mimosaceae, *Myrcia* (Myrtaceae), *Protium* (Burseraceae), Rubiaceae, Sapindaceae, Solanaceae, *Solanum* (Solanaceae), Tiliaceae, *Triumfetta* (Tiliaceae), Verbenaceae
Exotics	*Casuarina* (Casuarinaceae), *Pinus* (Pinaceae)

texture, and presents a great concentration of organic material (Figure 1). According to Silva (unpublished data), these alterations are related to the industrial phase. A strong decay in the total concentration of the palynomorphs occurred, presenting the lowest values in relation to all the other analyzed zones (Figure 7). An expressive reduction of pollen types of the ombrophilous forest was observed in relation to the previous zones,

associated to an increase of the open-land vegetation taxa, with high values of pollen grains of Poaceae and Amaranthaceae/Chenopodiaceae (Figure 5). The presence of exotic pollen grains, *Casuarina* and *Pinus*, was observed for the first time (Figure 6).

DISCUSSION

Well-preserved pollen grains and spores dominated most of the samples, except in the 232–212 cm interval sediments, next to the base of the core. The pollen grains of *Podocarpus* occurred in low abundance in the record, showing strong exine destruction, suggesting a long distance transport (Campell 1991). In accordance with Veloso et al. (1991) and the Radambrasil Project (1983), the Podocarpaceae colonize preferentially high mountains, being considered indicative of montane vegetation. The best-represented botanical taxa in the palynological record corresponded to the ombrophilous forest vegetation, reflecting the strong influence of regional vegetation.

ZONE I

The strong decrease of palynomorph concentration and the wide-ranging deposition of degraded pollen grains and spores together with the occurrence of an erosive contact layer in this core, reflect the lowering of sea level around 4,000 years BP (Martin et al. 1997, Suguio et al. 1985). At this time, the main deposition of palynomorphs occurred, probably related to sea regression, and indicates also erosion periods at river mouths (Amador 1997) providing the high deposition of degraded palynomorphs. The predominance of the ombrophilous forest, and the richness of pollen types of *Alchornea*, *Banara*, *Cecropia*, *Celtis*, *Lecythis*, Meliaceae, Piperaceae and *Trichilia*, confirms the existence of an exuberant Atlantic Forest in the region at this time (Barth et al. 2004). The high concentration of *Alchornea*, *Celtis* and *Cecropia* pollen grains indicates that probably these plants expanded, and colonized the spaces opened by sea level regression (Barth et al. 2001, Luz et al. 1999).

This regressive event was registered also in "Praia Vermelha" beach, located in the occidental portion of the entrance of Guanabara Bay. Its peat bog basal sediments were about 4,520 ^{14}C yrs BP years old, showing a predominance of Atlantic Forest plant species, that gradually changed from a "restinga" to a savanna type of vegetation (Bartholomeu et al. 2001).

In relation to two cores obtained in Sepetiba Bay, a region located next to Guanabara Bay, and studied by Coelho et al. (2002) and Santos et al. (2000), the pollen and vegetation types recognized indicated a regressive sea event also. A reduction of forest elements occurred at this time, and an increase of pollen types of the field vegetation ("campos") that had expanded by colonizing the areas opened during the sea level regression.

ZONE II

The general trend of palynomorph increase until the middle of this Zone indicates that the environmental conditions became more humid, mainly by the presence of higher percentages of pollen grains of the ombrophilous forest vegetation. The hygrophytes vegetation increased also, mainly the Scrophulariaceae. The highest concentration of spores of Pteridophyta and Bryophyta was detected in this stratigraphic level.

This zone may be correlated with the conditions of a more humid tropical climate recognized by Santos et al. (2000) in a core obtained in the Sepetiba Bay, during the period from about 3,800 to 1,600 ^{14}C yrs BP, when a high incidence of "restinga" and dense ombrophilous forest vegetation palynomorphs was detected, and a mild decline of mangrove and savana ones.

ZONE III

The reduction of palynomorph concentration of forest and humid environment pollen types in direction to the top of this zone, together with high percentages of field taxa, may be associated with more drought environmental conditions, the field expansion, and the retraction of the forest. This was recognized by Coelho et al. (1999) and Santos et al. (2000) also, in the two cores collected in Sepetiba Bay, from about 775 to 213 years BP and 700 to 115 years B.P. (extrapolated data), respectively.

On the other hand, the reduction of the total concentration of palynomorphs may be related to the beginning of the European colonizer settling in the region and starting of agricultural cycles around Guanabara Bay, advancing toward mountain slopes, resulting in large deforested areas.

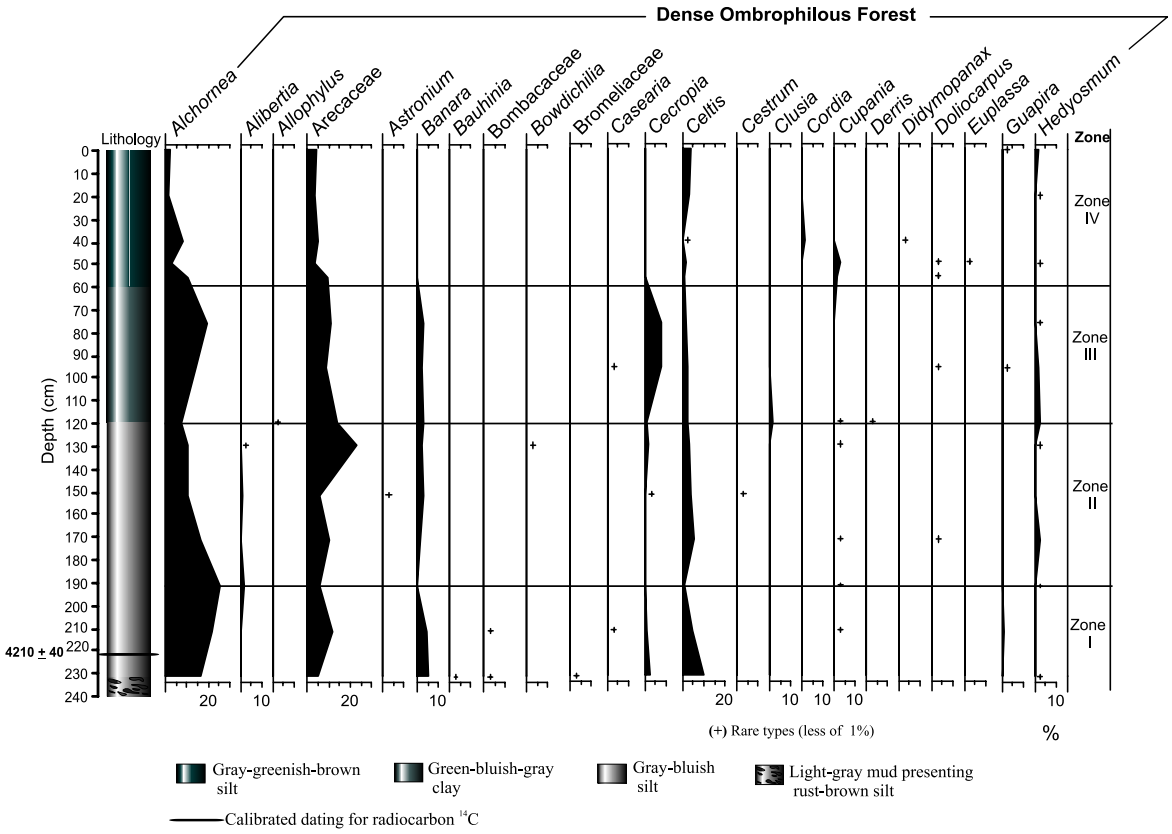

Fig. 3 – Percentage palynodiagram of the pollen types grouped into the Dense Ombrophilous Forest vegetation.

ZONE IV

The significant reduction of the ombrophilous forest pollen grains, and the occurrence of *Casuarina* and *Pinus* pollen grains next to the base of this zone, may be attributed to the environmental impact due to human activities, and a disordered urban and industry growing, resulting in strong deforestation and reduction of water supply. According to Amador (1997), 74% of the Guanabara region was covered formerly by an exuberant continuous Atlantic forest in 1,500 AD. Currently, only 16% of the original forest persists. These areas are located mainly in rough topographic mountain slopes and in the units of environment conservation (Kurtz and Araújo 2000). The pollen spectrum in this zone gave these circumstances back toward the top of this zone, by means of the reduction of pollen grain concentration and the bad preservation of palynomorph exines, as well as by the appearance of exotic taxa introduced by the Europeans.

Summarizing, the palynological analysis of a core obtained in Guanabara Bay allowed characterizing the environment history since about 4,210 ^{14}C yrs B.P. In the beginning of this period (Zone I) the water level in the bay was lower than the current and the region was under the domain of a regressive sea event, with the predominance of the Atlantic forest. The strong increase of palynomorphs indicative of a wet environment (Zone II) revealed that the climatic conditions went being more humid, resulting in a general expansion of the vegetation in this region. The gradual reduction of the Atlantic forest elements (Zone III), associated with a field vegetation increase (Zone IV), corroborates the hypothesis of more dry climatic conditions. Finally, the decrease of forest pollen concentration and the predominance of field vegetation, and the appearance of exotic pollen grains in the last decimeters of the core, occurred as a consequence of the strong influence of human activities around the Guanabara Bay.

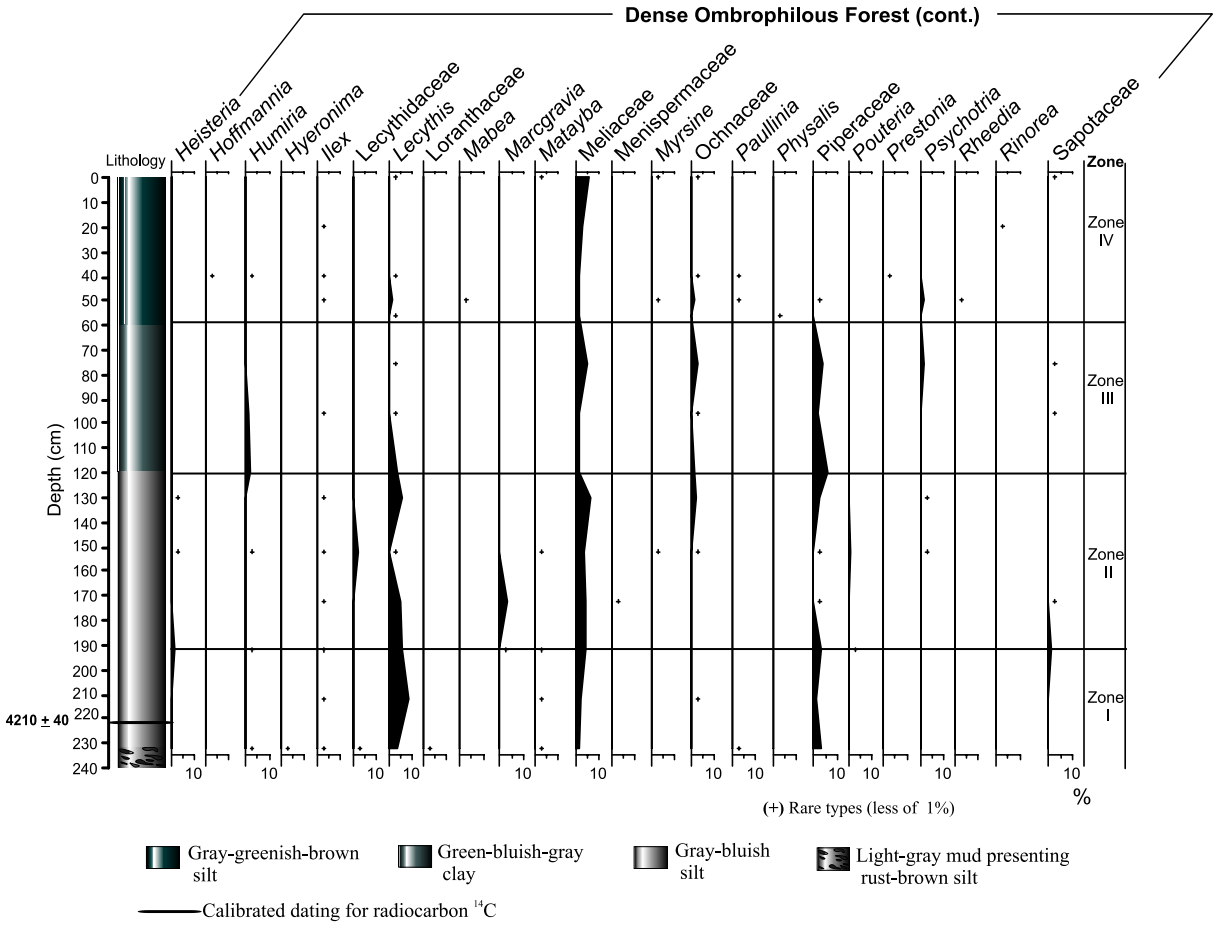

Fig. 4 – Percentage palynodiagram of the pollen types grouped into the Dense Ombrophilous Forest (cont.) recognized in the core of Guanabara Bay.

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RESUMO

Sedimentos de um testemunho de sondagem coletado a 2 km ao norte da Ilha de Paquetá, Baía de Guanabara foram submetidos à análise palinológica, com o objetivo de reconhecer e interpretar a dinâmica temporal da vegetação na região e a influência antrópica. A datação radiocarbônica realizada próxima à base do testemunho indicou uma idade de 4.210 ± 40 anos AP (idade calibrada). Os resultados possibilitaram determinar quatro zonas palinológicas. Na Zona I, a mais basal, observou-se o decréscimo da concentração total de palinomorfos em direção ao topo e elevada deposição de grãos de pólen e esporos degradados, com o predomínio de grãos de pólen concernentes à floresta ombrófila. Esse resultado pode indicar que nesta zona existia a Mata Atlântica exuberante, sob o domínio de um evento marinho regressivo. Na Zona II, ocorreu um aumento na concentração total de palinomorfos bem preservados, com o predomínio também da vegetação de floresta ombrófila e um aumento expressivo de higrófitas, indicando condições ambientais mais úmidas. Na Zona III, ocorreu uma diminuição nas concentrações dos palinomorfos em direção ao

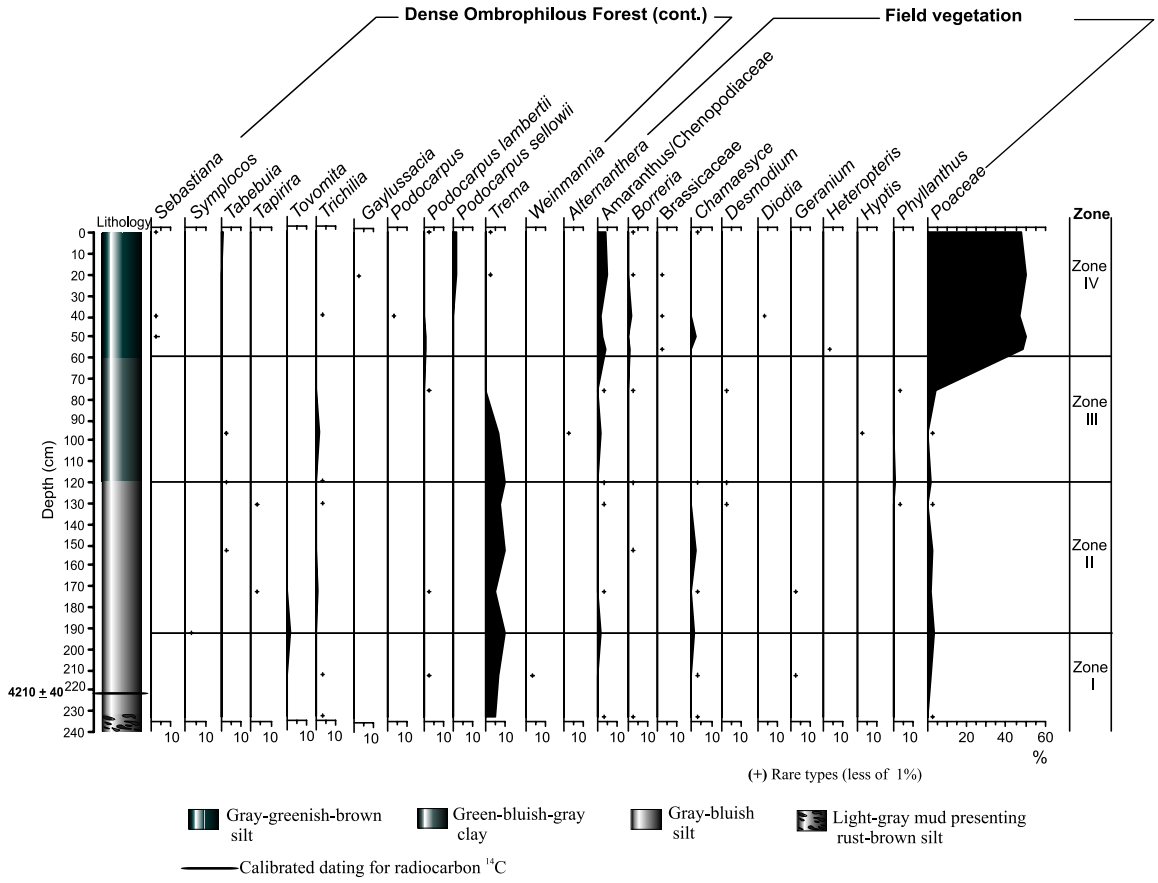

Fig. 5 – Percentage palynodiagram of pollen types grouped into Dense Ombrophilous Forest vegetation (cont.) and Field Vegetation.

topo, com o predomínio da vegetação campestre. Na Zona IV, localizada próximo ao topo do testemunho, ocorreu uma queda acentuada nas concentrações de pólen e esporos com o predomínio da vegetação campestre e o aparecimento de pólen exótico, evidenciando a influência antrópica no entorno da Baía de Guanabara.

Palavras-chave: pólen, Palinologia do Quaternário, Baía de Guanabara, paleo-ambiente.

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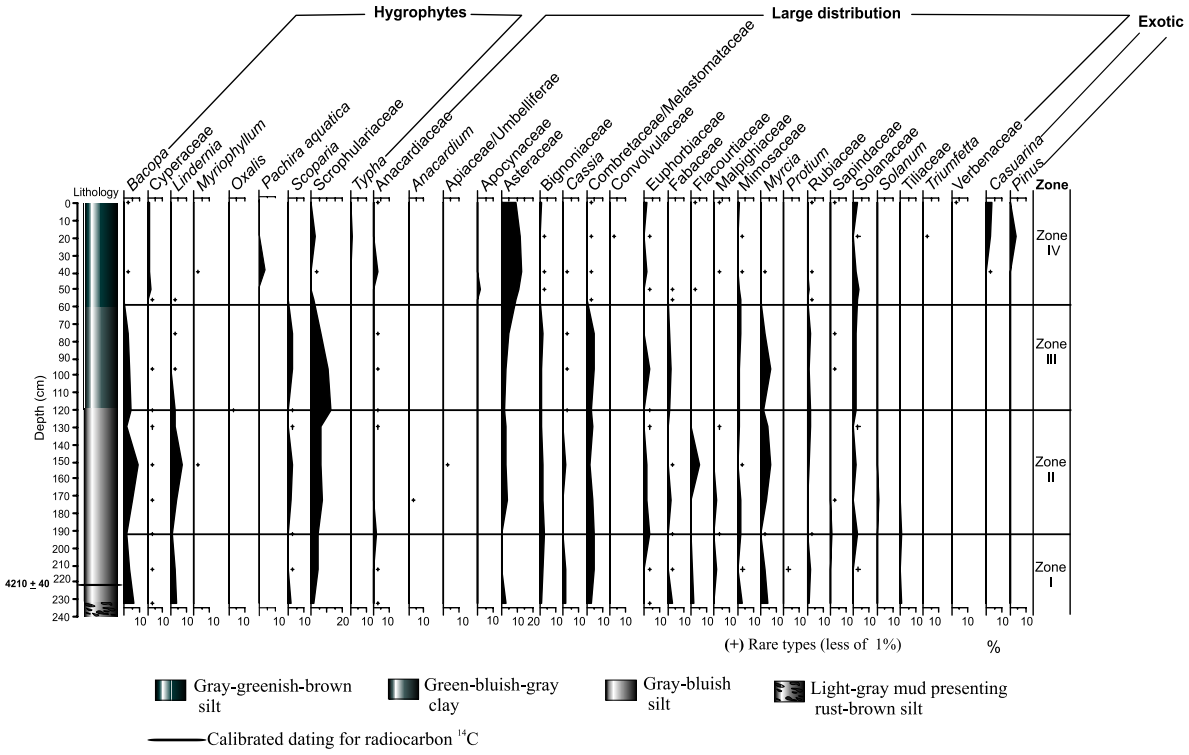

Fig. 6 – Percentage palynodiagram of the pollen types grouped into Hygrophytes, Wide Distribution and Exotic Genera.

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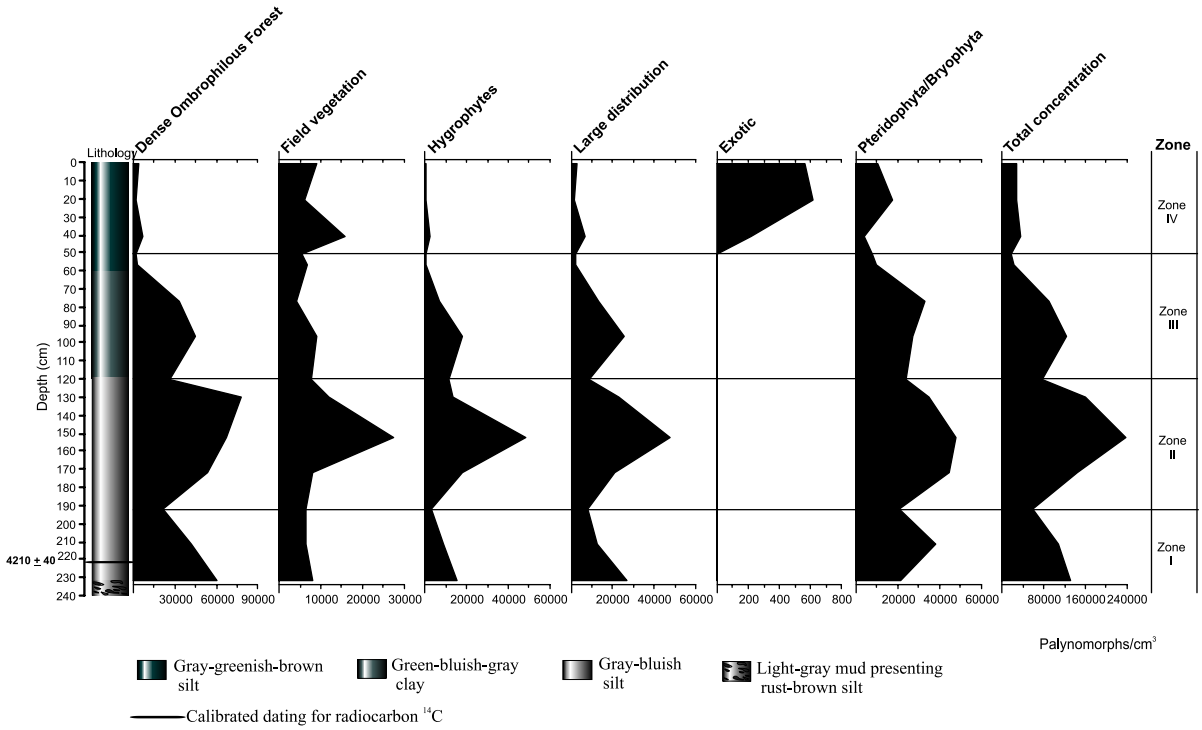

Fig. 7 – Concentration palynodiagram (variable values of scales) of the ecological groups recognized in the analysis of the core from Guanabara Bay.

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