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Palynological analysis of a late Holocene core from Santo Antônio da Patrulha, Rio Grande do Sul, Southern Brazil

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ABSTRACT

A sedimentary core collected at Santo Antônio da Patrulha, Rio Grande do Sul State, southwest Brazil, was submitted to pollen analysis to provide the vegetational history of this region, and the paleoecological and paleoclimatic changes. A total of 98 taxa of palynomorphs was identified from 35 subsamples. Three radiocarbon datings were obtained along a section of 115 cm depth, including the basal age of 4730 ± 50 yr BP. Pollen diagrams and cluster analysis were performed based on palynomorphs frequencies, demonstrating five distinct phases (SAP-I to SAP-V), which reflect different paleoecological conditions. The predominance of plants associated with grasslands in the phase SAP-I suggests warm and dry climate conditions. A gradual increasing of humidity conditions was observed mainly from the beginning of the phase SAP-III, when the vegetation set a mosaic of grasslands and Atlantic rainforest. Furthermore, the presence of some forest taxa (Acacia-type, Daphnopsis racemosa, Erythrina-type and Parapiptadenia rigida-type) from the phase SAP-IV, is interpreted as an influence of the seasonal semideciduous forest in the study region. From the phase SAP-V (ca. 4000 yrs BP), the vegetation became similar to the modern one (extant Atlantic rainforest Biome), especially after 2000 yrs BP (calibrated age).

Key words: Palynology, Paleoecology, Paleoclimatology, Atlantic rainforest, late Holocene, Rio Grande do Sul State.

INTRODUCTION

The vegetation of Rio Grande do Sul State (RS), Southern Brazil, is composed by grassland-forest mosaic as a result of paleoenvironmental changes, mainly characterized by climate variations during the Quaternary (Marchiori 2004). These grassland-forest mosaics were previously studied by pioneer naturalists at the end of the XIX century. Lindman (1906) observed that forests could expand over the grassland vegetation under dry paleoclimate conditions. Based on phytogeographic evidence, Rambo (1956, 1961) and Klein (1975) interpreted that the grasslands were the first plants constituents of the RS; therefore, advances of the forests is a
areas showed that forests had expanded from 3500 yrs BP, especially after 2000 yrs BP, due to higher humidity.

This paper presents interpretations about the vegetational succession of the Atlantic rainforest and seasonal semideciduous forest, as well as paleoclimates related to them, based on palynological data obtained from a core in Santo Antônio da Patrulha, RS, southmost Brazil. The results were compared with other palynological studies previously conducted in South Brazil.

STUDY AREA

The present study was made from a peat bog located in Santo Antônio da Patrulha municipality (coordinates 29°44'45" S, 50°32'56" W, high 37 m), far about 76 km from Porto Alegre and ca. 48 km from the Atlantic Ocean. The access to this site from Porto Alegre is through the highway RS-474, followed by a secondary road (Figs. 1a-b). According to Fortes (1959), this area is part of the physiographic region of the Lower Northeast Slopes of Serra Geral, RS.

The peat bog sediments from Santo Antônio da Patrulha were deposited on sandstones of the Botucatu Formation, Jurassic/Cretaceous of Paraná Basin, which constitutes the basement of the analyzed core.

The presence of a grassland-forest mosaic characterizes the phytophisiognomy of the landscape. The forest comprises a mixture of floristic elements of Atlantic rainforest and seasonal semideciduous forest (Rambo 1956, Teixeira et al. 1986, Reitz et al. 1988, Leite and Klein 1990).

The climate of Southern Brazil is influenced by the South Atlantic Anticyclone, a semi-permanent high pressure system that transports moist tropical air masses over the continent from easterly and north-easterly directions during the whole year. Disturbances are related to polar cold fronts, when it meets the tropical air masses and produces strong rainfall in Southern Brazil (Nimer 1989). This region is characterized by subtropical humid (Cfa) in the Koppen classification (Moreno, 1961), with regularly distributed rainfalls during the year and hot summers. The mean precipitation is around 1676.5 mm.a⁻¹, and the average annual temperature is 19.8°C; the average temperature of the hottest month is 24.4°C, while the coolest months are 15.4°C; the average temperature of the hottest month is 32°C, while the coolest months are 19.8°C; the average temperature of the hottest month is 32°C, while the coolest months are 19.8°C; and the average annual temperature is 29°C (data from Osório and Tramandaí meteorological station, IPAGRO 1979).

CONCLUSION

The core was taken from the deepest portion near the center of the peat bog using a Russian corer sampler, whose maximum depth reached 115 cm. Sections of 50 cm length were extruded in situ, wrapped in plastic film and aluminum foils. The section was transported to the Laboratory and stored in special conditions (ca. +4°C) before sampling. Three sediment subsamples of 3 cm thickness were taken from the core and dated by the Accelerator Mass Spectrometry (AMS) in the CAI Laboratory of the University of Georgia (USA). The calibration of radiocarbon datings was carried out after CALPAL (Weninger et al. 2004). Ages were also calculated for each interpolated pollen subsample and pollen phase.

For pollen and charcoal analysis, 35 subsamples (1 cm³ volume) were taken at 3 cm intervals along the 115 cm cored. All subsamples were processed by standard pollen analytical methods (Faegri and Iversen 1989), using HF, HCl, KOH, acetolysis, followed by filtering through a 250 μm net. The slides were prepared in glycerol-jelly. Pollen preparation included the addition of exotic Lycopodium clavatum L. spores to determine pollen concentration (grains/cm³) and accumulation rates (grains/cm²/year), in agreement with Stockmarr (1971).

A minimum of 300 pollen grains were counted for each subsample. This pollen sum includes trees, shrubs and herbs. Aquatic, ferns and mosses spores, algae taxa, fungal spores and animal remains, as well as carbonized particles (5-150 μm), were also counted, constituting a separated list expressed as the percentage of the total pollen sum. Calculations of concentration were also made for the carbonized particles (particles/cm³), as well as for accumulation rates (particles/cm²/year). Pollen identification was based on catalogues of published palynomorphs, as well as on pollen reference collections of Brazil Lutheran University (ULBRA). The word "type" was used when an accurate identification was impossible. Taxonomic descriptions and illustrations of the identified palynomorphs was an additional contribution (Macedo et al. 2009) and constitute the basis for the pa-
Fig. 1 – Location map showing the general situation (a) and position of the Santo Antônio da Patrulha core (b).
The pollen diagrams include individual records of the taxa and records of the groups: grasslands, forest, indeterminate, aquatics, ferns, mosses, algae, fungi and concentration and influx of the pollen and charcoal particles, and a cluster analysis. The phases of the pollen record (sensu Salgado-Labouriau 2007 p. 335-336) were established from changes in the pollen assemblages and from cluster analysis.

Ordination by Principal Coordinates Analysis (PCoA) was used for a synthetic view of community compositional changes (Orlóci et al. 2002). PCoA was based on pairwise Euclidean distances among subsamples (Legendre and Legendre 1998, Podani 2000). Distances were computed from squares root transforming pollen percentages in order to reduce the excessive weight of dominant pollen taxa. Algae, spores, indeterminate palynomorphs and Cyperaceae taxa were not included on multivariate analysis, as well as subsamples that did not present pollen grains (phase SAP-II).

The significance of ordination axes was evaluated by bootstrap according to Pillar (1999). The multivariate analysis PCoA was calculated using software MULTIV (Pillar 2008).

In order to assist the interpretation regarding the vegetation succession, a rapid survey of the flora was made near the point of collection of the core.

RESULTS

LITHOLOGY

The core retrieves a section of 115 cm of unconsolited sediments. Between 115 to 90 cm depth, sediments are mainly characterized by brown sandstones with decomposed organic matter. From 90 to 50 cm depth, sediments comprise dark mudstones/siltstones with organic material completely decomposed, including few root remains. Between 50 to 13 cm, sediments are constituted by brown-dark sandstones and a mixture of decomposed organic matter with abundant roots and plant remains. From 13 cm depth to the top of the core, the sediments are highly weathered, constituting the regolith, which was not palynologically analyzed.

the deposition of the studied core entirely positioned along the late Holocene. However, sedimentation was not continuous. Three datings were obtained. The basal dating corresponds to 4730 ± 50 ¹⁴C yr BP (calibrated age 5461 yr BP), while the sample at 55 cm depth was dated as 4225 ± 25 ¹⁴C yr BP. It suggests a rapid rate of sedimentation between this interval (115 to 55 cm depth). The sample at 13 cm core depth indicates modern age (Anno Domini 1850). The results between 55 and 13 cm core depth suggest a slow sedimentation, involving the vegetation history of the last 4200 yrs BP.

DESCRIPTION OF POLLEN RECORD

A total of 98 taxa of palynomorphs were retrieved and identified along the Santo Antônio da Patrulha core, including taxa of algae, Briophyte, Pteridophytes, Gymnosperms, Angiosperms, as well as fungi and animal remains. The pollen diagram (Figs. 2a-b-c) shows the distribution of the palynomorphs, which were grouped according to their ecological affinities (habit and/or habitat), beyond pollen sum of different botanical groups (Fig. 3). Marked changes in the pollen assemblages, indicated by cluster analysis (CONISS), allow the establishment of five pollen phases: SAP-I, SAP-II, SAP-III, SAP-IV and SAP-V, which are described below (SAP is the abbreviation for Santo Antônio da Patrulha area) in an ascending stratigraphic order.

Phase SAP-I (5461-5443 cal yr BP)

This phase was characterized from the two basal subsamples (115-110 cm of depth), which are dominated by Cyperaceae (40-55%), Poaceae (46-28%), Baccharis-type (6-9%), Eryngium L., Spermacoce L. and other minor herbaceous components (Fig. 2b-3). The group of trees and shrubs presents lower percentages (1-4%), comprising mainly Ilex L. and Arecaceae. Other taxa are less than 1% (with Melastomataceae, Myrtaceae and Mimosa serie Lepidotae Benth., Fig. 2a). Percentages of pollen from aquatic plants (Ludwigia L. and Utricularia L.) are also less than 1%. Ferns spores are scarce. Mosses spores are abundant in higher samples (27%), which are mainly represented by Phaeoceros laevis (L.)
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Fig. 2 – Pollen diagram percentages of Trees and Shrubs (a), Herbs (b).

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Fig. 2 – (c) Pollen diagram percentages of Aquatics, Ferns, Mosses, Algae, Fungi and Animal remains.
Fig. 3 – Pollen diagram summary showing the AMS radiocarbon dates, calibrated ages, interpolated ages, lithology, ecological groups, sum of pollen, pollen and charcoal concentration and accumulation records, pollen phases and the cluster analysis (CONISS).
Phase SAP-II (5443-5402 cal yr BP)

The interval at 110-105 cm depth (two subsamples) is characterized by the non-preservation of pollen grains. Few ferns and mosses spores, as well as algae taxa, were poorly preserved.

Phase SAP-III (5402-4955 cal yr BP)

This phase comprises 12 subsamples within the interval between 105-69 cm core depth. It is marked by the abundance of herb pollens (52-95%), which are represented by Poaceae (31-53%), Cyperaceae (5-40%) and Baccharis-type (5-35%), as well as other less frequent taxa, like Eryngium, Cuphea carunculata Koehne, Cuphea Koehne, Vernonia-type, Spermacoce, Gnaphaliunum-type, Polygala L., Senecio-type, Holochelilus-type, Amananthus/Chenopodiaceae-type and Elephantopus-type. Sums of forest taxa are better represented (between 4-48%) due to the increasing of Ilex, which reaches up to 28%. Other forest taxa, such as Arecaceae, Myrtaceae, Melastomataceae, Alchornea Sw., Celtis L., Trema micrantha (L.) Blume., Anacardiaceae and Podocarpus L’ Hér. ex Pers., also increased their proportions during this phase. Pollen grains from Araucaria angustifolia (Bertol.) Kuntze and Drymis brasiensis Miers. occur respectively at 79-76 cm depth (Fig. 2a). Fern spores also increase in this phase, mainly Blechnum-type, Microgramma vacciniifolia-type and Polypodium L. Spores from Dicksonia sellowiana Hook were found at 97 cm depth (Fig. 2c). Moss spores from Phaeoceros laevis decrease during this phase. The concentration and accumulation rates of the charcoal particles and pollen grains were the highest ones in the core.

Phase SAP-IV (4955-4402 cal yr BP)

The highest stratigraphic phase comprises 13 subsamples within the interval between 51-13 cm depth. This phase is characterized by a significant increasing of pollen sum of forest taxa (21-37%) and by the decreasing of herb pollens (62-78%). In general, all taxa related to forest were better represented in this phase than in the previous one. On the other hand, Podocarpus decreases in frequency. In the transition between phases SAP-IV and SAP-V, there is the first record of Zea mays L. and Pinus L., which were found in mostly subsamples of this last phase. Aquatic taxa were also better represented in this phase, mainly by Ludwigia, which reached up to 12%. Spores of ferns increased their percentages (6-31%), while spores of mosses and algae taxa decreased them. Spores of fungi also increased (Glomus Tus. & C. Tus., Gelasinospora calospora (Mouton) C. Moreau & M. Moreau and Gelasinospora reticulispora (Greis & Greis-Dengler) C. Moreau & M. Moreau, Gaecumanno-
previous phase, while accumulation rates of the charcoal particles and pollen grains were lower.

**Multivariate Analysis**

The multivariate analysis (PCoA) shows a synthesis of the changes in the pollen composition since 5461 cal yr BP until present 137 cal yr BP (Anno Domini 1850). The two dimensional ordination diagram accounts for 61% of the total variation in the data set, with 53 taxa in 33 subsamples (Figs. 4a-b). Pollen composition dynamics depicted by the ordination analysis shows phases of random, non-directional changes and periods in which the changes were directional toward more abundant forest taxa. Directional jumps, characterizing transitions of phases, were most evident from 5386 to 5314 cal yr BP, 5206 to 5189 cal yr BP, and 4402 to 3991 cal yr BP. Multivariate analysis of phase SAP-I shows the dominance of grasslands up to 5386 cal yr BP, which are represented by Poaceae and Baccharis-type. At ca. 5314 cal yr BP (phase SAP-III), ordination diagrams suggest important vegetational changes by the appearance of forest taxa, such as Myrtaceae, Ilex, Arecaceae and Podocarpus. After 5058 cal yr BP, within the SAP-III/IV transition, grassland taxa diversified, including Holochelius-type, Trixis-type, Spermacoce, Senecio-type, Vernonio-type, Lamiaceae, Gomphrena L., Eryngium, Melastomataceae and Cuphea. The phase SAP-V is evidenced in the PCoA diagrams by the increasing and diversity of trees and shrubs components, such as Anacardiaceae, Sebastiana, Chrysophyllum, Alchornea, Trema micrantha, Myrsine L., Daphnopsis racemosa, Mimosa L., Celtis and Erythrina-type.

**Botanical Data**

The main components of the modern flora around the peat bog are listed in the Figure 5, according to their type, physiognomy, habit and habitat, and including the taxonomic basis for genera and species.

**Discussion**

The results obtained from the pollen analysis of Santo Antônio da Patrulha core revealed changes in the vegetational composition during the last millennia on the lower slopes of Serra Geral, RS. These vegetational successional composition during the last millennia on the Lower Antônio da Patrulha core revealed changes in the vegetational and paleoclimatic interpretations to this interval. These results can be related to taphonomic limitations, though no sedimentological and lithological different evidences are observed. This limitation was recorded by Bauermann (2003) from the interval ca. 6000 cal yr BP to 3163 ± 29 14C yr BP in a core recovered from Barrocadas, RSCP.

The Phase SAP-I (5461-5443 cal yr BP) shows the predominance of plants associated with grasslands, mainly represented by Poaceae and Baccharis-type (Figs. 2b-3). Furthermore, few records of tree shrubs, fern spores and algae taxa, as well as high frequency of mosses spores (Phaeoceros laevis), suggest warm and dry climate conditions, in agreement with interpretations of Behling (2002) to South and southeast regions of Brazil. According to this author, precipitations and a long annual dry season, probably of three months, should have limited the expansion of trees taxa during the middle Holocene in Southern Brazil. Perhaps these paleoclimates conditions should be related to changes in the trajectory of Polar cold fronts from the Atlantic Ocean, similar to modern events of La Niña, which causes drought in Southern Brazil. Other palynological studies performed in RSCP and adjacent area also showed similar results (Bauermann 2003, Macedo et al. 2007, Leal and Lorscheitter 2007).

Poor preserved palynomorphs occur in Phase SAP-II (5443-5402 cal yr BP), in low frequency, preventing vegetational and paleoclimatic interpretations to this interval. These results can be related to taphonomic limitations, though no sedimentological and lithological different evidences are observed. This limitation was recorded by Bauermann (2003) from the interval between ca. 6000 cal yr BP to 3163 ± 29 14C yr BP in a core recovered from Barrocadas, RSCP.

The Phase SAP-III (5402-4955 cal yr BP) reveals pollen changes in the grasslands vegetation clearly lighted by the multivariate analysis of PCoA, taking into account the gradual increasing of Baccharis-type, Poaceae and other herbaceous components, such as Celtis, Eryngium, Gomphrena, Holochelius-type, Lamiales, Melastomataceae, Polygala, Senecio-type, Spermacoce, Trixis-type and Vernonio-type (Figs. 4a-b). This trend is also marked by the increase of pionners taxa of Atlantic rainforest, such as Alchornea, Anacardiaceae, Areceae, Cecropia L., Celtis, Chrysophyllum, Melastomataceae, Myrtaceae, Myrsine, Podocarpus, Sebastiania and Trema micrantha (Figs. 2a-3). These pollen records suggest the beginning of the grassland mosaics. These Atlantic rainforest components,
Fig. 4 – The diagram map of the vegetation trajectory for the last 5461 cal yr BP in (a) and (b). Calibrated years BP (i.e. before AD 1950) are indicated for some points. Arboreal (in bold) and herb taxa are shown in positions that are proportional to their correlation level with the ordination axis (only taxa with the highest correlations are indicated); the corresponding overlapped diagrams would form biplots. The tick marks on the axes indicate the origin coordinates. Taxa abbreviations: Alch = Alchornea, Anac = Anacardiaceae, Arec = Arecaceae, Bacc = Baccharis-type, Celt = Celtis, Chry = Chrysophyllum, Cuph = Cuphea, Darh = Darmaninis racemosa, Eryn = Eryngium, Eryt = Erythrina-type, Fab = Fabaceae, Gomp = Gomphrena, Holo = Holocheilus-type, Ilex = Ilex, Lami = Lamiaceae, Mela = Melastomataceae, Meli = Meliaceae, Mimo = Mimosa, Lepidotae = Lepidotae, Myrs = Myrsine, Myrt = Myrtaceae, Poac = Poaceae, Podo = Podocarpus, Poly = Polygala, Seba = Sebastiania, Sene = Senecio-type, Sper = Spermacoce, Trem = Trema micrantha, Trix = Trixis-type, Vern = Vernonia-type.
Fig. 5 – Extant species of the forest and grasslands in Santo Antônio da Patrulha, RS, Brazil.

<table>
<thead>
<tr>
<th>Vegetation type/physiognomy</th>
<th>Important species</th>
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<tbody>
<tr>
<td><strong>Forest</strong></td>
<td></td>
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<tr>
<td>Trees:</td>
<td></td>
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<tr>
<td>Alchornea triplinervia (Spreng.) Müll. Arg. (Euphorbiaceae), Allophyles edulis Radix ex Warm. (Sapindaceae), Campomanesia xanthocarpa O Berg. (Myrtaceae), Casearia sylvestris Sw. (Flacourtiaceae), Ceiba L. (Ulmaceae), Copaifera verna L. (Euphorbiaceae), Daphnopsis racemosa Griseb. (Thymelaeaceae), Dodonaea viscosa Jacq. (Sapindaceae), Erythrina cristagalli L. (Fabaceae), Erythroxylum argentinum O E. Schultz (Erythroxylaceae), Eugenia uniflora L. (Myrtaceae), Ixora dumi Reiss., I. pseudobuxus Reiss. (Aubletaceae), Lithrea brasiliensis March. (Anacardiaceae), Myrsine lorentziana (Mez) Arechav., M. ferruginea (R. &amp; P.) Mez (Myrsinaceae), Parapiptadenia rigida (Benth.) Brenan. (Mimosaceae), Sebastiana commersoniana (Baill.) L. B. Smith &amp; R. J. Downs., S. serrata (Mull. Arg.), S. basilissias (Spreng. (Euphorbiaceae), Syagrus romanzoffiana Cham. (Arecaceae), Syplocos Jacq. (Syplocaceae), Tabebuia Gomes ex DC. (Bignoniaceae), Trema micrantha (L.) Blume (Ulmaceae), Verbenoxylum retizii (Mold.) Tronc. (Verbenaceae).</td>
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<tr>
<td><strong>Epiphytes</strong></td>
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<td><strong>Herbs and Shrubs</strong></td>
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<tr>
<td>Chiococca alba Hitchc.(Rubieaceae), Peperomia Ruiz &amp; Pav. (Piperaceae), Psychotria cartagensis Jacq. (Rubieaceae).</td>
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<tr>
<td><strong>Ferns</strong></td>
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<tr>
<td>Anemia phylitis (L.) Sw (Schizaeaceae), Microgramma C. Presl (Polypodiaceae), Selaginella P. Beau (Selaginellaceae).</td>
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</tr>
<tr>
<td><strong>Border forest</strong></td>
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<tr>
<td>Herbs and Shrubs:</td>
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<tr>
<td><strong>Ferns</strong></td>
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<tr>
<td>Blechnum L. (Blechnaceae), Doryopteris J. Sm. (Adiantaceae).</td>
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<tr>
<td><strong>Grasslands</strong></td>
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<tr>
<td>Herbs:</td>
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| **Microgramma vaccinifolia-type** and **Polypodium gae (Zygmena C.A. Agardh)** and fungi spores corroborate this humidity conditions (Figs. 2c-3). According to Martin et al. (1993), the constant rainfalls during the last 5000 yrs BP is probably due to El Niño which caused strong storms in South Brazil. The increasing in temperature and humidity coincides with the last maximum transgressive event marked in the lowlands RSCP at ca. 5000 yrs BP (Villwock et al. 1986, Villwock and Tomazelli 1987). These paleoenvironmental interpretations are consistent with the appearance of human occupation as observed by Dias (2003) and Dias and Jacobus (2003) in the An Acad Bras Cienc (2010) 82 (3).
arqueologic site “RS-S-327” located about 2 km of this study area. In addition, mammalian fossils of small size, related to grassland vegetation (*Thylamys* Grey, *Clyomys* sp. nov. and *Dicolpomys* fossor Winge) and others typical of forests (*Gracilinanus* microtarsus Wagner and *Phyllomys* sp.), were found in the archaeological site above mentioned at stratigraphical levels corresponding to this phase. It confirms the grassland-forest mosaics hypothesis (Rodrigues 2008) to this region.

An important theme to be reanalyzed concerns the rates of concentration and accumulation of carbonized particles, which are the highest in this phase. It was expected that, by the increasing of humidity conditions as reflex of the entrance of Atlantic rainforest elements, natural events of fire could be less expressive. Human origin to these highest rates of carbonized particles is discarded. In those times, arqueological record of fire seem to be restricted to rock shelter, related to hunt of human Umbu tradition (Dias 2003). These carbonized particles are relatively well preserved, demonstrating that this site of deposition received most contributions from the nearest area, with a strong influence of organic matter. It is reinforced by the lithological data and by the highest sedimentation rate of the core (Fig. 3).

The Phase SAP-IV (4955-4402 cal yr BP) is very similar to the previous one, with a well-represented grasslands vegetation in the studied region. However, pioneer components of the Atlantic rainforest (*Arecales*, *Ilex*, *Myrtaceae*, *Myrsina* and *Celtis*) showed a slightly reduction in their frequencies, as also verified by other authors (Lorscheitter 2003, De Oliveira et al. 2005). This reduction is attributed to the marine transgression above mentioned (ca. 5000 yrs BP) that controlled the Atlantic rainforest expansion, mainly at the Rio Grande do Sul Northern Coastal Plain with indirect reflexes in the studied area.

The first pollen records of *Acacia*-type, *Daphnopsis racemosa* Griseb., *Erythrina*-type, and *Parapiptadenia rigida*-type are interpreted as seasonal semideciduous forest influence. In addition, probably *Ephedra tweediana* moved from west to east. According to Rambo (1954), this species migrated from the Andes regions and subsequently penetrated in the South of RS from 4402 cal yr BP, showing a significant expansion of the forest vegetation and constituting the grassland-forest mosaics similar to the modern ones. The increasing of biodiversity of the Atlantic rainforest and seasonal semideciduous forest in the region was synchronous to the marine regression after 4000 yrs BP in RSCP. After this event, processes of desalinization in soils allowed that certain elements replaced the RSCP region and adjacent areas, according to Lorscheitter (2003), De Oliveira et al. (2005) and Leal and Lorscheitter (2007). High percentages of algae taxa (*Pseudoschiziae rubina* Rossignol ex Christopher, *Zygnema*) and mosses spores (*Sphagnum* Dill. Hedw) suggest the permanence of these humidity conditions and intense rainfall in this phase. Ferns spores such as *Blechnum*-type, *Cyatheaceae* and *Selaginella* became well represented even as aquatic elements (mainly *Ludwigia*). Spores of fungi mycorrhizal increased in frequency and can be associated with the development of soils. The expansion of the Atlantic rainforest and seasonal semideciduous forest may have minimized the fire frequency, which is also evidenced by the reduction of rates of concentration and accumulation of carbonized particles. According to Pillar (2003) and Overbeck et al. (2005), fire in the grasslands vegetation did not reach the inner part of forest due to the lack of biomass to promote flammability. Finally, the uppermost subsamples (from the 0.35 m to top) of the core showed the human influence by the marked presence of *Zea mays* L.

The dating performed at 55 cm depth reveals an interesting and exciting aspect about the geological evolution of the analyzed sedimentary interval. According to the obtained datings, the section between 115 and 55 cm had a high sediment rate, of about 0.124 cm/yr, including a time of ca. 485 years. Otherwise, for the interval between 55 and 13 cm depth, the sedimentation rate is much lower, of ca. 0.01 cm/year. Considering the dating accuracy and the granulometry sustenance, this difference can be explained by changes in the shape of paleotopography. At the beginning, the point of sampling probably corresponded to a more irregular surface on the ground, such as minor depressions or a cavity. The upper section was deposited on a more regular and planar
CONCLUDING REMARKS

The palynological record obtained from a peat bog at Santo Antônio da Patrulha, RS, southmost Brazil, revealed five phases, named SAP-I to SAP-V. These phases reflect different ecological and environmental conditions, mainly related to the vegetational succession and the paleoclimate variations, as summarized below. The results reinforced the use of pollen and spores assemblages for Quaternary analysis.

(i) A total of 98 taxa of palynomorphs were identified from 35 subsamples recovered from the Santo Antônio da Patrulha core, whose basal radiocarbonic dating (at 115 cm of depth) revealed an age of 4730 ± 50 yr BP (calibrated age 5461 yrs BP).

(ii) Among the five identified phases, only the SAP-II (two subsamples 110 to 105 cm core depth) did not reveal an amount of pollen and spores for paleoecological and paleoclimatic interpretations.

(iii) Taking into account the main tendencies of the vegetational record, it is possible to observe a gradual increasing of humidity, mainly from the beginning of the SAP-III, when the pioneers of the Atlantic rainforest components, fern spores and fungi, became significant. Furthermore, grasslands present more diversity of taxa.

(iv) Grassland components are dominant along the entire core. However from the SAP-V (ca. 4000 cal yrs BP) forest taxa, Atlantic rainforest and seasonal semideciduous forest, present a gradual and significant increasing.

(v) The records and frequency of grasslands and forest taxa from the SAP-III show the beginning of the vegetation as a mosaic, as interpreted by other authors. Mammalian fossils and arqueological data support this idea, especially correlated to the SAP-III. The progressive establishment of these forest elements in the region suggests warm condition from ca. 4000 cal yrs BP to present, corroborating previous palynological data obtained in the RS, following the marine regression during the late Holocene times.

(vii) The presence of some pollen taxa, such as Acacia-type, Daphnopsis racemosa, Erythrina-type, and Parapiptadenia rigida-type, is interpreted here as an influence of the seasonal semideciduous forest. Other authors recorded these taxa from late Holocene cores in southmost Brazil, but they seem to be included as Atlantic rainforest components.

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RESUMO

Um testemunho de sondagem coletado em Santo Antônio da Patrulha, Rio Grande do Sul, Brasil, foi submetido para análise palinológica a fim de revelar a história vegetacional e mudanças paleoecológicas e paleoclimáticas. Um total de 98 táxons foi identificado a partir de 35 subamostras. Três datações radio-cárbonicas foram obtidas ao longo de uma seção de 115 cm de profundidade, incluindo a idade basal de 4730 ± 50 yr AP. Diagramas polinicos e análises de agrupamentos foram realizadas com base nas frequências dos palinomorfos, mostrando cinco fases distintas (SAP-I a SAP-V), que refletiram diferentes condições paleoecológicas. A presença de certos táxons florestais (tipo Acacia, Daphnopis racemosa, tipo Erythrina e tipo Parapiptadenia rigida), a An Acad Bras Cienc (2010) 82 (3)
partiu da fase SAP-IV, é interpretada como influência da Floresta Estacional Semidecidual na região de estudo. A partir da fase SAP-V (ca. 4000 anos AP) a vegetação tornou-se similar à moderna (atual Bioma da Floresta Atlântica), especialmente após 2000 anos AP (idade calibrada).

**Palavras-chave:** Palinologia, Paleoecologia, Paleoclimatologia, Floresta Atlântica, Holoceno tardio, Rio Grande do Sul.

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