Anais da Academia Brasileira de Ciências (2005) 77(2): 353-365
(Annals of the Brazilian Academy of Sciences)
ISSN 0001-3765
www.scielo.br/aabc

Progress on the palynostratigraphy of the Permian strata in Rio Grande do Sul State, Paraná Basin, Brazil

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Manuscript received on March 8, 2004; accepted for publication on September 21, 2004;
presented by LÉO A. HARTMANN

ABSTRACT

A review of published papers and results of analysis of new material have allowed improvements on the palynostratigraphy of the Permian strata of the Paraná Basin in Rio Grande do Sul State. Based on first and last occurrences of certain species of pollen taxa, two palynozones are formalized, these are the *Vittatina costabilis* and *Lueckisporites virkkiae* Interval Zones, in ascending order. The *Vittatina costabilis* Interval Zone is subdivided into two units, in ascending order the *Protohaploxypinus goraiensis* and the *Hamiapollenites karrooensis* Subzones, and is recognized from the glacial (Itararé Group) and post-glacial sequence (Rio Bonito Formation and the base of the Palermo Formation). The *Lueckisporites virkkiae* Interval Zone occurs from the uppermost Rio Bonito Formation, through the Palermo and Irati formations, and into the Serra Alta and Teresina formations. The main characteristics and reference sections are established, as well as additional criteria to recognize biostratigraphical units, in accordance with the International Stratigraphic Guide. Palynostratigraphical correlation suggests that the *Vittatina costabilis* Zone concerns the Early Permian (early Cisuralian), while the *Lueckisporites virkkiae* is regarded as late Early Permian to early Middle Permian (late Cisularian to early Guadalupian).

Key words: Palynology, Permian, Paraná Basin, biostratigraphy, Rio Grande do Sul.

INTRODUCTION

Palynology is an important tool in solving geological problems, providing information on paleoclimatology, paleobiogeography and palaeoenvironments. However, biostratigraphy and correlation are its primary applications. In particular, palynology is valuable since it allows correlations between terrestrial and marine deposits (Christopher and Goodman 1996), because palynomorphs are commonly found in both marine and nonmarine strata.

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The Upper Paleozoic strata of the Paraná Basin bear diverse and abundant fossils, including invertebrates, vertebrates, plant remains and palynomorphs. However, correlateable horizons and independently dated fossils, such as marine invertebrates are scarce, preventing precise correlation and accurate age calibration. In this context, palynological assemblages are commonly used, contributing to correlation and characterization of depositional environments.

Previous palynological papers for the Paraná Basin are known since the ending of the 1960s, contributing to taxonomy and preliminary zonation

schemes. The most important of these papers are Daemon and Quadros (1970) and Marques-Toigo (1991). Further studies were made improving the stratigraphical and the palynological knowledge of the Paraná Basin (e.g. Souza and Marques-Toigo 2001).

New palynological data have recently been obtained, allowing palynostratigraphic improvements. This contribution deals exclusively with the Late Paleozoic palynostratigraphy in Rio Grande do Sul State (RS), in the South of Brazilian Paraná Basin. Formal biostratigraphical units are proposed, named and described, detailing the previous proposal of Marques-Toigo (1991), in accordance with the International Stratigraphic Guide, as well as adding new data obtained from recent studies.

GEOLOGICAL SYNOPSIS

The Paraná Basin is a large intracratonic basin, located at the central-eastern part of the South-American Platform. It was formed in response to the geological stabilization after the Braziliano Cycle (Upper Proterozoic/early Early Paleozoic). This basin comprises a thick and extensive sedimentary-magmatic sequence, which covers an area of about 1,700,000 km^2, situated in Brazil, Uruguay, Argentina and Paraguay, reaching thicknesses of ca. 5,000 m. Its geological units, Late Ordovician to the Upper Cretaceous in age, are the following: Rio Ivaí Group (Ordovician-Silurian), Paraná Group (Devonian), Tubarão Supergroup (Carboniferous-Permian), Passa Dois Group (Permian), São Bento Group (Jurassic-Cretaceous) and Bauru Group (Cretaceous) (Milani et al. 1994).

The Rio Grande do Sul Upper Paleozoic and Triassic units are shown in Figure 1. The main palyniferous beds are the Itararé Group, and the Rio Bonito, Palermo and Irati formations. Palynomorphs are scarce, or absent from the upper units.

Holz (1998) recognized four third-order depositional sequences within the Tubarão Supergroup (Itararé Group, Rio Bonito and Palermo formations) and in the base of the Passa Dois Group (Irati Formation) in RS. According to this author, Sequence I (Itararé Group) is a pro-glacial turbiditic facies of a lowstand systems tract, which is overlain by mudstones that represent a major flooding event. Sequence II (Rio Bonito Formation) is a trangressive system tract represented by fluviodeltaic, floodplain, barrier/lagoon, shoreface with supratidal facies. Sequence III (upper Rio Bonito, Palermo and lower Irati formations) comprises inter- and supratidal deposits, and facies related to an epicontinental sea. Sequence IV occurs within the Irati Formation, and is related to restricted marine conditions.

PREVIOUS PALYNOSTRATIGRAPHY

Palynological zonations of different scales and based on different biostratigraphic concepts have been proposed for the Upper Paleozoic of the Paraná Basin. The scheme proposed by Daemon and Quadros (1970) is the most complete. These authors proposed six interval zones with subzones, named as G, H (H_1, H_2, H_3), I (I_1, I_2+I_3+I_4), J, K and L (L_1, L_2, L_3), in ascending order, based on the distribution of forty pollen taxa. Monosaccate pollen grains dominate the G, H_1 and H_2 intervals, including *Cannanoropollis*, *Plicatipollenites*, *Potonieisporites* and *Caheniasaccites*; a taeniate disaccate pollen grain also occurs (*Protohaploxypinus*). From the H_3 subinterval up to the I interval, *Protohaploxypinus*, *Vittatina* and *Illinites* become dominant. The J, K and L intervals are marked by the abundance and diversity of taeniate and polyplicate pollen grains, mainly *Vittatina* and *Lueckisporites*.

Subsequent papers have improved the knowledge on the stratigraphical distribution of certain taxa. According to Daemon and Quadros (1970), *Plicatipollenites trigonalis* (= ''P-490'') and *Cannanoropollis triangularis* (= ''P-501'') are stratigraphically restricted to the G Interval. However, Dias (1993) recorded these species in the Itararé Subgroup in the RS, which is, according to Daemon and Quadros (1970), related to the H_3 subinterval. *Plicatipollenites gondwanensis* (P-906) has been recorded at the base of the Itararé Group, that

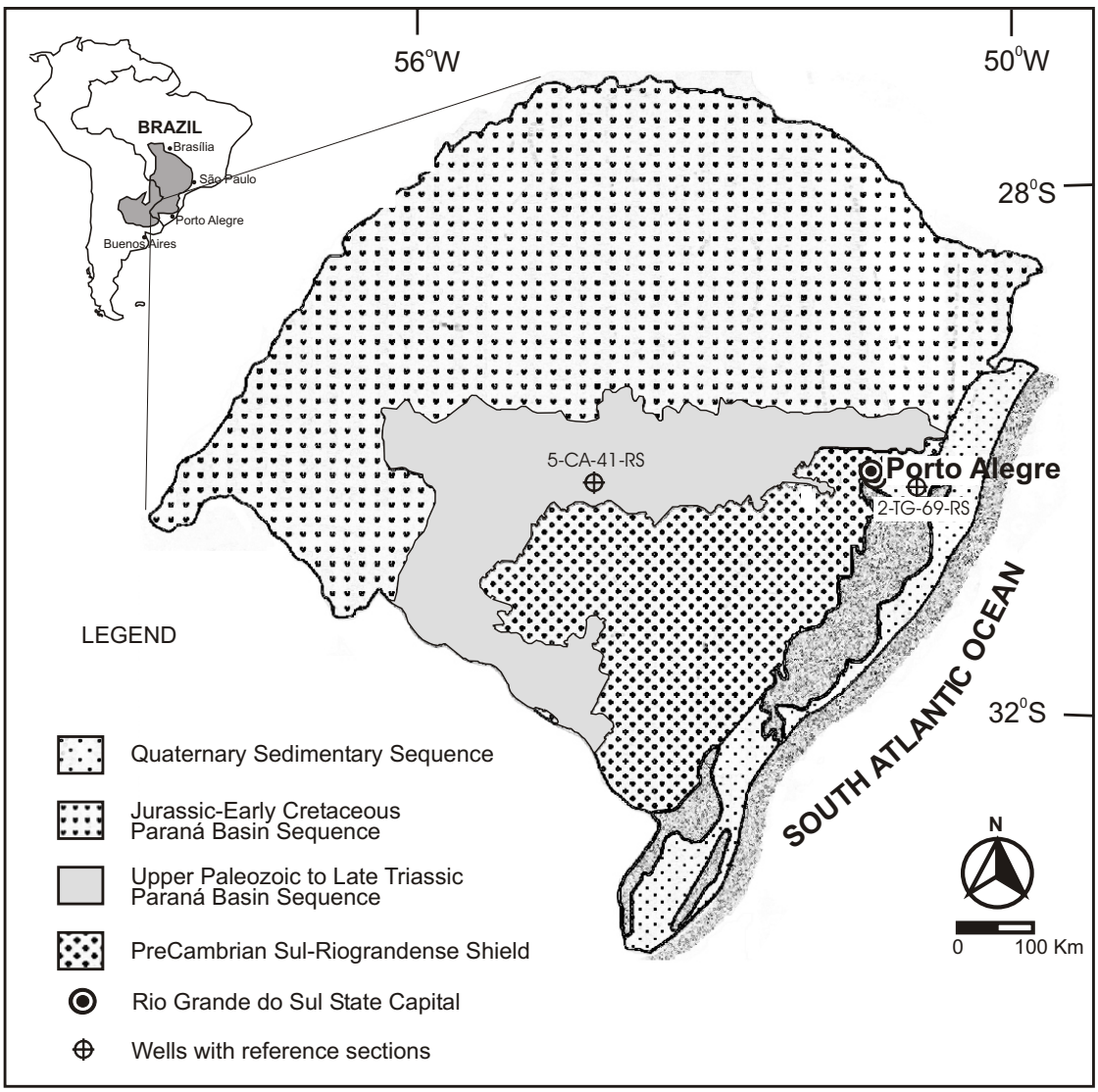

Fig. 1 – Geological sketch map of Rio Grande do Sul, southmost Brazilian Paraná Basin.

is related to the G-H intervals (Souza et al. 2003), but according to Daemon and Quadros (1970) it is restricted to the I and K intervals.

A significant contribution has come from Marques-Toigo (1991), who detailed and formalized the palynostratigraphical succession recorded in the southern portion of the Paraná Basin, involving the Tubarão Supergroup and the lower Passa Dois Group (Irati Formation) in the RS and the State of Santa Catarina. The zones were named as the *Cannanoropollis korbaensis* Biozone and the *Lueckisporites virkkiae* Biozone, in ascending order. The former was subdivided into three subzones: the *Protohaploxypinus goraiensis* Subzone, the *Caheniasaccites ovatus* Subzone and the *Hamiapollenites karrooensis* Subzone. According to Marques-Toigo (1991), these subzones correlate with the H_3-J intervals of Daemon and Quadros (1970), while the *Lueckisporites virkkiae* Zone correlates with the K and L intervals.

During the past two decades, data collected from the north-eastern portion of the basin have resulted in new palynostratigraphical zonations (unpublished data). Some of these results were preliminarily presented by Souza and Marques-Toigo (2001, 2003), who summarized the palynological succession of the Upper Paleozoic of the Brazilian Paraná Basin.

According to Souza and Marques-Toigo (2001, 2003), four interval zones characterize the Upper Paleozoic of the Paraná Basin: *Ahrensisporites cristatus*, *Crucisaccites monoletus*, *Vittatina costabilis* and *Lueckisporites virkkiae*, in stratigraphical order. The first two are restricted to the northeastern portion of the Paraná Basin, being Carboniferous in age (Westphalian/Stephanian) and correlate, in part, with the G-H_2 intervals. The *Vittatina costabilis* and *Lueckisporites virkkiae* interval zones are recognized along to the Basin and are focused herein.

MATERIALS AND METHODS

This study is based on review of published papers, mainly Marques-Toigo (1991), and reanalysis of slides housed in the Laboratório de Palinologia of the Instituto de Geociências, Universidade Federal do Rio Grande do Sul, as well as of new material. A detailed taxonomic re-examination was held to check the ranges of the species that were previously thought as diagnostic of some units and stratigraphical intervals. Furthermore, new palynological assemblages were obtained from surface and subsurface samples.

Analysis of the stratigraphical distribution was mainly based on wells related to coal research and exploration, as follows: 2-TG-69-RS well (drilled in the locality of Santa Terezinha Coal), 5-CA-03-RS, 5-CA-41-RS (Charqueadas Coal), 5-CA-91-RS (Gravataí-Morungava Coal), 2-TG-88-RS (Chico Lomã Coal), P7 (Iruí Coal) and N3 (Santa Rita Coal). These wells were drilled by the Companhia Riograndense de Mineração (CRM) and by the Companhia de Pesquisas de Recursos Minerais (CPRM). Geological and palynological data from these wells were published by Marques-Toigo and Pons (1974), Bortoluzzi et al. (1980), Marques-Toigo et al. (1982, 1984) and Picarelli et al. (1987).

PALYNOSTRATIGRAPHY

The palynozones erected herein correspond to interval biozones. They have been established in accordance to the criteria of the International Subcommission on Stratigraphic Classification of IUGS, and summarized by Murphy and Salvador (1999), as commonly applied to palynological units (Christopher and Goodman 1996). Selected taxa of the two palynozones are illustrated in the Figures 2 and 3, including main diagnostic taxa and other taxa common in the biozones (e.g. *Punctatisporites gretensis*, *Lundbladispora braziliensis* and *Vittatina subsaccata*). Table I gives the full author citation of the taxa referred to in this paper.

Vittatina costabilis Interval Zone

General characteristics

The most common palynomorphs of this biozone are bilaterally and radially symmetrical monosaccate pollen, such as *Cannanoropollis*, *Plicatipollenites*, *Caheniasaccites*, *Potonieisporites* and *Striomonosaccites*, reaching up to 50-60% of assemblages. Disaccate pollen grains are dominant in the upper portion of this zone (the *Hamiapollenites karrooensis* Subzone) and common taxa are *Limitisporites*, *Vittatina*, *Scheuringipollenites* and *Protohaploxypinus*. Spores are locally dominant, reaching up to 80% in coal beds, reflecting the local flora and suggesting parautochtonous conditions.

In several wells, the genus *Vittatina* occurs in the basal portion of this zone, demonstrating a wide geographical distribution. Furthermore, it is represented by considerable species, e.g. *Vittatina costabilis*, *V. saccata*, *V. subsaccata*, *V. vittifera*, *V. corrugata* and *V. wodehousei*. Among these species, *Vittatina costabilis* has been chosen to name the biozone because it is easily recognizable and very abundant, although it also occurs in the subsequent biozone. This last detail does not prevent its use in

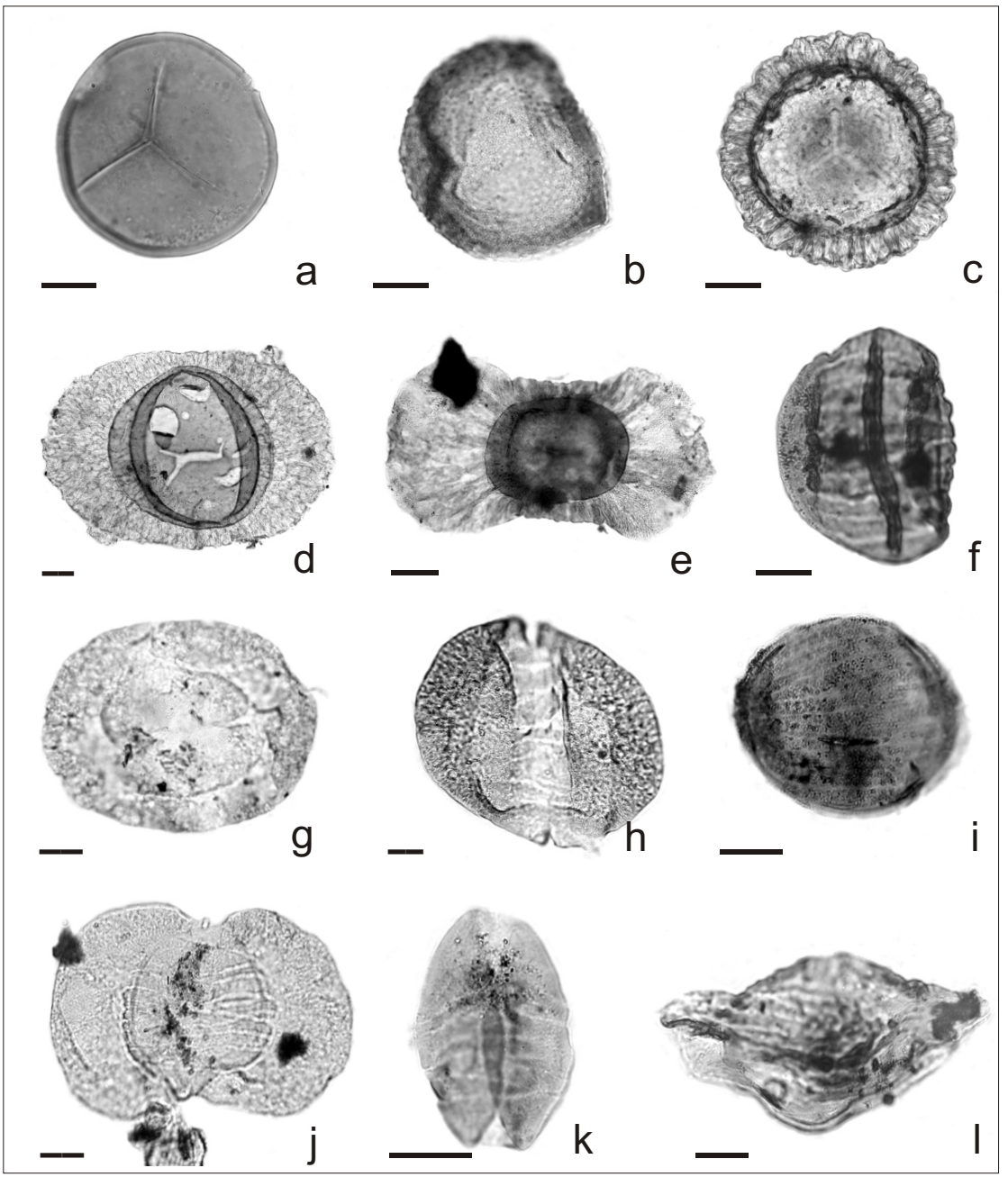

Fig. 2 – Selected spores and pollen taxa of the *Vittatina costabilis* Zone. **a.** *Punctatisporites gretensis* (slide MP-P: 324, England Finder coordinate: J49/2); **b.** *Lundbladispora braziliensis* (P324, J49/2); **c.** *Cannanoropollis korbaensis* (15, M37); **d.** *Potonieisporites novicus* (14, L40/1); **e.** *Caheniasaccites flavatus* (4033, R54); **f.** *Vittatina costabilis* (3573, G36/2); **g.** *Illinites unicus* (4033, U50); **h.** *Protohaploxypinus goraiensis* (324, R35/1); **i.** *Vittatina subsaccata* (2541, L40/2); **j.** *Striatopodocarpites fusus* (312, U27/2); **k.** *Fusacolpites fusus* (333/287, P44); **l.** *Hamiapollenites karrooensis* (1534, Q35-2). Slides are housed at the Departamento de Paleontologia e Estratigrafia/UFRGS. Scale bar corresponds to 20 μm.

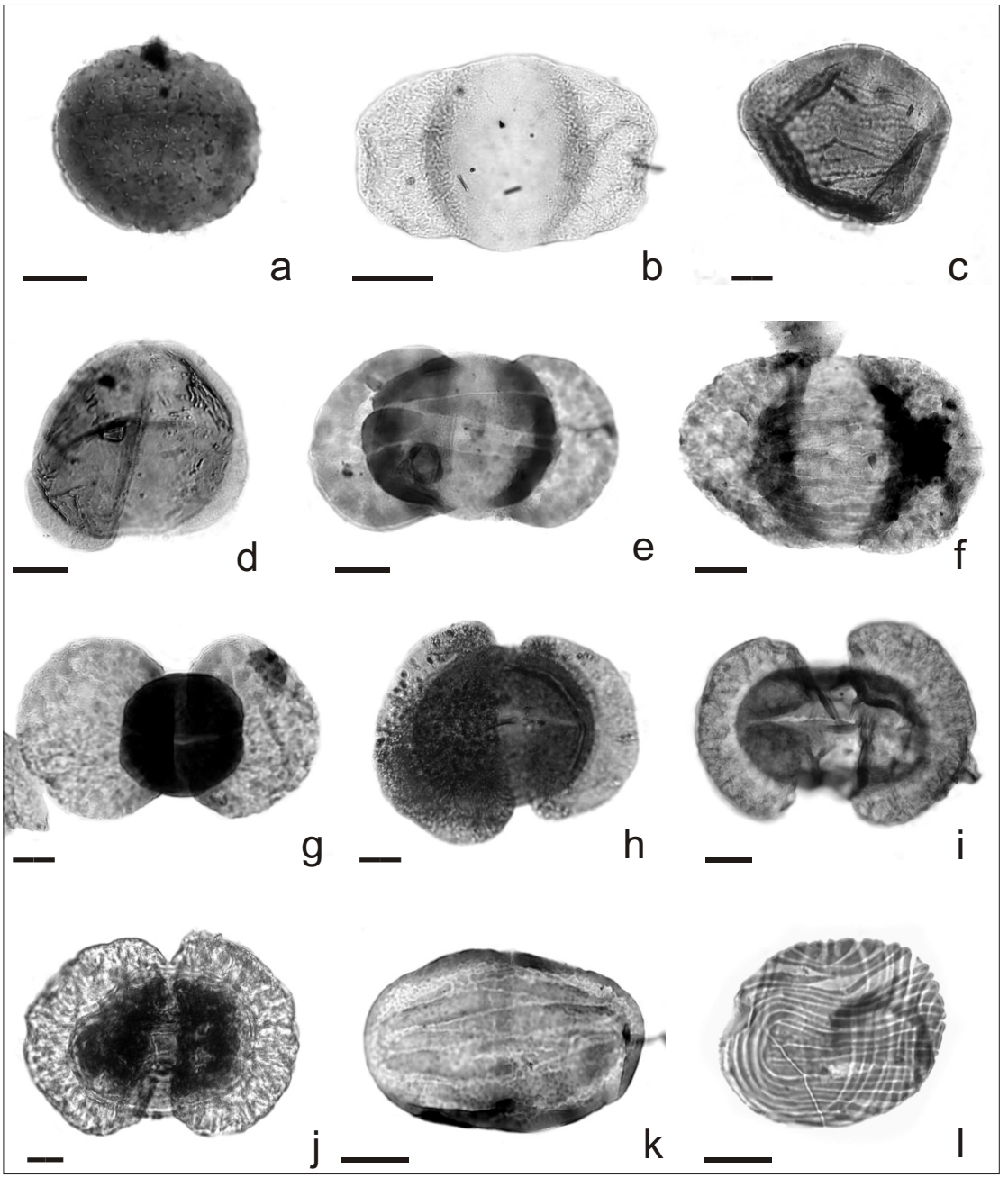

Fig. 3 – Selected spores and pollen taxa of the *Lueckisporites virkkiae* Zone. **a.** *Thymospora criciumensis* (slide MP-P:1447, England Finder coordinate: J24); **b.** *Alisporites nuthallensis* (P344C, O25); **c.** *Marsupipollenites striatus* (4033, Q45); **d.** *Staurosaccites cordubensis* (2541, U41); **e.** *Lunatisporites variesectus* (P5, M51); **f.** *Protohaploxypinus microcorpus* (MP-P1: 4, F41); **g.** *Lueckisporites densicorpus* (P5, N40/4); **h** and **i.** *Lueckisporites virkkiae* (h: 2541, W33; i: 8, N36); **j.** *Lueckisporites stenotaeniatus* (46, Q39); **k.** *Vittatina vittifera* (P5, P47); **l**. *Weylandites lucifer* (P4, O52/2). Slides are housed at the Departamento de Paleontologia e Estratigrafia/UFRGS. Scale bar corresponds to 20 μm.

an interval biozone (see Murphy and Salvador 1999, p. 263).

Limits

The lower limit of this zone is marked by the first appearance of the genus *Vittatina* (*V. saccata*, *V. subsaccata*, *V. costabilis*, *V. vittifera*), species of *Protohaploxypinus* (*P. goraiensis*, *P. limpidus*), *Fusacolpites fusus* and *Illinites unicus*. This is commonly within the upper Itararé Group. The upper limit is marked by the appearance of diagnostic species of the *Lueckisporites virkkiae* Interval Zone. The upper limit commonly occurs within the uppermost Rio Bonito Formation and lowermost Palermo Formation.

Subzones

This palynozone is divided in two units, the *Protohaploxypinus goraiensis* and *Hamiapollenites karrooensis* subzones. The first is defined by the range of *Protohaploxypinus goraiensis*, *Illinites unicus*, and *Protohaploxypinus limpidus*. The *Hamiapollenites karrooensis* Subzone is defined by the range of the eponymous species; its base is additionally defined by the first appearance of *Striatopodocarpites fusus* and *Staurosaccites cordubensis*.

The *Caheniasaccites ovatus* Subzone of Marques-Toigo (1991) is regarded as part of the *Protohaploxypinus goraiensis* Subzone. The lower limit of the former was defined by the last appearance of *Protohaploxypinus goraiensis*, and the upper limit by the disappearance of *Cahenisaccites flavatus* (= *Caheniasaccites ovatus*). However, according to Cazzulo-Klepzig (personal communication), *Protohaploxypinus goraiensis* occurs in the Candiota Coal, which was considered to belong to the *Caheniasaccites ovatus* Subzone (Cazzulo-Klepzig et al. 2002). Besides, *Caheniasaccites flavatus* has a large range in the Paraná Basin, from the Itararé Group to the Palermo Formation (see Souza et al. 2003). Thus, the limits of the *Caheniasaccites ovatus* Subzone of Marques-Toigo (1991) could not be marked as proposed. Among its stratigraphically restricted species (according Marques-Toigo 1991), *Horriditriletes pathakheraensis* and *Anguisporites ornatus* are very rare in the sequence and *Scheuringipollenites maximus* has been recorded in the middle-upper portion of the Itararé Group, within the *Crucisaccites monoletus* Zone (Souza and Marques-Toigo 2003).

Reference section

The interval between 535 and 500 m depth in the 2-TG-69-RS well (Santa Terezinha Coal), in Osório Municipality, is the reference section for this biozone. Geological data on this sequence are given by Picarelli et al. (1987, p. 364). The palynozone is also identified in several wells in RS, such as 2-TG-99-RS (ca. 645 to 580 m in depth) and P7 (ca. 345 to 320 m in depth; see Marques-Toigo and Pons 1974, Picarelli et al. 1987).

Lueckisporites virkkiae Interval Zone

General characteristics

Pollen taxa which appear from its lower limits and species of *Protohaploxypinus*, *Striatopodocarpites*, *Striatoabieites*, *Lunatisporites* and *Marsupipollenites*, are dominant in this biozone. Monosaccate and disaccate pollen grains (*Potonieisporites*, *Limitisporites*) are less common. Spores are scarce, and two new species appear within this zone, these are *Thymospora criciumensis* and *Convolutispora pintoi*, from levels within the Palermo and the Irati formations, respectively.

Lueckisporites virkkiae is morphologically easily recognizable and seems to have a stratigraphically consistent first appearance in the Paraná Basin, from the base of the K interval of Daemon and Quadros (1970), that is considered a datum in the Paraná Basin, from the RS (southmost portion of the Brazilian Paraná Basin) to the State of Mato Grosso (northmost portion).

Limits

The lower limit of this zone is defined by the last appearance of *Hamiapollenites karrooensis* and *Stellapollenites talchirensis* and by the first appearance

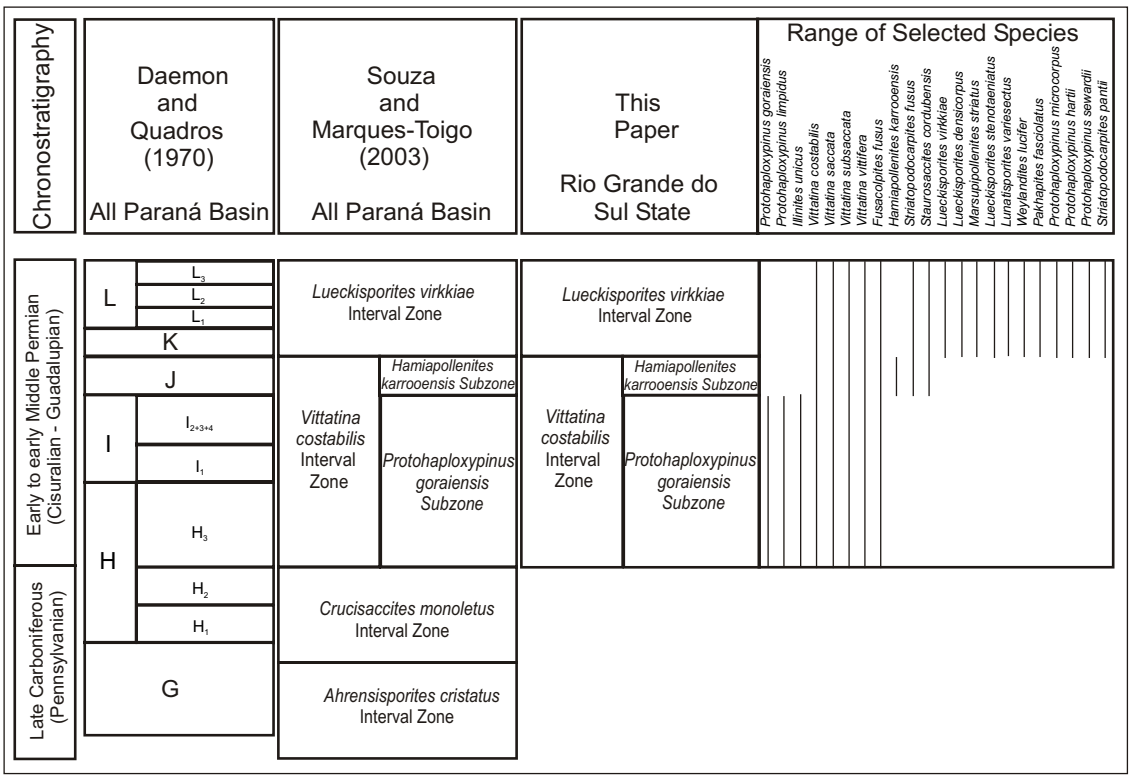

Fig. 4 – Correlation between main Upper Paleozoic Brazilian Paraná Basin palynozones and the units recognized in the State of Rio Grande do Sul, including ranges of its selected species.

of *Lueckisporites virkkiae*, *L. densicorpus*, *L. stenotaeniatus*, *Pakhapites fasciolatus*, *Weylandites lucifer*, *Protohaploxypinus hartii*, *P. sewardi*, *P. microcorpus*, *Lunatisporites variesectus*, *Alisporites nuthallensis* and *Striatopodocarpites pantii*, within the uppermost Rio Bonito Formation and lowermost Palermo Formation. Its upper limit is marked by the disappearance of species of *Lueckisporites*, within levels of the Serra Alta and Teresina formations.

Reference section

The reference section is the interval between 168.5 m and 118.65 m in the 5-CA-41-RS well from levels of siltstone of the Irati Formation. Diagnostic species of this biozone (e.g. *Lueckisporites virkkiae*, *L. stenotaeniatus*, *Weylandites lucifer*) occur in subsurface, in the wells 5-CA-74-RS, 5-CA-03-RS (Charqueadas Coal), P7 (Iruí Coal), 2-TG-69-RS and 2-TG-99-RS (Santana Terezinha Coal), as well as in outcrops (Dellazzana 1976, Menéndez 1976, Picarelli et al. 1987).

Ranges of selected species are shown in Figure 4, which summarizes the zonation proposed herein, as well as the ages adopted.

DISCUSSION

Palynological Correlation

Within the Paraná Basin, the *Vittatina costabilis* Interval Zone can be correlated with the H_3-J Interval of Daemon and Quadros (1970). The appearance of *Striatopodocarpites fusus* (= ''P360'' in Daemon and Quadros 1970) suggests correlation to the *Hamiapollenites karrooensis* Subzone with the J interval. The *Lueckisporites virkkiae* Interval Zone is related to the K-L intervals of Daemon and Quadros (1970), which are characterized by the increase of taeniate

TABLE I

List of taxa.

Spores
Ahrensisporites cristatus Playford & Powis 1979
Anguisporites ornatus Nahuys, Alpern & Ybert 1968
Convolutispora pintoi Dellazzana 1976
Horriditriletes pathakheraensis Anand Prakash 1970
Lundbladispora braziliensis (Pant & Srivastava) Marques-Toigo & Pons *emend.* Marques-Toigo & Picarelli 1984
Psomospora detecta Playford & Helby 1968
Punctatisporites gretensis Balme & Hennelly 1956
Thymospora criciumensis Quadros, Marques-Toigo & Cazzulo-Klepzig 1995
Pollen grains
Alisporites nuthallensis Clarke 1965
Caheniasaccites Bose & Kar 1966
Caheniasaccites flavatus Bose & Kar *emend.* Azcuy & Di Pasquo 2000
Cannanoropollis Potonié & Sah 1960
Cannanoropollis korbaensis (Bharadwaj & Tiwari) Foster 1975
Cannanoropollis triangularis (Mehtae) Bose & Maheshwari 1968
Fusacolpites fusus Bose & Kar 1966
Hamiapollenites fusiformis Marques-Toigo *emend.* Archangelsky & Gamerro 1979
Hamiapollenites karrooensis (Hart) Hart 1964
Illinites Kosanke *emend.* Azcuy, Di Pasquo & Ampuero 2002
Illinites unicus Kosanke *emend.* Jansonius & Hills 1976
Limitisporites Leschik *emend.* Schaarschmidt 1963
Lueckisporites (Potonié & Klaus) Klaus 1963
Lueckisporites densicorpus Archangelsky & Gamerro 1979
Lueckisporites stenotaeniatus Menéndez 1976
Lueckisporites virkkiae (Potonié & Klaus) Klaus 1963
Lunatisporites (Leschik) Scheuring 1970
Lunatisporites variesectus Archangelsky & Gamerro 1979
Marsupipollenites (Balme & Hennelly) Balme 1970
Marsupipollenites striatus (Balme & Hennelly) Foster 1975
Marsupipollenites triradiatus Balme & Hennelly 1956
Pakhapites fasciolatus (Balme & Hennelly) Hart 1965
Plicatipollenites Lele 1964
Plicatipollenites trigonalis Srivastava 1970
Plicatipollenites gondwanensis (Balme & Hennelly) Lele 1964
Potonieisporites Bhardwaj *emend.* Bharadwaj 1964
Potonieisporites novicus Bhardwaj *emend.* Poort & Veld 1997
Protohaploxypinus Samoilovich *emend.* Morbey 1975
Protohaploxypinus goraiensis (Potonié & Lele) Hart 1964
Protohaploxypinus hartii Foster 1979
Protohaploxypinus limpidus (Balme & Hennelly) Balme & Playford 1967
Protohaploxypinus microcorpus (Schaarschmidt) Clarke 1965
Protohaploxypinus sewardii (Virkki) Hart 1964

TABLE I (continuation)

Pollen grains
Scheuringipollenites Tiwari 1973
Scheuringipollenites maximus Tiwari 1973
Staurosaccites cordubensis Archangelsky & Gamerro 1979
Stellapollenites talchirensis Lele 1965
Striatoabieites (Zoricheva & Sedova ex Sedova) Hart 1964
Striatopodocarpites (Sedova) Hart 1964
Striatopodocarpites fusus (Balme & Hennelly) Potonié 1958
Striatopodocarpites pantii (Jansonius) Balme 1970
Striomonosaccites Bharadwaj 1962
Vittatina (Luber) Wilson 1962
Vittatina corrugata Marques-Toigo 1974
Vittatina costabilis Wilson 1962
Vittatina saccata (Hart) Jansonius 1962
Vittatina subsaccata Samoilovich 1963
Vittatina vittifera (Luber & Waltz) Samoilovich 1953
Vittatina wodehousei (Jansonius) Hart 1964
Weylandites lucifer (Bharadwaj & Srivastava) Foster 1975

pollen grains and are well established in the Paraná Basin.

Tentative correlations with palynological zonations from the Upper Paleozoic of South America could be established. The *Vittatina costabilis* Zone shares common elements with the *Potonieisporites-Lundbladispora* Zone and *Cristatisporites* Zone of the Chacoparanense Basin of Argentina (Vergel 1993), such as *Vittatina subsaccata* and *Protohaploxypinus limpidus*. However, the appearance of the genus *Vittatina*, that is regarded as a basal marker of the *Vittatina costabilis* Zone in the Paraná Basin, occurs from the *Potonieisporites-Lundbladispora* Zone, where it is rare.

Similar problems are verified when comparing the *Lueckisporites virkkiae* Zone and the *Striatites* Zone of the Chacoparanense Basin. However, *Lueckisporites virkkiae*, *Lunatisporites variesectus* and *Marsupipollenites striatus* (wrongly referred to as *M. triradiatus* in the chart 1 of Souza and Marques-Toigo 2003) mark the lower limit of these last two zones and could characterize a biohorizon of correlation.

Considering the zonation of the Central-Western Argentina proposed by Césari and Gutiérrez (2000), the *Vittatina costabilis* Zone seems to correlate to the *Fusacolpites fusus-Vittatina subsaccata* Interval Biozone, with *Vittatina subsaccata*, *Protohaploxypinus limpidus* and *Hamiapollenites fusiformis* as common species. The *Lueckisporites virkkiae* Interval Zone correlates to the *Lueckisporites-Weylandites* Assemblage Biozone, taking into account the distribution of *Lueckisporites* and *Weylandites lucifer*.

Assemblages with common species and similar quantitative features have been recognized in Africa (e.g. Falcon 1975), Antarctica (e.g. Lindström 1995, 1996), Australia (e.g. Jones and Truswell 1992), Oman and Saudi Arabia (e.g. Stephenson and Filatoff 2000). However, correlations are not precise. As an example, spores species that are stratigraphically restricted to the basal portion of the Upper Paleozoic sequence in the Paraná Basin (Itararé Group), such as *Ahrensisporites cristatus* and *Psomospora detecta*, show a long stratigraphic range in Australian basins (see Jones and Truswell 1992), preventing long distance correlations. Palynological differences between the microfloras can

be explained by phytogeographic distribution.

Age

The main problems of the palynological Gondwana correlation with the international stratigraphical stages were recently discussed by Stephenson et al. (2003, p. 471-472) and are related to palaeophytogeographical variations, different criteria used to established zones and correlations, as well as little radiometrical data. Correlation with the marine Permian stages is difficult and speculative.

Only one absolute age is available for the Upper Paleozoic of the RS. Matos et al. (2001) obtained a date of 267.1 ± 3.4 (U/Pb) from a tonstein interbedded in the upper coal seam of Candiota Coal (Rio Bonito Formation), within the *Caheniasaccites ovatus* Subzone (Cazzulo-Klepzig et al. 2002). This coal bed is regarded herein within the *Protohaploxypinus goraiensis* Subzone.

Melchor (2000) indicated a probable minimum absolute age for the base of the *Striatites* Biozone (Chacoparanense Basin) in Argentina as 266.3 ± 0.82, based on the Ar/Ar method. This zone may correlate to the *Lueckisporites virkkiae* Zone, taking into account the first appearance of *Lueckisporites* as a biohorizon.

An absolute age of 270 My was obtained from tuff beds of the Collingham Formation, in Namibia (Stollhofen et al. 2000). This unit overlies the Whitehill Formation, which is correlated to the Irati Formation (Faure and Cole 1999), in Paraná Basin, and is related to the *Lueckisporites virkkiae* Interval Zone. Considering that there is no considerable diachronism between these two lithostratigraphical units, the Irati Formation should be regarded as older than 270 My. This dating disagrees with those established by Melchor (2000) and Matos et al. (2001) that come from stratigraphically lower sections.

Because of this and considering the changes on geochronologic positioning that have been brought on by the recently introduced formal Permian subdivision (Jin et al. 1997 and the IUGS chart), this work has adopted the traditional standards for both units. *Vittatina costabilis* Zone is regarded as Early Permian (early Cisuralian), while the *Lueckisporites virkkiae* is regarded as late Early Permian to early Middle Permian (late Cisularian to early Guadalupian). The suggested age for the *Vittatina costabilis* Zone is based on previous palynological and paleobotanical data (e.g. Daemon and Quadros 1970, Rösler 1978) as well as on radiometrical data obtained from correlative *Fusacolpites fusus-Vittatina subsaccata* Interval Zone of Argentina (César and Gutiérrez 2000, p. 134).

ACKNOWLEDGMENTS

The authors thank Roberto Iannuzzi and Michael Holz for suggestions, as well as the referees for offering their critical reviews and suggestions. This work was supported by research grants awarded by Fundação de Amparo à Pesquisa do Rio Grande do Sul (FAPERGS).

RESUMO

Com base na distribuição de grãos de pólen, duas unidades palinobioestratigráficas são formalisadas para o Permiano da Bacia do Paraná no Rio Grande do Sul. As unidades correspondem, da base para o topo, às zonas de intervalo *Vittatina costabilis* e *Lueckisporites virkkiae*, sendo a primeira subdividida em duas subzonas: *Protohaploxypinus goraiensis* e *Hamiapollenites karrooensis*. A primeira zona é considerada eopermiana (Eo a Mesocisuraliano), tendo sido detectada junto à seqüência glacial e pós-glacial referente ao Grupo Itararé e Formação Rio Bonito, abrangendo ainda porções inferiores da Formação Palermo. A Zona *Lueckisporites virkkiae*, considerada neo-eopermiana a mesopermiana (neocisuraliana a eoguadalupiana), ocorre nas formações Palermo e Irati, podendo ainda ser estendida a estratos mais superiores da bacia (formações Serra Alta e Teresina). Suas principais características e seções de referência são apresentadas, bem como outros critérios requeridos pelo Código Estratigráfico Internacional na proposição de unidades bioestratigráficas.

Palavras-chave: Palinologia, Permiano, Bacia do Paraná, bioestratigrafia, Rio Grande do Sul.

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