



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

PAULO A. SOUZA<sup>1</sup> and MARLENI MARQUES-TOIGO<sup>2</sup>

<sup>1</sup>Instituto de Geociências, Universidade Federal do Rio Grande do Sul, Cx. Postal 15.001  
91501-950 Porto Alegre, RS, Brasil

<sup>2</sup>*in memoriam*

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### 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 *Protohaploxylinus 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 Cisuralian 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.

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

Correspondence to: Paulo Alves de Souza  
E-mail: paulo.alves.souza@ufrgs.br

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 Brazilian 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<sup>2</sup>, 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 For-

mation) 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 transgressive 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<sub>1</sub>, H<sub>2</sub>, H<sub>3</sub>), I (I<sub>1</sub>, I<sub>2</sub>+I<sub>3</sub>+I<sub>4</sub>), J, K and L (L<sub>1</sub>, L<sub>2</sub>, L<sub>3</sub>), in ascending order, based on the distribution of forty pollen taxa. Monosaccate pollen grains dominate the G, H<sub>1</sub> and H<sub>2</sub> intervals, including *Cannanoropollis*, *Plicatipollenites*, *Potonieisporites* and *Caheniasaccites*; a taeniate disaccate pollen grain also occurs (*Protohaploxylinus*). From the H<sub>3</sub> subinterval up to the I interval, *Protohaploxylinus*, *Vittatina* and *Illinites* become dominant. The J, K and L intervals are marked by the abundance and diversity of taeniate and polylicate 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<sub>3</sub> subinterval. *Plicatipollenites gondwanensis* (P-906) has been recorded at the base of the Itararé Group, that

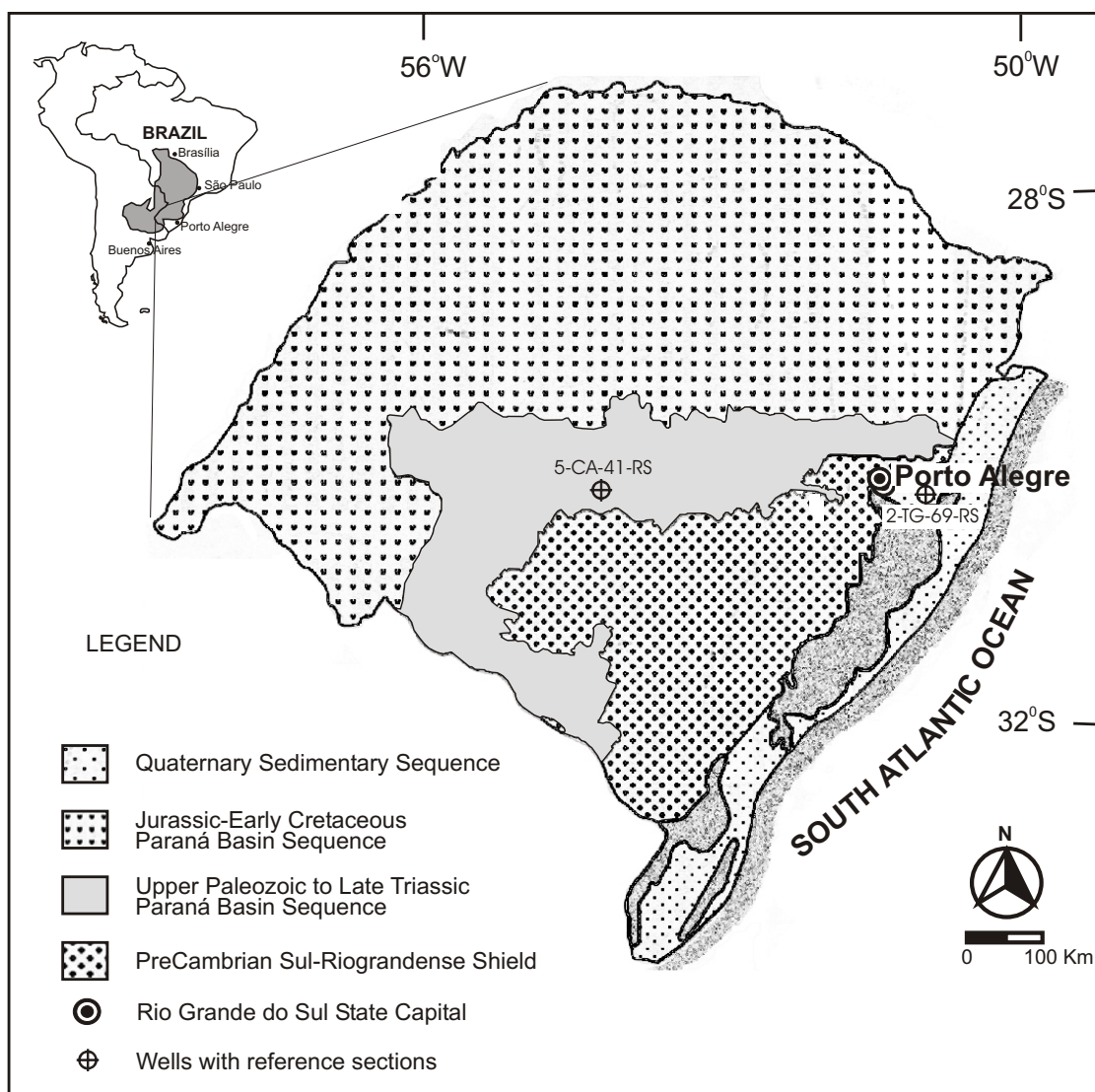


Fig. 1 – Geological sketch map of Rio Grande do Sul, southmost Brazilian Paraná Basin.

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 *Protophloxypinus goraiensis* Subzone, the *Caheniasaccites ovatus* Subzone and the *Hamiapollenites karrooensis* Subzone. According to Marques-Toigo (1991), these subzones correlate with the H<sub>3</sub>-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: *Ahrensia* *cris-tatus*, *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<sub>2</sub> 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 Subcommittee 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 karroensis* Subzone) and common taxa are *Limitisporites*, *Vittatina*, *Scheuringipollenites* and *Protohaploxylinus*. Spores are locally dominant, reaching up to 80% in coal beds, reflecting the local flora and suggesting parautochthonous 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

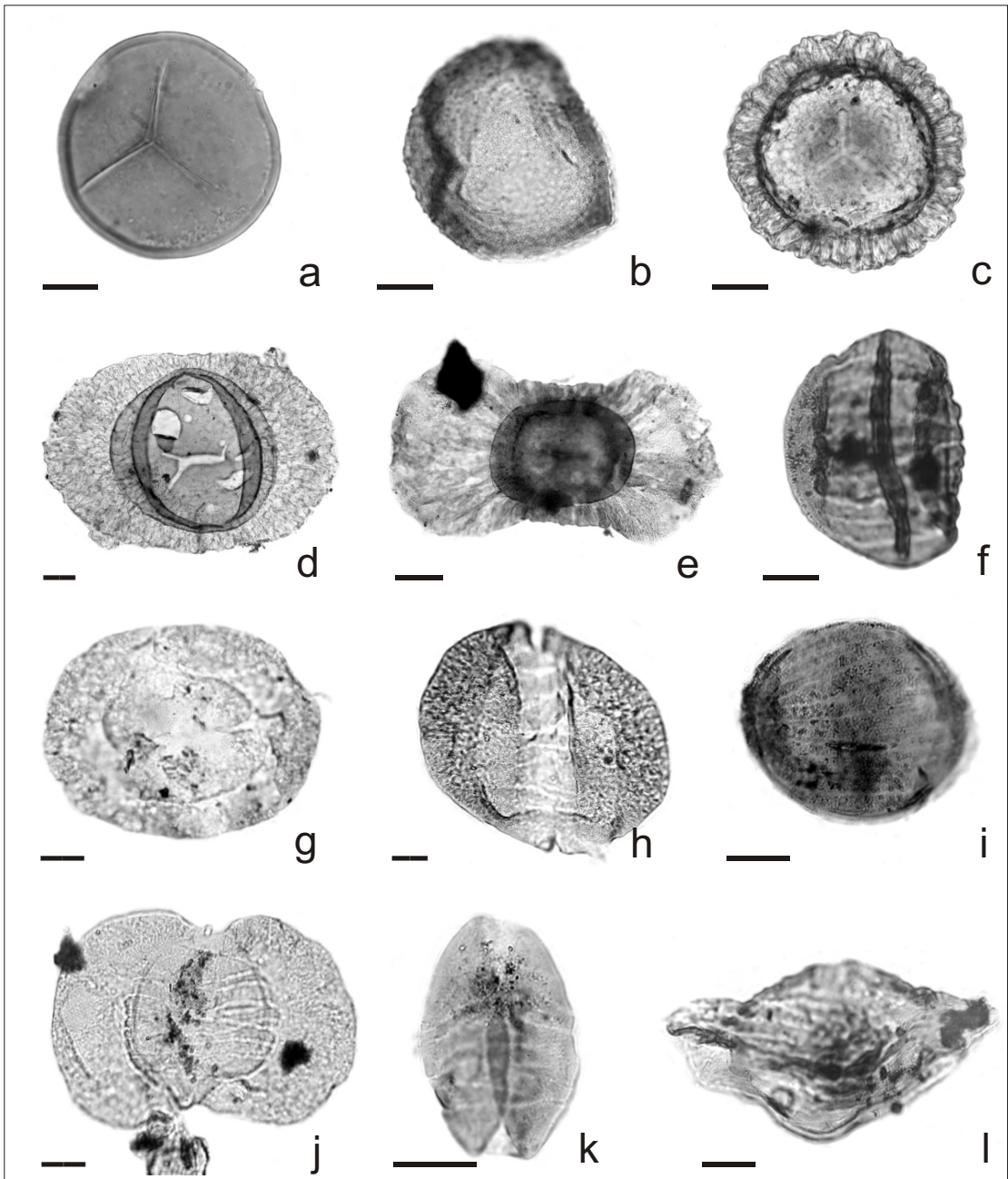


Fig. 2 – Selected spores and pollen taxa of the *Vittatina costabilis* Zone. **a.** *Punctatisporites gretensis* (slide MP-P: 324, England Finder coordinate: J49/2); **b.** *Lundbladispora braziliensis* (P324, J49/2); **c.** *Cannanoropollis korbaensis* (15, M37); **d.** *Potonieisporites novicus* (14, L40/1); **e.** *Caheniasaccites flavatus* (4033, R54); **f.** *Vittatina costabilis* (3573, G36/2); **g.** *Illinites unicus* (4033, U50); **h.** *Protohaploxylinus 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  $\mu\text{m}$ .



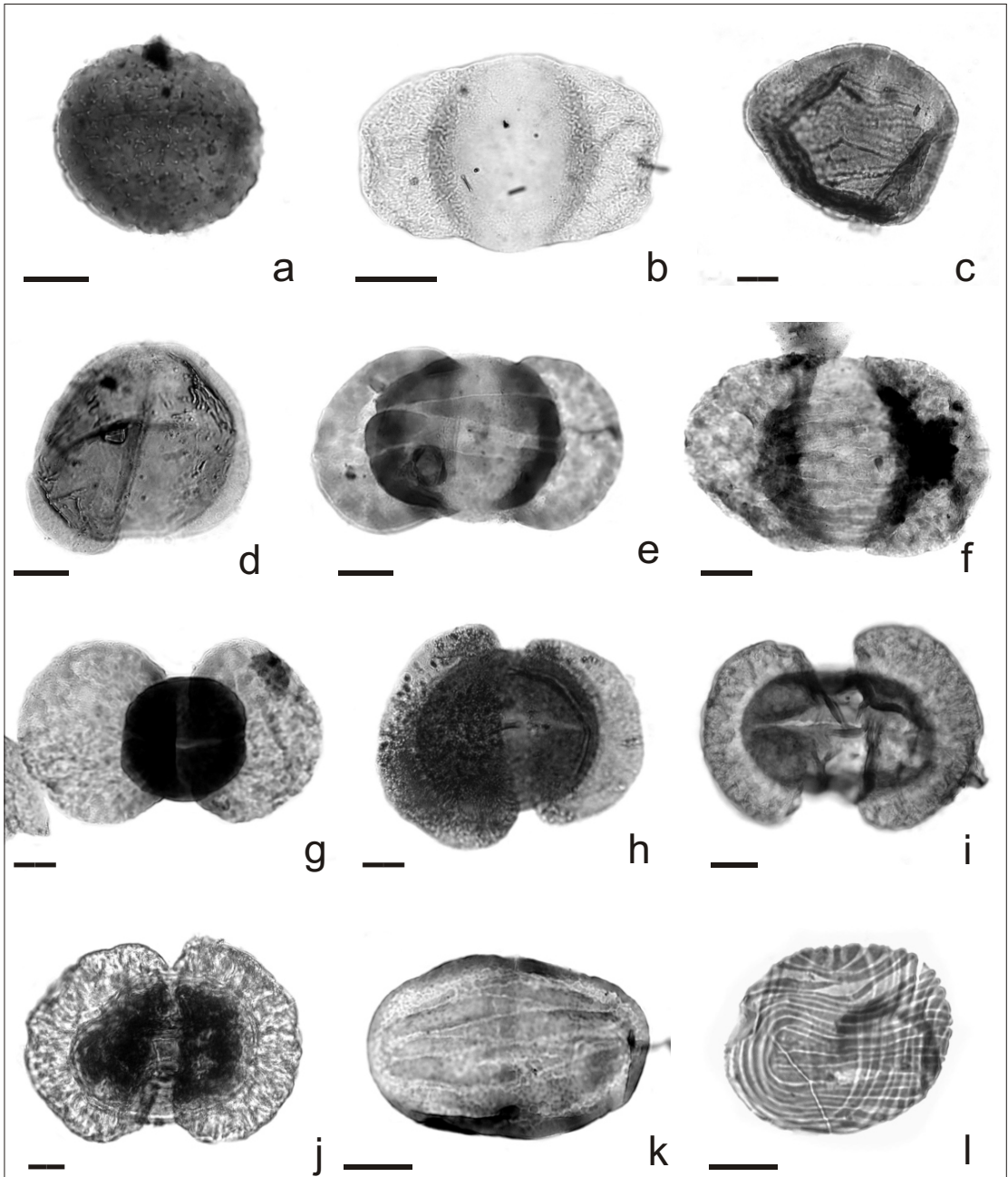


Fig. 3 – Selected spores and pollen taxa of the *Lueckisporites virkkiae* Zone. **a.** *Thymospora criciumensis* (slide MP-P:1447, England Finder coordinate: J24); **b.** *Alisporites nuthallensis* (P344C, O25); **c.** *Marsupipollenites striatus* (4033, Q45); **d.** *Staurosaccites cordubensis* (2541, U41); **e.** *Lunatisporites variesectus* (P5, M51); **f.** *Protohaploxyipinus microcorpus* (MP-P1: 4, F41); **g.** *Lueckisporites densicarpus* (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  $\mu$ m.

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 *Caheniasaccites 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), *Horrid-*

*itriteles 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 cricumensis* and *Convolutispora pin-toi*, 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 *Stel-lapollenites talchirensis* and by the first appearance

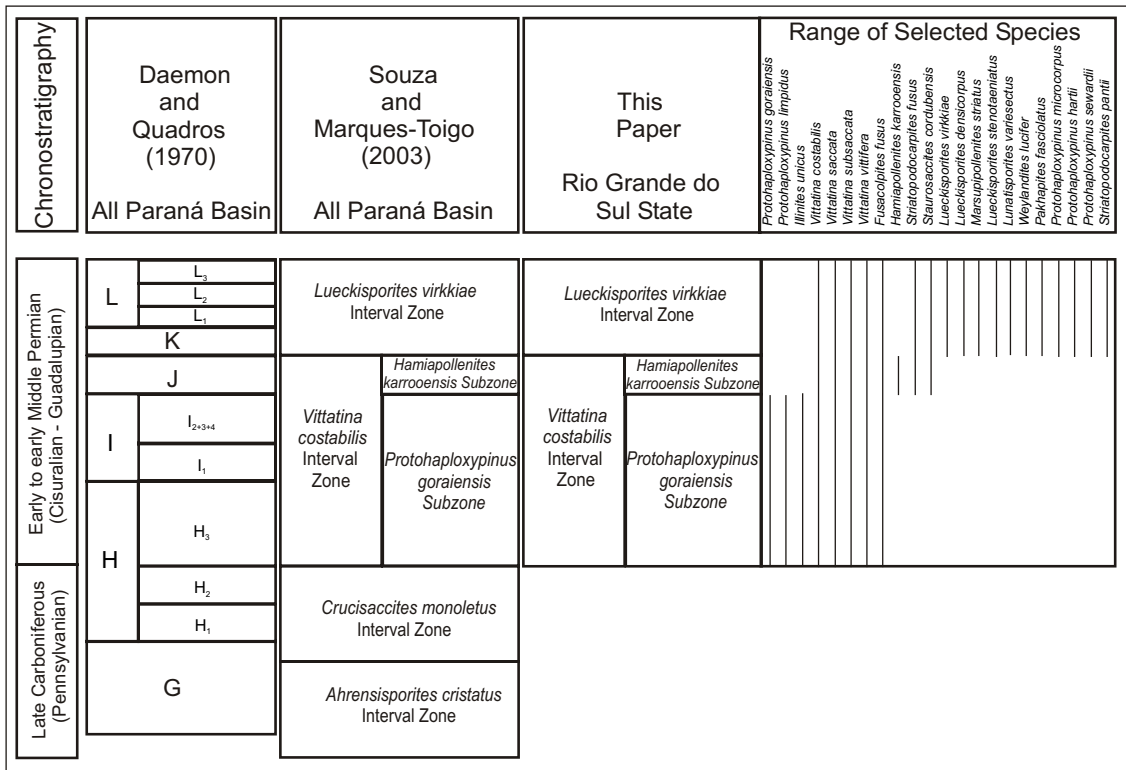


Fig. 4 – Correlation between main Upper Paleozoic Brazilian Paraná Basin palynozones and the units recognized in the State of Rio Grande do Sul, including ranges of its selected species.

of *Lueckisporites virkkiae*, *L. densicarpus*, *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<sub>3</sub>-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 taeniata



TABLE I  
List of taxa.

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

TABLE I (continuation)

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

pollen grains and are well established in the Paraná Basin.

Tentative correlations with palynological zonation from the Upper Paleozoic of South America could be established. The *Vittatina costabilis* Zone shares common elements with the *Potonieisporites-Lundbladispota* Zone and *Cristatisporites* Zone of the Chacoparanense Basin of Argentina (Vergel 1993), such as *Vittatina subsaccata* and *Protohaploxylinus 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-Lundbladispota* 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*, *Protohaploxylinus 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 *Ahrensiporites 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 palaeo-phytogeographical 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  $267.1 \pm 3.4$  (U/Pb) from a tonstein interbedded in the upper coal seam of Candiota Coal (Rio Bonito Formation), within the *Caheniasaccites ova-tus* Subzone (Cazzulo-Klepzig et al. 2002). This coal bed is regarded herein within the *Protohaploxylinus goraiensis* Subzone.

Melchor (2000) indicated a probable minimum absolute age for the base of the *Striatites* Biozone (Chacoparanense Basin) in Argentina as  $266.3 \pm 0.82$ , 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 Cisuralian 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 (Césari and Gutiérrez 2000, p. 134).

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#### RESUMO

Com base na distribuição de grãos de pólen, duas unidades palinobioestratigráficas são formalizadas 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: *Protohaploxylinus goraiensis* e *Hamiapollenites karroensis*. 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 Palermo. A Zona *Lueckisporites virkkiae*, considerada neo-eopermiana a mesopermiana (neocisuraliana a eogadalupiana), 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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