An overview on the Palynostratigraphy of the Upper Paleozoic strata of the Brazilian Paraná Basin*

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Abstract: Based on analysis of previous zonations and new studies, an overview of the palynological succession of the Upper Paleozoic strata of the Paraná Basin is given, and new data are introduced. The Cannanoporpolis kobaensis Zone is renamed Vitattina costabilis Zone, and one of its subzones (Caheniasaccites ovatus) is regarded as belonging to the Protohaploxypinus goraensis Subzone. Four interval zones characterize this stratigraphic section; in ascending order, these are the Ahrensiisporites cristasus, Crucisaccites monoleus, Vitattina costabilis and Luechisporites virkhiare Zones. The ranges of some species have been modified and new trends of investigation are suggested, including a definitive palynological study on the lithostratigraphical limits in order to understand environmental influences.

Key words: palynology, Paraná Basin, palynostratigraphy, Upper Paleozoic, Brazil.

Resumen: Se presenta una revisión y puesta al día de la palinoestratigrafía del Paleozoico Superior de la Cuenca Paraná (Brasil), sobre la base de un nuevo análisis de las propuestas anteriores sobre el tema y la incorporación de nuevos datos. La Biozona Cannanoporpolis kobaensis es renombrada como Biozona Vitattina costabilis y una de sus subzonas, la Sub-biozona Caheniasaccites ovatus, es considerada como perteneciente a la Sub-biozona Protohaploxypinus goraensis. Cuatro biozonas de intervalo caracterizan la sección, las Biozonas Ahrensiisporites cristasus, Crucisaccites monoleus, Vitattina costabilis y Luechisporites virkhiare, en orden estratigráfico. Modificaciones en los rangos de los principales taxones de esporas y granos de polen son presentados, así como nuevos desafíos en la resolución de algunos de los problemas estratigráficos y paleoambientales de la cuenca.

Palabras clave: palinología, Cuenca Paraná, palinoestratigrafía, Paleozoico Superior, Brasil.

The biostratigraphy of the Upper Paleozoic strata of the Brazilian Paraná Basin has been studied by several authors, who proposed different zonations based on plants, invertebrates and palynomorphs. Palynology seems to be the most efficient tool in providing biostratigraphic data for the Paraná Basin, because of the abundance, diversity and widespread distribution of spore-pollen assemblages. Radiometric data are scarce and there are no clear reference-levels with chronologically significant elements, like marine invertebrates, which could permit wide correlation and more accurate age calibration among the available biostratigraphic schemes.

Pioneering studies on Paraná Basin palynology were started in the 1960’s, related to oil and coal investigations. Then, regional and local schemes were proposed on distinct criteria and scales. Most of the papers concerned the southern part of the basin, especially the Rio Bonito Formation coal beds in Rio Grande do Sul and Santa Catarina States. Palynological data from the northeastern Paraná Basin has been meaningfully improved only during the past two decades.

This contribution aims to present an overview on this theme, including recent advances and new proposals, main problems, and new trends of investigation.

GEOLOGY AND PALEONTOLOGY SYNOPSIS

The Paraná Basin comprises a thick, widespread sedimentary-magmatic sequence, located in central-eastern South America, covering about 1,700,000 km² in area in Brazil, Uruguay, Argentina and Paraguay and reaching thicknesses of ca. 5,000 m (Fig. 1). According to Milani (1997), six supersequences represent the sedimentary record of this basin: Río Ivaí (related to the Rio Ivaí Group
of Ordovician-Silurian age), Paraná (Paraná Group, Devonian), Gondwana I (Tubarão and Passa Dois Groups, Carboniferous-Permian), Gondwana II (Triassic formations), Gondwana III (São Bento Group, Jurassic-Cretaceous) and Bauru Supersequence (Bauru Group, Cretaceous) (see Fig. 1).

The Gondwana I Supersequence corresponds to a major transgressive-regressive cycle. The Tubarão The Gondwana I Supersequence corresponds to a major transgressive-regressive cycle. The Tubarão Group is partially representative of the late Palaeozoic Gondwana glacial event. Its lower beds constitute the Itararé Subgroup, followed upwardly by the Rio Bonito and Palermo Formations (Guató Subgroup), comprising a transgressive cycle. These last units are correlated with the Tatuí Formation in the northeastern basin, and with the Aquidauna Formation, exposed in the northern portion.

The Passa Dois Group comprises the Irati, Serra Alta, Teresina and Rio do Rasto Formations, in ascending order. These last three units are represented in the north portion by the Corumbataí Formation. A summary on this lithostratigraphic subdivision and its geological significance is given by Milani et al. (1994).

The upper Palaeozoic sequence contains diverse and abundant fossils, representing marine, transitional marine to continental and continental environments. Its paleontological content includes invertebrates, vertebrates, plant remains and palynomorphs. Permo-Carboniferous invertebrates are related to the Euridesma Fauna and the plant remains are linked to the Preglossopteris and the Glossopteris Flora, very commonly found in the Lower Gondwana strata.
Palynological zonations have been proposed by Daemon (1966), Daemon & Quadros (1970), Bharadwaj et al. (1976), Saad (1977), Araújo (1980), Sundaram (1980, 1986), Marques-Toigo (1988, 1991) and Souza (2000). Souza & Marques-Toigo (2001) summarized the palynological succession, based on these previous papers, mainly on Daemon & Quadros (1970), Marques-Toigo (1988, 1991) and Souza (2000), which were based on substantial geographic and stratigraphic sampling. Furthermore, analysis of new samples were made and new data were introduced, and new species were selected as guides, in order to refine the palynological units.

**PALYNOSTRATIGRAPHY**

Further studies on this theme have been developed after Souza & Marques-Toigo (2001) and were synthesized herein. Changes in the palynzone names and occurrence and ranges of selected species are proposed preliminarily.

Four interval zones characterize the palynological succession of the Upper Palaeozoic strata of the Paraná Basin. These take into account spore-pollen distribution and horizons of appearance and disappearance of selected species.

A tentative correlation between these units and the previous proposal for the Paraná Basin is shown in the Figure 2. The ranges of the selected species of spores and pollen grains used as guides in these palynozones are shown in the Chart 1. The most important spore and pollen taxa are illustrated in the Figure 3.

Detailed biostratigraphic data, such as assemblage characteristics and stratotype section, will be given in subsequent papers.

**Ahrensisporites cristatus Interval Zone**

This zone is characterized by eleven stratigraphically restricted spore species: *Anapiculatisporites argentinensis*, *Raistrickia pinguis*, *Foveosporites hortonensis*, *Granulatisporites varigranifer*, *Ahrensisporites cristatus*, *Cristatisporites menendezii*, *C. inordinatus*, *C. spinosus*, *C. indignobundus*, *Cirrattriradites veversii*, and *Psomospora detecta*. It has been recognised in the lowermost Itararé Subgroup, in
the northeastern portion of the basin (São Paulo and Paraná States). Several palynofloras attributed to this palynozone occur in subsurface and outcrop samples in São Paulo State, like the ones at Araçoiaba da Serra (Lima et al., 1983; Souza, 1996; Souza et al., 2003), Buri (Souza et al., 1993; Souza, 2003) and Monte Mor (Souza et al., 1997) and others in Paraná State (Daemon & França, 1993; Souza, 2000).

**Crucisaccites monoletus Interval Zone**

This zone is characterized by the disappearance of restricted species of the former unit and by the appearance of *Scheuringipollenites maximus* and *Crucisaccites monoletus*. The latter species is stratigraphically restricted to this unit. The upper limit of the palynozone is marked by disappearance of several species of spores and pollen grains, such as *Cyclogranisporites firmus*, *Dibolisporites disfasciatus*, and *Potoniesporites triangulatus*, and by the appearance of characteristic species of the subsequent unit. This interval zone occurs in the northeastern portion of the basin and has been recognized from the lower to middle portion of the Itará Subgroup. Palynofloras of the Itaporanga subsurface (Di Pasquale et al., 2003a, 2003b), as well as from outcrops, such as Juniaí (Souza et al., 2000), Salto (Longhín, 2003) and in Paraná State (Souza, 2000), are included in this palynozone.

In these two palynozones, the most important genera of spores and monosaccate pollen grains include *Punctatisporites*, *Leiotiriletes*, *Lundbladispora*, *Vallatisporites*, *Cristatisporites*, *Cannanoropollis*, *Plicatipollenites*, *Potoniesporites*, and *Caheniasaccites*. A tentative correlation can be established with the *G*, *H*, and *H₂* intervals of Daemon & Quadros (1970), taking into account only pollen grains. Species stratigraphically restricted to the *Ahrensisporites cristas* Interval Zone were found from subsurface samples included within the *G* Interval (Daemon & Quadros, 1970), e.g. from the 2-PP-1-SP borehole. Correlations are indicated with Argentinean palynozones, i.e. *Ancistrasporea* and *Potoniesporites* palynozones of Azcue & Jelin (1980), or *Ratstrickiopsis densa-Convolutispora muriornata* Assemblage Biozone (Césari & Gutiérrez, 2001) of central western Argentina. Similarities are also evident with material from Tarija Basin belonging to the *Kraeuselisporites volkheinermii-Circumplacipollis plicatus* Superzone (Di Pasquale, 2003). According to Souza (2000) and Di Pasquale (2003), about 50% of the taxa are shared by the Carboniferous strata of these basins.

**Vittatina costabilis Interval Zone**

This palynozone was previously proposed as the *Cannanoropollis horkaensis* Interval Zone (Marques-Toigo, 1988, 1991). However, this pollen grain was recognized from the Lower Itará Subgroup (see Chart 1). Instead, the genus *Vittatina* occurs from a well marked biohorizon, related to the *H₂* subinterval (Daemon & Quadros, 1970).

Its lower limit is marked by the first appearance of the genus *Vittatina* (*V. saccata*, *V. saccata*, *V. costabilis*, *V. vittifera*), species of *Protohaploxypinus* (*P. goraiensis*, *P. micros*) and *Illinites unicus*. Pollen grains, in general more abundant than the spores, include species of *Caheniasaccites*, *Scheuringipollenites*, and *Vesicaspora*.

This palynozone is well represented in the Paraná Basin, and is now subdivided into two units, the *Protohaploxypinus goraiensis* and *Hamiapollenites karroensis* Subzones. The first is defined by the range of *P. goraiensis* and *Illinites unicus* and comprises coal bearing strata from the uppermost Itará Subgroup to the middle Rio Bonito Formation (Guatá Subgroup). These coal beds were previously referred to as the *Caheniasaccites ovatus* subzone (Marques-Toigo, 1991), which is here regarded as an ecofacies. Such spores as *Punctatisporites*, *Horriditiriletes*, *Lundbladispora*, *Cristatisporites*, and *Vallatisporites* are dominant in these coal beds. The *Hamiapollenites karroensis* Subzone is defined by the range of this species and by the first appearance of *Striatopodocarpites fuscus* and *Staurosaccites cordubensis*. It has been recognized in the uppermost Rio Bonito Formation.

Correlations can be made with the *H₁* intervals of Daemon & Quadros (1970). Closely correlated assemblages, commonly found from Argentina, are the *Cristatisporites Zone* (sensu Vergel, 1993) and the *Fusacolpites fuscus-Vittatina subsacca* Interval Biozone (Césari & Gutiérrez, 2001). Similar assemblages occur elsewhere in Gondwana, in Australia, India, Antarctica, Oman and Saudi Arabia (e.g., Jones & Truswell, 1992; Stephenson & Filatoff, 2000).

**Lueckisporites virkkiiae Interval Zone**

This zone is characterized mainly by the appearance of the genus *Lueckisporites* (*L. virkkiiae*, *L. densicorpus*) and species of *Staurosaccites* and *Weylandites lucifer*. These pollen grains, as well as species of *Protohaploxypinus*, *Striatopodocarpites*, *Striatobacteria*, *Lunatisporites* and *Marsupipollenites*, are dominant in this zone, reaching up to 80% of the association. Some species of spores
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and monosaccate pollen grains of the former units are also present and new species of the genera *Convolutispora* and *Thymospora* occur. This zone has been recognized from the uppermost Rio Bonito Formation, Palermo Formation (Upper Guatá Subgroup) to the Irati Formation (Lower Passa Dois Group), and is correlated with the K and L intervals of Daemon & Quadros (1970). Palynomorphs recovered from Serra Alta, Teresina and Rio do Rasto Formation are very scarce. Based on Daemon & Quadros (1970) and new unpublished data, they seem to correspond to the *Lueckisporites virkiiae* Interval Zone. Like the *Vittatina costabilis* Zone, this unit is widely known from the middle to late Permian Gondwana strata.

These last two palynozones are correlated with the H2-L intervals of Daemon & Quadros (1970), and occur throughout the Paraná Basin. Assemblages have been recovered from subsurface material (e.g., Daemon & Quadros, 1970; Picarelli et al., 1987), and from outcrops, the states of Rio Grande do Sul (e.g., Dellazzana, 1976; Ybert, 1975; Dias, 1993), Santa Catarina (Pons, 1977, 1978), Paraná (Marques-Toigo et al., 1981) and São Paulo State (Menéndez, 1976; Souza et al., 1999).

CONCLUDING REMARKS

New palynofloras have been recorded from the Paraná Basin in recent decades, especially from its northeastern portion, based on subsurface and surface samples. These studies have enabled refinement of the palynological succession. Certain changes in the range of diagnostic species of some previous zonation schemes are proposed and selected species are used as additional zonal criteria.

According to Daemon & Quadros (1970), *Plicatipollenites gondwanensis* (P906) appears from the I1 subinterval and *P. trigonalis* (P490) and *Cannanoropollis triangularis* (P501) would be restricted to the G Interval. These last two species were recorded in the Upper Itararé Subgroup in Rio Grande do Sul State (Dias, 1993) from strata assignable to the H2-L interval. Moreover, *P. gondwanensis* occurs from the base of the Itararé Subgroup in the northeastern basin, at Araçoiaba da Serra (Souza, 1996; Souza et al., 2003) and from its middle-upper portion at Itaporanga (Di Pasquio et al., 2003b). Additional information on the spore-pollen distribution in these intervals was given by Daemon & Quadros (1970) and Daemon (1981).

Late Carboniferous palynofloras have been recognized in the Lower and Middle Itararé Subgroup in São Paulo and Paraná States, northeastern basin. The Carboniferous ages assigned to these palynozones are based on the presence of diagnostic species, and on correlation between the main Gondwanan palynozones, especially from the Argentinian basins (e.g., Paganzo, San Rafael, Tarija and Chacoparaná basins), where the Carboniferous sequence are more complete. Radiometric data are scarce in the Paraná Basin, and absent in the Carboniferous sequence, limiting against accurate age calibration among the available palynostratigraphic schemes.

The subzones comprised in the *Vittatina costabilis* Zone have been reanalysed in order to find biohorizons of significant floral changes. The *Caheniasaccites ovatus* Subzone (sensu Marques-Toigo, 1991) seems to be related to a restricted facies, i.e., the southern Brazilian coal beds in Santa Catarina and Rio Grande do Sul States. The taeniate pollen *Protohaploxypinus goraensis* and *Illinites unicus* range from the base of the *Protohaploxypinus goraensis* Subzone to the base of the *Hamiapollenites karroensis* Subzone, and are used herein as guides to this subzone.

Lithostratigraphic boundaries are not coincident with the main biohorizons. The *Vittatina costabilis* Interval Zone includes the Upper Itararé Subgroup and part of the Rio Bonito Formation. No significant biostratigraphic difference has been recorded in these sections, despite lithological changes in the basin. The boundary between the *Vittatina costabilis* and *Lueckisporites virkiiae* Interval Zones is recorded in the Upper Rio Bonito Formation and the Lower Palermo Formation, and is related to the J/K intervals (Daemon & Quadros, 1970).

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REFERENCES


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Appendix. List of taxa.

Spores
Ahrensissporites cristatus Playford & Powis
Anapaticlissopites argentensis Azcuy
Bascaudaspora canipa Owens
Brevitrites levis (Balme & Hennelly) Bharadwaj & Srivastava
Cirratritidites veversii Playford
Conosulataspora Hoffmeister, Staplin & Malloy
C. martinnata Menéndez
C. ordonenzi Archangelsky & Gammero
Cristatisporites (Potonié & Kremp) Butterworth et al.
C. inconstans Archangelsky & Gammero
C. indignabundus (Potonié & Kremp) Staplin & Janssionius
C. inordinatus (Menéndez & Azcuy) Playford
C. menendezii (Menéndez & Azcuy) Playford emend. Césari
C. spinosus (Menéndez & Azcuy) Playford emend. Césari
C. stellatus (Azcuy) Gutiérrez & Limarino
Cytyroganissopites firmus Jones & Truswell
Dibolissopites disfacies Jones & Truswell
Foveosporites hortonensis (Playford) Azcuy
Granulatisporites austroamericanus Archangelsky & Gammero
G. confluens Archangelsky & Gammero
G. triconvexus Staplin
G. varigonifer Menéndez & Azcuy
Horriditrites Bharadwaj & Saluja
Kraeuselissopites volkheimerii Azcuy
Leiotritites (Numova) Potonié & Kremp
Lundbladispora (Balme) Playford
Lundbladispora riobitionensis Marques-Toigo & Picarelli
Pseudoaspispora detecta Playford & Helby
Punctatisporites (Ibrahim) Potonié & Kremp

Raistrickia paganciana Azcuy
R. pinguis Playford
R. rotunda Azcuy
Speleotritites ybertii (Marques-Toigo) Playford & Powis emend. Playford, Dino & Marques-Toigo
Thymospora (Wilson & Venkatachala) Alpern & Doubinger
Vallatisporites Hacquebard
Vallatisporites ciliaris (Luber) Sullivan

Pollen grains
Caheniasacites Bose & Karend. Azcuy & Di Pasquo
Cannanoropollis Potonié & Sah
Cannanoropollis horbaensis (Bharadwaj & Tiwari) Foster
C. triangularis (Mehta) Bose & Maheshwari
Costapolliennes ellipticus Tschudy & Kosanke
Cruciasacites monoletus Maithy
Dicarissacites stringoplicatus Ottone
Hanttiapolliannites fusiformis (Marques-Toigo) Archangelsky & Gammero
H. harroensis Hart
Ilinites unicus Kosanko emend. Janssionius & Hills
Lueckisporites (Potonié & Klaus) Klaus
Lueckisporites densicorpus Archangelsky & Gammero
L. stenoamericanus Menéndez
L. virkhiensis (Potonié & Klaus) Klaus
Lunatisporites (Leschki) Scheuring
Marsupolliennes triradiatus Balme & Hennelly
Marsupolliennes (Balme & Hennelly) Balme
Marsupolliennes triradiatus Balme & Hennelly
Pakhapites fasciolatus (Balme & Hennelly) Hart
Plicatilipollis Lele
Plicatipollenites gondwanensis (Balme & Hennelly) Lele
P. trigonalis Lele
Potonieisporites Bhardwaj emend. Bhardwaj
P. congoensis Bose & Maheshwari
P. novicus Bhardwaj emend. Poort & Veld
P. triangulatus Tiwari
Protohaploxypinus Samoilovich emend. Morbey
P. geraiensis (Ptonié & Lele) Hart
P. hartii Foster
P. micros (Hart) Hart
P. sewardii (Virkki) Hart
Scheuringipollenites Tiwari
Scheuringipollenites maximus (Hart) Tiwari
Staurosaccites Dolby
Staurosaccites cordubensis Archangelsky & Gamorro
Stellapollenites talchirensis Lele
Striatopodocarpites (Zoricheva & Sedova ex Sedova) Hart
Striatopodocarpites fuscus (Balme & Hennelly) Ptonié
S. pantii (Jansonius) Balme
Vesicaspora Schemel
Vittatina (Luber) Wilson
Vittatina costabilis Wilson
V. saccata (Hart) Jansonius
V. subsaccata Samoilovich
V. vittifera (Luber & Waltz) Samoilovich
Weylandites lucifer (Bhardwaj & Srivastava) Foster