



Biostratigraphy and paleoecology of an unusual palynological record from the Aquidauana Formation, Late Pennsylvanian of Paraná Basin

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ABSTRACT

The Aquidauana Formation is a Permo-Carboniferous sedimentary unit, widely stratigraphically distributed in the northwestern and northern portions of the Paraná Basin. However, little paleontological data is available from this formation, preventing accurate biostratigraphic and paleoecological interpretations. An abundant, diversified and well preserved assemblage of palynomorphs was recognized from sampling conducted in an outcrop section in Cipolândia District of Aquidauana Municipality, state of Mato Grosso do Sul, Brazil. A total of 35 indigenous palynomorph taxa was recognized, comprising 6 species of spores (related to 5 genera), 28 species of pollen grains (14 genera) and 1 species of chlorophycean algae. Monosaccate pollen grains are exceptionally dominant, representing 90.38% of the association, particularly constituted by species of the genera *Cannanoropollis* (30.41% of the total assemblage), *Potonieisporites* (28.14%) and *Plicatipollenites* (19.52%). This quantitative overrepresentation is not usual from Gondwana deposits, revealing a particular plant dominance of Cordaitales in the terrestrial flora. These results are interpreted as an upland ecology characterized by plants with a moisture-independent reproduction strategy, under a glacial climate influence. Certain species of pollen allow assignment of this assemblage to the *Crucisaccites monoletus* Zone (Late Pennsylvanian), which had been recognized only in the middle portion of the Itararé Group at the northeastern margin of the basin.

Key words: biostratigraphy, paleoecology, palynology, Pennsylvanian.

INTRODUCTION

The northwestern margin of the Paraná Basin exhibits a thick section of sedimentary outcrops, related to the Furnas, Ponta Grossa (both of Devonian age) and the Aquidauana (Permo-Carboniferous) formations. The Aquidauana Formation is mainly composed of sandstones and diamictites, and it is laterally

correlated with the Itararé Group (França and Potter 1988, Milani et al. 2007). This unit, as well as the Itararé Group and correlated units in South America and Africa are representatives of the Upper Paleozoic glacial event in the Western Gondwana. Fossils of different nature are well known from these glaciogenic units, such as those from the Itararé Group, comprising plant remains, palynomorphs, vertebrates and invertebrates, allowing significant

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biostratigraphic and paleoecological contributions (see summary in Holz et al. 2010). However, paleontological records from the Aquidauana Formation are very scarce and when present, they describe sporadic isolated few fossil specimens.

The fossil content of the Aquidauana Formation in the state of Mato Grosso do Sul comprises one record of an ichnofossil (invertebrate traces), records of fish scales (Paleoniscids), one fragment of insect wing, indeterminate plant remains (see synthesis in Scheffler et al. 2010), and limited palynomorphs (Daemon and Quadros 1970). These scarce, low variety and sparse occurrences prevent adequate age attributions as well as limiting paleoenvironmental reconstructions.

Palynomorphs listed from the Aquidauana Formation concern few specimens of pollen grains, some of them with open nomenclature (Daemon and Quadros 1970). This palynological content is relatively poor when compared with associations derived from the northeastern and south portions of the basin, preventing accurate correlations.

Efforts have been made recently, attempting new palynological studies from outcrop samples of the Aquidauana Formation. However, samples are generally barren of palynomorphs, with only semi-destroyed phytoclasts and amorphous organic matter recorded. These limitations are attributed to the lithological nature of the outcrops, with sediments primarily comprised of red to yellow sandstones and diamictites with high degree of weathering, indicating deposition in oxidizing conditions (see Milani et al. 2007), where palynomorphs are generally destroyed by oxidation.

This paper presents new palynological records from the Aquidauana Formation derived from an outcrop section located at Cipolândia, state of Mato Grosso do Sul, Brazil, from an expressive and unusual layer of shale, once this lithology is rare or absent in the Aquidauana Formation. These data were preliminarily presented by Souza et al. (2013), who registered several species of spores and

pollen grains, which amplify the paleontological content to this unit, with biostratigraphical and paleoenvironmental significance.

MATERIALS AND METHODS

The outcrop section studied comprises ca. 50 m of sediment, exposed on the state road MS-447, approximately 12 km from the east/northeast of the Cipolândia District, in the municipality of Aquidauana, state of Mato Grosso do Sul (Fig. 1). The sampled section (Fig. 2a) is comprised, in ascending stratigraphic order, of a massive diamictite (Fig. 2b), with faceted and striated polymitic pebbles, cobbles and boulders, of variable dimensions (decametric to metric), chaotically distributed within a silty-sandy matrix. This diamictite is stratigraphically followed by a sandstone package (Fig. 2c and d), of varied granulometry, exhibiting planar and trough cross-stratification (in sets sometimes separated by marked surfaces of pebbles and cobbles), with rare matrix and dispersed pebbles. A thin layer of dark grey to greenish shale occurs in the upper portion of the section (Fig. 2e), with varying degrees of weathering, and rare dropstones.

Three samples (AQ-84, 86 and 87, see figs. 1c and 2a) were processed according to the standard palynological technique for Paleozoic materials (Quadros and Melo 1987), which comprises the removal of carbonates and silicates by using hydrochloric and hydrofluoric acids. Palynomorphs within the 10-250 μm size range were concentrated in the final organic residues, from which glass slides were mounted with polyester resins. Taxonomic identifications and photomicrographs were made under a standard optical microscope. The slides are housed at the Paleontological Museum of the Rio Grande do Sul Federal University (UFRGS), under codes MP-P (AQ-84: MP-P 8920, 10259; AQ-86: 8921; AQ-87: 8919, 10257, 10258). All palynomorphs recorded from the AQ-87 outcrop (geographic coordinates 678,346 E and 7,773,846 N) were considered in the quantitative analysis,

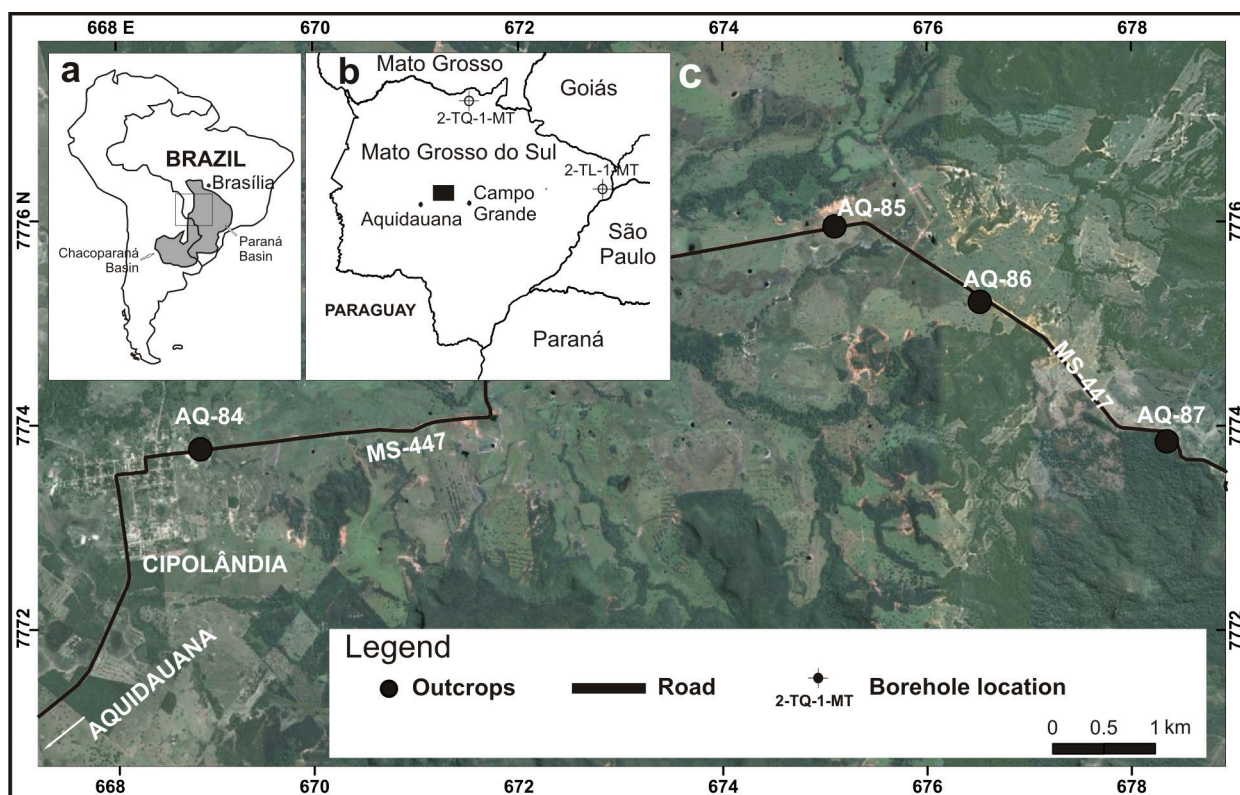


Figure 1 - Location of study area. (a) Paraná and Chacoparaná Basins in South America, with indication of area in b; (b) Location of area and boreholes previously study by Daemon and Quadros (1970) in the state of Mato Grosso do Sul, Brazil; (c) Outcrops studied nearby Cipolândia, based on Google Earth Image.

totalizing 707 taxa considered indigenous and another 17 reworked from older strata.

RESULTS

Among the three processed samples, only which derived from the AQ-87 outcrop revealed a significant palynological assemblage, with potential for biostratigraphical and paleoecological interpretations. The other samples presented limited palynomorphs, with poor preservation, dominated by degraded phytoclasts and amorphous organic matter.

The AQ-87 assemblage is composed of diverse, well preserved and abundant palynomorphs, comprising 35 species of indigenous taxa, related to 6 species of spores (related to 5 genera), 28 species of pollen grains (14 genera) and 1 species of chlorophycean algae, as listed in table I.

Furthermore, reworked species of spores, acritarchs and prasinophycean algae were also registered. Photomicrographs of selected species are presented in figures 3 and 4.

Palynomorphs from AQ-87 outcrop are very well preserved, rarely showing fragmentation or corrosion. Phytoclasts are subordinate, comprising opaque and non-opaque (brown to dark yellow) types, including fragments of cuticles and tracheids, generally with angular sides, elongated to equidimensional in shape. Interestingly and exceptionally, three specimens of indigenous pollen grains, present evidence of shearing, containing breaking but with no complete fragmentation of the grain. This is a type of taphonomic damage compared to those in Devonian palynomorphs described by Arai and Melo (2003).

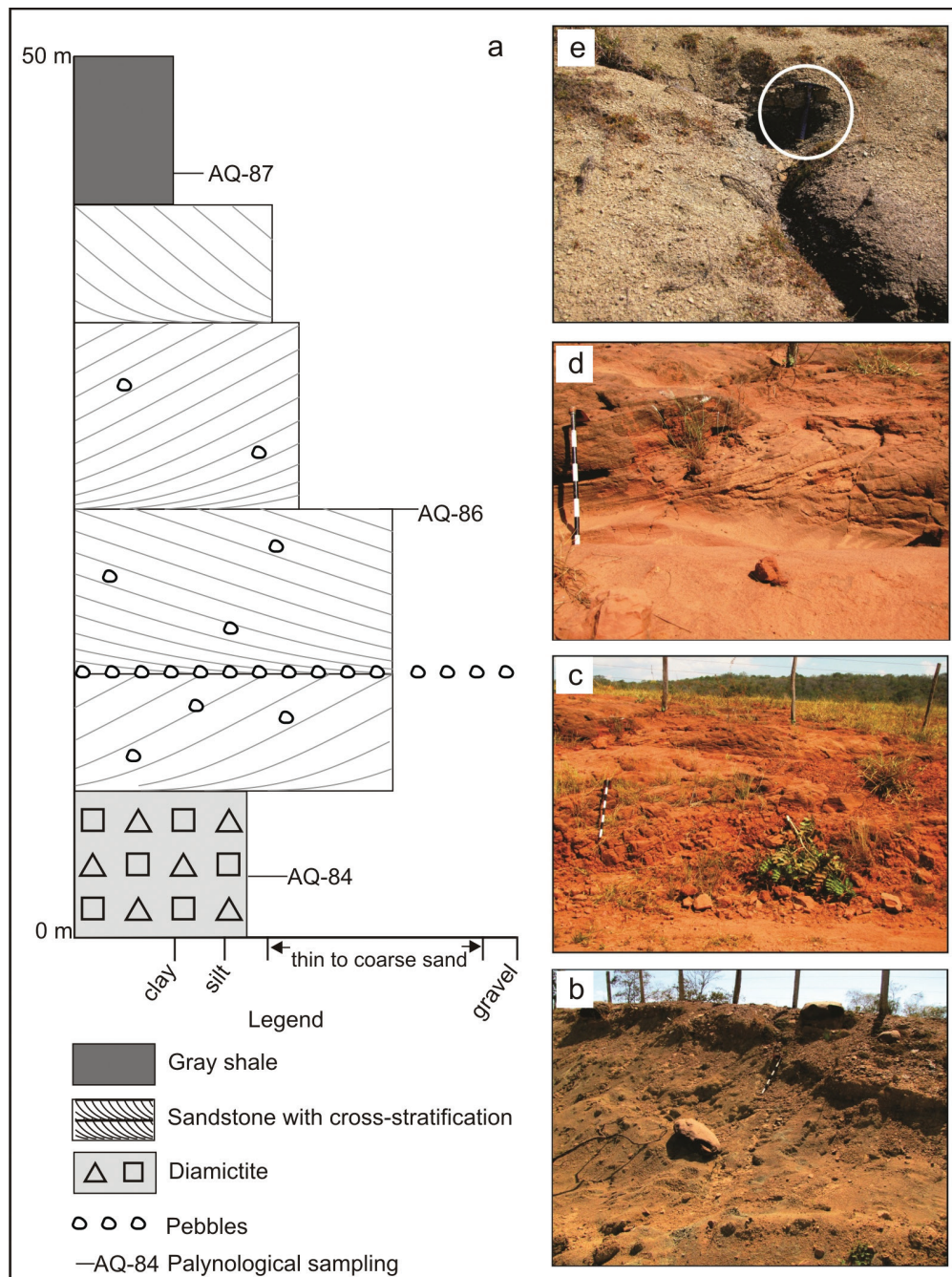


Figure 2 - Outcrops and general stratigraphy. **(a)** Columnar section of the outcrops sampled along the Road MS-447; **(b)** AQ-84: diamictites with submetric clasts; **(c and d)** AQ-86: medium to thick sandstones, with dispersed clasts and planar/trough cross-stratification; **(e)** AQ-87: grey shale. Scale in b, c and d has spacing intervals of 10 cm; hammer as scale in a.

In terms of quantitative analysis, 707 specimens are considered coeval to the sediments (see Table II). In order of dominance, monosaccate pollen grains represent 90.38% (mainly species of

the genera *Cannanoropollis*, *Potonieisporites* and *Plicatipollenites*), spores 5.66%, bisaccate pollen grains 2.26% and chlorophycea algae (*Botryococcus braunii*) 1.70%.

TABLE I
List of palynomorphs recorded in this paper from the Aquidauana Formation and respective illustrations in Figures 3 and 4.

Spores	Fig.
<i>Calamospora</i> sp.	3.a
<i>Punctatisporites gretensis</i> (Hart) Balme and Hennelly 1956	3.b
<i>Convolutispora</i> sp.	3.c
<i>Cristatisporites inconstans</i> Archangelsky and Gamarro 1979	3.d
<i>Lundbladispota riobonitensis</i> Marques-Toigo and Picarelli 1984	
<i>L. braziliensis</i> (Pant and Srivastava) Marques-Toigo and Pons emend. Marques-Toigo and Picarelli 1984	
Pollen grains	
<i>Florinites occultus</i> Habib 1966	3.l
<i>Costatascyclus crenatus</i> Felix and Burbridge 1967	4.f
<i>Cannanoropollis janakii</i> Potonié and Sah 1960	3.e
<i>Cannanoropollis densus</i> (Lele) Bose and Maheshwari 1968	3.g
<i>Cannanoropollis triangularis</i> (Mehta) Bose and Maheshwari 1968	3.f
<i>Cannanoropollis mehtae</i> (Lele) Bose and Maheshwari 1968	
<i>Plicatipollenites malabarensis</i> (Potonié and Sah) Foster 1975	3.h
<i>Plicatipollenites densus</i> Srivastava 1970	3.i
<i>Plicatipollenites trigonalis</i> Lele 1964	
<i>Circumplicatipollis plicatus</i> Ottone and Azcuy 1988	
<i>Divarisaccus stringoplicatus</i> Ottone 1991	3.k
<i>Crucisaccites latisulcatus</i> Lele and Maithy 1964	
<i>Crucisaccites monoletus</i> Maithy 1965	3.j
<i>Stellapollenites talchirensis</i> Lele 1965	
<i>Caheniasaccites flavatus</i> Bose and Kar emend. Azcuy and Di Pasquo 2000	4.g
<i>Caheniasaccites verrucosus</i> (González-Amicón) Gutiérrez 1993	
<i>Potonieisporites novicus</i> Bhardwaj emend. Poort and Veld 1997	4.a
<i>Potonieisporites neglectus</i> Potonié and Lele 1961	
<i>Potonieisporites barrelis</i> Tiwari 1965	4.b
<i>Potonieisporites densus</i> Maheshwari 1967	4.e
<i>Potonieisporites congoensis</i> Bose and Maheshwari 1968	4.d
<i>Potonieisporites magnus</i> Lele and Karim 1971	3.m
<i>Potonieisporites triangulatus</i> Tiwari 1965	4.i
<i>Potonieisporites lelei</i> Maheshwari 1967	4.c
<i>Gondwanapollis</i> sp.	
<i>Meristocarpus explicatus</i> Playford and Dino 2000	4.h
<i>Scheuringipollenites maximus</i> (Hart) Tiwari 1973	4.j
<i>Limitisporites rectus</i> Leschik 1956	
Chlorophyceae algae	
<i>Botryococcus braunii</i> Kützing 1849	4.k

Reworked taxa are represented by 17 specimens, corresponding to Prasinophycean algae (*Maranhites* spp., *Tasmanites* spp., *Navifusa bacilla*), acritarchs (*Gorgonisphaeridium* spp.) and spores (*Grandispora* spp., *Emphanisporites rotatus*, *Geminispora lemurata* and *Retusotriletes crassus*). In comparison with the coeval palynomorphs, no difference was observed in their preservation (color or fragmentation degree).

DISCUSSION

BIOSTRATIGRAPHY

The palynostratigraphic proposal of Daemon and Quadros (1970) is the only available zonation that encompasses the Aquidauana Formation in the north and northwestern portion of the basin (Fig. 5). According to those authors, the G, H and I intervals

TABLE II
Absolute amount and relative
frequency of palynomorphs.

Group of coeval palynomorphs	Absolute amount	%
Spores	40	5.66
Monosaccate pollen grains	639	90.38
<i>Caheniasaccites</i>	29	4.10
<i>Cannanoropollis</i>	215	30.41
<i>Circumplicatipollis</i>	3	0.42
<i>Costatacycclus</i>	3	0.42
<i>Crucisaccites</i>	12	1.70
<i>Divarisaccus</i>	34	4.81
<i>Florinites</i>	2	0.28
<i>Plicatipollenites</i>	138	19.52
<i>Potonieisporites</i>	199	28.14
<i>Meristocarpus</i>	2	0.28
<i>Stellapollenites</i>	2	0.28
Bisaccate pollen grains	16	2.26
<i>Gondwanapollis</i>	1	0.14
<i>Limitisporites</i>	2	0.28
<i>Scheuringipollenites</i>	13	1.84
Chlorophyceae algae	12	1.70
Total	707	100.00

were recognized from the Aquidauana Formation. These intervals were mainly recorded from core samples of the 2-TL-1-MT borehole (Três Lagoas). Palynomorphs were also recorded by those authors from the 2-TQ-1-MT borehole (Taquari) and the A284 outcrop (“Colônia Merure”), but assemblages are scarcer and lack diversity and are less accurate for biostratigraphy. The approximate location of these last boreholes is indicated in Fig. 1b; location of the A284 outcrop is not available from the original paper of Daemon and Quadros (1970).

Taking into account the assemblage recorded here, a general correlation could be made with the subsurface cores T19 to T21 of the 2-TL-1-MT, where the intervals G-H₃ were recognized. A correlation with a younger interval is unable due the presence of *Stellapollenites talchirensis* (originally designated as “P393” by Daemon and Quadros 1970) and *Protohaploxylinus goraiensis* (designated as *Protohaploxylinus* sp. “P391”) from the samples of this borehole. Both species are absent in the

AQ-87 assemblage and they are, according to new palynostratigraphic interpretations presented here, guide species for higher stratigraphic levels within the correlated Itararé Group, as discussed below.

According to Souza and Marques-Toigo (2005) and Souza (2006), four interval zones based on spore-pollen taxa are distributed through the Gondwana I Supersequence of the Paraná Basin (see Fig. 5): *Ahrensiporites cristatus* (AcZ), *Crucisaccites monoletus* (CmZ), *Vittatina costabilis* (VcZ) and *Lueckisporites virkkiae* (LvZ). The AcZ and CmZ are Pennsylvanian in age (equivalent to the G-H₂ intervals of Daemon and Quadros 1970), whilst VcZ and LvZ (equivalent to the H₃-L₃ intervals) are Cisuralian to early Guadalupian in age (Early to Middle Permian), according to Holz et al. (2010) and Mori et al. (2011). The Pennsylvanian zones of Souza (2006) are yet to be found outside the area where they were erected, stratigraphically corresponding to the basal to middle deposits of the Itararé Group, in the states of São Paulo and Paraná.

In general, both AcZ and CmZ as well as the intervals G-H₃ present palynological assemblages dominated by spores and monosaccate pollen grains. Among the latter, radiometric and bilateral taxa are more common, mainly represented by species of *Plicatipollenites*, *Cannanoropollis* and *Potonieisporites*, as verified in the AQ-87 assemblage of the Aquidauana Formation.

Certain guide palynomorph from the zonation of Souza (2006) were recorded from the AQ-87 sample assemblage, allowing biostratigraphic calibration. Among them, *Crucisaccites monoletus* and *Scheuringipollenites maximus* are the only pollen species stratigraphically restricted to the CmZ, confirming this biozone attribution. This biostratigraphic assignment represents a more detailed refinement in comparison to the intervals of Daemon and Quadros (1970), whereby the association of the AQ-87 would correspond to the G-H intervals, with ages between the Late Pennsylvanian to the Early Permian.

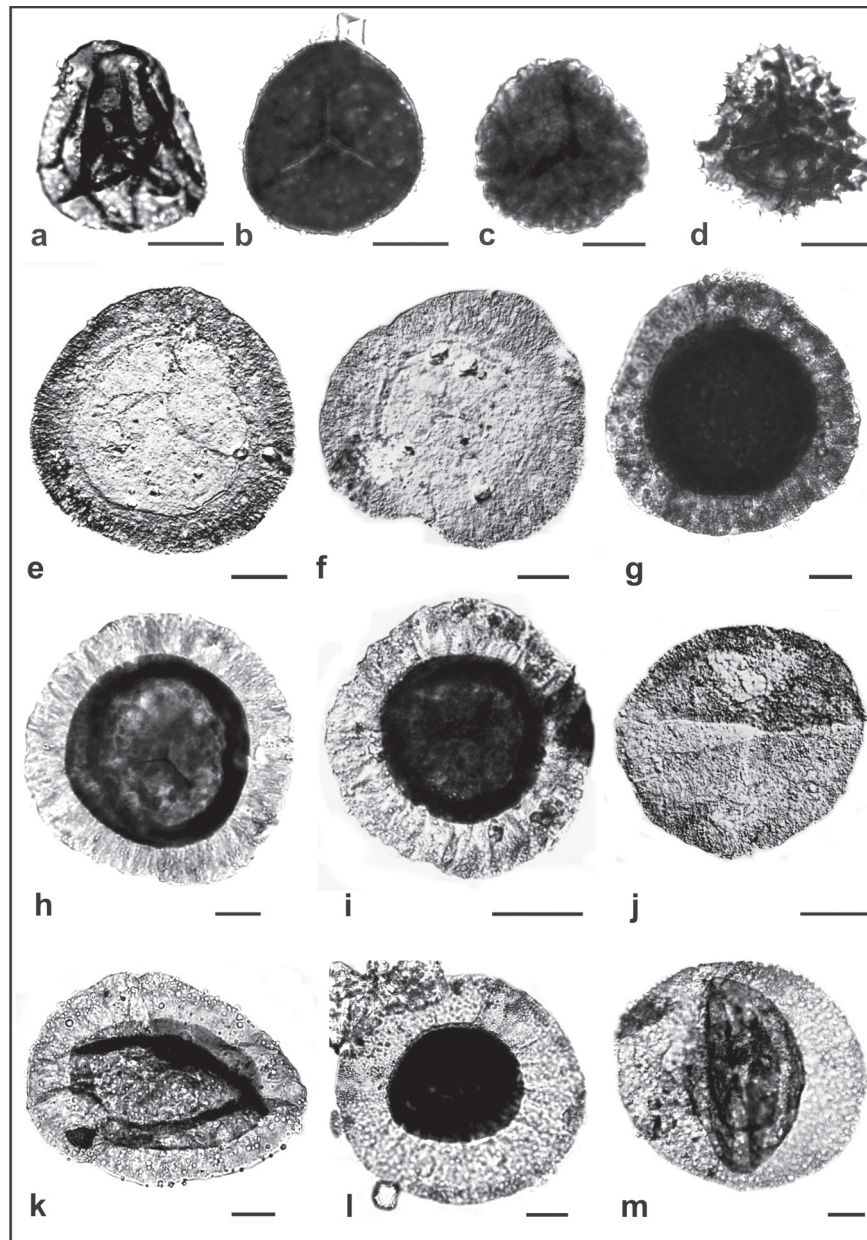


Figure 3 - Photomicrographs of selected palynomorphs. **(a)** *Calamospora* sp., slide MP-P 8919, England Finder coordinate J37-2, **(b)** *Punctatisporites gretensis*, 10257, V36; **(c)** *Convolutispora* sp., 10257, L47; **(d)** *Cristatisporites inconstans*, 10258, N48; **(e)** *Cannanoropollis janakii*, 10257, U44; **(f)** *Cannanoropollis triangularis*, 10257, T43-2; **(g)** *Cannanoropollis densus*, 10257, R31-4; **(h)** *Plicatipollenites malabarensis*, 8919 W60; **(i)** *Plicatipollenites densus*, 8919, Q43; **(j)** *Crucisaccites monoletus*, 8919, V36-2; **(k)** *Divarisaccus stringoplicatus*, 8919, S32; **(l)** *Florinites occultus*, 10258, O41-3; **(m)** *Potonieisporites magnus*, 8919, V47. Scale bar corresponds to 20 μm .

Besides palynomorph taxa considered coeval, species of spores (*Retusotriletes crassus*, *Geminospora lemurata*, *Emphanisporites rotatus*,

Grandispora spp.), acritarch and prasinophycean algae (*Navifusa bacilla*, *Maranhites* spp., *Tasmanites* spp., and *Gorgonisphaeridium* spp.) from older strata

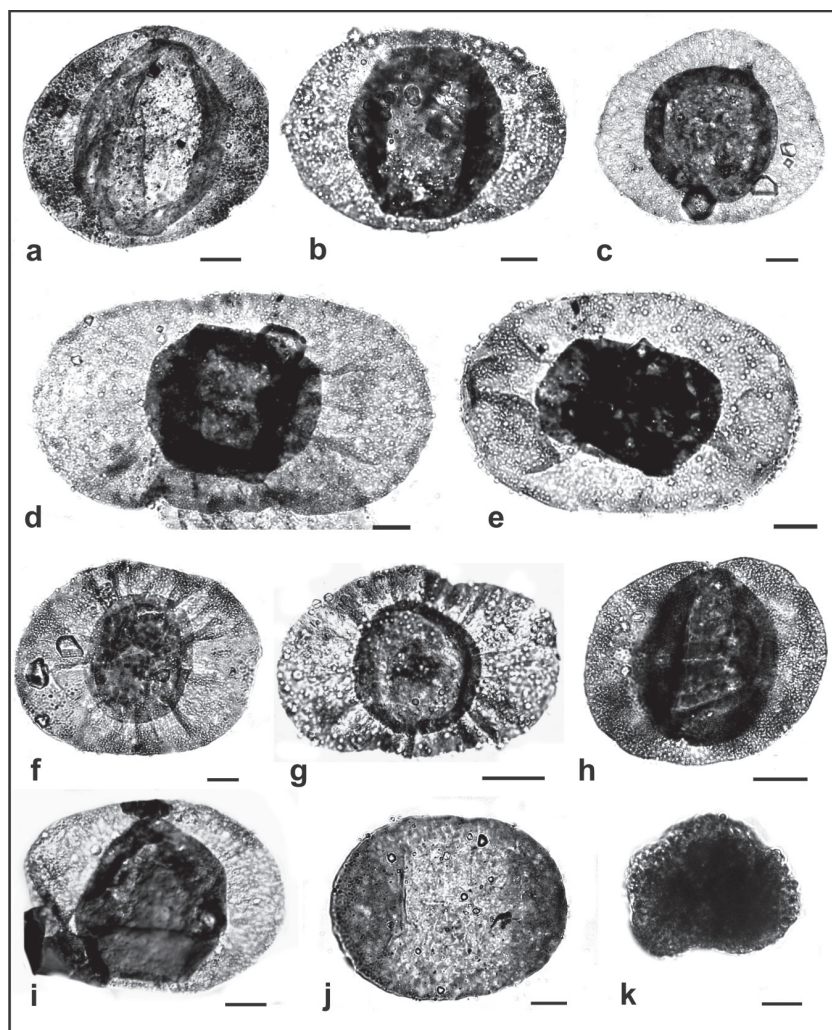


Figure 4 - Photomicrographs of selected palynomorphs. **(a)** *Potonieisporites novicus*, slide MP-P 10257, England Finder coordinate T38; **(b)** *Potonieisporites barrelis*, 8919, E53; **(c)** *Potonieisporites lelei*, 8919, W52; **(d)** *Potonieisporites congoensis*, 10257, W48-4; **(e)** *Potonieisporites densus*, 8919, V54; **(f)** *Costatascyclus crenatus*, 10257, F42; **(g)** *Caheniasaccites flavatus*, 8919, B53-4; **(h)** *Meristocarpus explicatus*, 8919, U52-2; **(i)** *Potonieisporites triangulatus*, 8919, K41-2; **(j)** *Scheuringipollenites maximus*, 10257, U42; **(k)** *Botryococcus braunii*, 10257, M40. Scale bar corresponds to 20 μm .

were found, interpreted as reworked (17 specimens in total). For the most part, these specimens are well preserved with no evidence of damage during reworking, such as color differentiation or fragmentation. These features are very common from the basal and middle portions of the Itararé Group (see Souza and Petri 1998, Souza 2006), where AcZ and CmZ are present.

PALEOECOLOGY AND PALAEOENVIRONMENT

Spores and monosaccate pollen grains are dominant within the palynological assemblages from Pennsylvanian to early Permian Gondwanan deposits. This pattern of representation is interpreted as a general tendency for spore-pollen distribution across Gondwana (Venkatachala et al. 1995, Felix et al. 2007, Stephenson 2008). However, dominance

Geochronology				Palynostratigraphy			
Period	Epoch	Stage	Age (Ma)				
PERMIAN	Lopingian	Changhsingian	251.0 ± 0.4	Daemon and Quadros (1970)		Souza and Marques-Toigo (2003, 2005) and Souza (2006)	
		Wuchiapingian	253.8 ± 0.7				
		Capitanian	260.4 ± 0.7	L ₃	<i>Lueckisporites virkkiae</i> Interval Zone		<ul style="list-style-type: none"> ▪ Dominance of taeniate and polyplicate pollen grains (<i>Lueckisporites</i>, <i>Lunatisporites</i>, <i>Weylandites</i>) ▪ Rare spores (<i>Laevigatosporites</i>, <i>Thymospora</i>, <i>Convolutispora</i>) and monosaccate pollen grains ▪ Appearance of <i>Lueckisporites</i>
	Wordian	265.8 ± 0.7	L ₂				
	Roadian	268.0 ± 0.7	L ₁				
	Cisuralian	Kungurian	270.6 ± 0.7	K		<i>Vittatina costabilis</i> Interval Zone	<ul style="list-style-type: none"> ▪ Low to high frequency of taeniate and polyplicate pollen grains ▪ Local dominance of trilete spores (coal beds) ▪ Appearance of <i>Vittatina</i> and <i>Illinites</i>
		Artinskian	275.6 ± 0.7	J			
		Sakmarian	284.4 ± 0.7	I	I ₂ + I ₃ + I ₄	<i>Hamiapollenites karroensis</i> Subzone	
		Asselian	294.6 ± 0.8	I ₁	H ₃	<i>Protohaploxypinus goraiensis</i> Subzone	
	UPPER CARBONIFEROUS	Pennsylvanian	Gzhelian	299.0 ± 0.8	H		<i>Crucisaccites monoletus</i> Interval Zone
Kasimovian			303.9 ± 0.9	H ₂			
Moscovian			306.5 ± 1.0	H ₁			
Bashkirian			311.7 ± 1.1	G		<i>Ahrensisporites cristatus</i> Interval Zone	
			318.1 ± 1.3				

Figure 5 - Correlation of main Pennsylvanian/Permian palynozones proposed for the Brazilian part of the Paraná Basin and their most important characteristics (modified from Souza 2006).

of monosaccate pollen over spores are not rare, with several occurrences in distinct parts of Gondwana, most part concerning to glacial deposits, such as in South America (Azcuy 1979, Playford and Dino 2000), India (Tiwari and Tripath 1992, Srivastava and Agnihotri 2009), Antarctica (Lindström 1995) and Australia (Balme 1980, Backhouse 1991, Jones and Truswell 1992). In these cases, radiosymmetric and bilateral monosaccate pollen mostly belonging to the genera *Cannanoropollis*, *Plicatipollenites* and *Potonieisporites* are well represented in terms of abundance and/or diversity.

In the Brazilian area of the Paraná Basin, dominance of monosaccate pollen grains over spores was presented from distinct deposits of the glaciogenic Itararé Group, in different stratigraphical levels, concerning its basal (Souza et al. 2003), middle

(Di Pasquo et al. 2003) and upper (Gandini et al. 2007) portions. Although absolute frequencies were not always stated by those authors, none of these records from the Paraná Basin exhibit such dominance by this group of pollen grains, as observed herein.

Pollen related to *Plicatipollenites*, *Cannanoropollis* and *Potonieisporites* were derived from a primitive, monosaccate-producing gymnosperm (Balme 1995), related to Late Paleozoic arboreal plants (probably Cordaitales) characterized by a moisture-independent reproduction strategy, representing an upland flora (Stephenson and Osterloff 2002). Cordaitales are an extinct group of Gymnosperm, of widespread distribution within Pennsylvanian to Permian deposits, variable in habit (mainly arboreal) and ecological requirements. These plant remains have also been reported from

deposits of poorly drained soils (Wagner 2001). Although macrofloristic remains of this taxon are more frequent in swamp environments, as a coal-forming component, palynological associations are generally dominated by spore-producing taxon, mainly lycopsids and subordinately sphenopsids and filicopsids as demonstrated by Cazzulo-Klepzig et al. (2005) and Boardman et al. (2012) from Permian coals of the Paraná Basin.

Thus the higher frequency of these monosaccate three genera in the AQ-87 Aquidauana association is unusual in palynological records from Pennsylvanian to Permian Gondwana strata. This evidence can be explained, according to Stephenson and Osterloff (2002), by a monosaccate-producing upland ecology and a lowland fern ecology in Gondwana, being influenced by a cold climate during the Permo-Carboniferous. According to those authors, the monosaccate-producing flora was present in upland areas during occupation of floodplains by the cold climate fern community; lacustrine flooding resulting from minor deglaciation events could prevent the persistence of lowland spore-producing plants and, consequently, the increase in representation of the upland flora. Spores and bisaccate pollen grains are very scarce, both representing less than 8% of the total assemblage (see table II). Bisaccate pollen grains are more abundant in Gondwana basins from deposits overlying glaciogenic units, as a result of climate amelioration, representing a changeover of the upland ecology.

This scenario is also supported by the lithofaciological analysis. The section is interpreted as representing a fining upward cycle, as result of a decrease energy, characterizing an event in the front of glacial retreat and subsequent flooding. Although rare, dispersed dropstones within the shale, indicates glacial influence. The continental nature of the sedimentation is confirmed by the presence of *Botryococcus*, a chlorophycean algae typical of freshwater (Batten and Grenfell 1996). No marine sedimentary or palynological evidence was recorded.

CONCLUSIONS

This paper examines a well preserved assemblage of palynomorph, comprised by taxa of spores, pollen grains and chlorophycean algae which contribute new ideas concerning the relative age and paleoecology of the Aquidauana Formation, northwestern Paraná Basin. Predominance of oxidized sandstones, conglomerates and diamictites harms preservation of palynomorphs, which become very rare in the Aquidauana Formation; here we sampled a productive shale layer, which is an uncommon lithology in this unit.

The presence of *Crucisaccites monoletus* and *Scheuringipollenites maximus* allowed correlation with the *Crucisaccites monoletus* interval Zone (CmZ) previously established in the northeastern area of the basin. It implies a late Late Pennsylvanian age and a biostratigraphical correlation of the studied section of the Aquidauana Formation with the middle portion of the Itararé Group, both glaciogenic in origin. It is the first recognition of this Pennsylvanian interval zone outside the area it was erected (states of São Paulo and Paraná), demonstrating a wider area of continuous deposition. However, the age span of Aquidauana Formation reaches the Early Permian, when taking into account previous subsurface data with typical guide species of the *Vittatina costabilis* Zone.

An unusually dominant monosaccate pollen grain representation (90.38%) was recorded from the Aquidauana association, particularly Cordaitales pollen types, such as *Cannanoropollis*, *Plicatipollenites* and *Potonieisporites*, which represent up to ca. 78% of the total assemblage. Considering other similar records throughout Gondwanan basins, a relationship with glaciogenic deposits of Late Pennsylvanian and Early Permian ages is inferred. The paleoecological significance of these data suggests predominance of an upland ecology characterized by plants with a moisture-independent reproduction strategy. A continental

interpretation is indicated by palynological and sedimentological evidence, characterizing deposition in the front of retreating glacier, with consequent flooding of the lowland areas. Palynological association is derived almost exclusively from upland surrounding areas, where a Cordaitales flora was dominant.

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RESUMO

A Formação Aquidauana é uma unidade sedimentar permocarbonífera, estratigraficamente bem distribuída nas porções norte e noroeste da Bacia do Paraná. Entretanto, poucos dados palinológicos são disponíveis para esta formação, limitando interpretações bioestratigráficas e paleoecológicas acuradas. Uma abundante, diversificada e bem preservada assembleia de palinómorfs foi registrada a partir de uma amostragem de uma seção aflorante realizada no Distrito de Cipolândia, cidade de Aquidauana, Estado do Mato Grosso do Sul, Brasil. Um total de 35 táxons de palinómorfs indígenas foi reconhecido, compreendendo seis espécies de esporos (relacionados a cinco gêneros), 28 espécies de grãos de pólen (14 gêneros) e 1 espécie de alga clorofíceas. Grãos de pólen monossacados são excepcionalmente dominantes, representando 90,38% da associação, particularmente constituídos por espécies dos gêneros *Cannanoropollis* (30,41% do total da assembleia), *Potonieisporites* (28,14%) e *Plicatipollenites* (19,52%). Esta super

representatividade quantitativa não é usual em depósitos do Gondwana, revelando uma dominância especial das Cordaitales na flora terrestre. Estes resultados são interpretados como resultante de condições ecológicas caracterizadas por plantas que ocupavam terras altas, com independência de umidade na estratégia de reprodução, sob influência climática glacial. Certas espécies de grãos de pólen permitem posicionamento na Zona *Crucisaccites monoletus* (Pennsylvaniano tardio), a qual tem sido reconhecida somente na porção média do Grupo Itararé na margem nordeste da bacia.

Palavras-chave: bioestratigrafia, paleoecologia, palinologia, Pennsylvaniano.

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