
Palynology of the Permian San Miguel Formation (Western Paraná Basin, Paraguay): Gondwanan biostratigraphic correlations

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| A B S T R A C T |

The palynological analysis of five samples from three levels in cores of the Mallorquín-1 well (Paraná Basin, eastern Paraguay) is presented here. The borehole penetrated the San Miguel Formation, the basal lithostratigraphic unit of the Independencia Group. This palynoflora represents the westernmost palynological record reported from Upper Paleozoic sequences along this basin margin at this latitude. This diverse spore-pollen flora includes several age marker taxa, viz. *Verrucosisporites insuetus*, *Lueckisporites* spp., *Lunatisporites variesectus*, *Striatosporites heyleri*, *Weylandites lucifer*, and *Tornopollenites toreutos*, as well as *Reduviasporonites chalastus*. The assemblages from the Mallorquín-1 well are assignable to the *Lueckisporites virkkiae* Zone from the Brazilian sector of the Paraná Basin, thus suggesting a Late Cisuralian-Guadalupian age for the section studied and its correlation with the Brazilian Palermo and Irati Formations. Moreover, palynostratigraphic regional correlation can be established with the *Tornopollenites toreutos* Biozone (northern Brazil), the *Striatites* and *Lueckisporites-Weylandites* Biozones (Argentina) and the *Striatoabieites anaverrucosus-Staurosaccites cordubensis* Biozone (Uruguay). The presence of abundant taeniate pollen also suggests similarities with palynofloras from South Africa and Australia.

KEYWORDS | Permian. Paraguay. Paraná Basin. Palynology.

INTRODUCTION

The palynostratigraphy of the Paraná Basin along its eastern margin in Brazil is well known. Since the seminal studies by Daemon and Quadros (1970) many contributions have been published. Recent compilations include the contributions by

Souza and Marques-Toigo (2001, 2003, 2005), and Souza (2006). However, significantly fewer palynological studies have been performed in the western margin in Paraguay (Muff et al., 1999; Fulfaro et al., 1995) and Argentina (Archangelsky and Gamero, 1980; Vergel, 1993; Césari et al., 1995; Playford and Dino, 2002). The importance of these studies is not only ac-

ademic but also crucial for a better understanding of the stratigraphic framework of the Upper Paleozoic sequences in the basin in light of the probable presence of both gas and oil reservoirs and potential source rocks (França and Potter, 1988).

The aim of this study is to document the abundant and rich palynological assemblages recovered from the San Miguel Formation in the Texaco Mallorquín-1 well (25°28'48" S latitude, 55°16'40" W longitude, Fig. 1). This well shows the most complete Upper Paleozoic succession along the western margin of the Paraná Basin in Paraguay. A new correlation scheme based on this new evidence found in the San Miguel samples is proposed for the Upper Paleozoic sequences.

GEOLOGIC SETTING

The Paraná Basin is the largest intracratonic basin of South America, mainly developed in Brazil and the eastern region of Paraguay (Fig. 1A). It extends southward to northern Uruguay and toward the west into Argentina where is known as the Chaco-Paraná Basin. The basin covers an area of about 1.600.000 km², and its fill consists of up to 5000 m-thick Upper Ordovician to Cretaceous sedimentary and volcanic rocks (Milani et al., 1998; Zalán et al., 1990). The San Miguel Formation is a sandstone-rich unit present in eastern Paraguay (Fig. 1B) on the western margin of the

Paraná Basin. The San Miguel Formation is part of the 600 m-thick Independencia Group (Fig. 2), which has been subdivided into four formations (Jalfin, 1986), which are summarized herein in ascending stratigraphic order.

San Miguel Formation

This unit has an approximate thickness of 390 meters at the Mallorquín well and rests on postglacial, offshore shales of the uppermost part of the Coronel Oviedo Formation (Fig. 3). It is composed of medium- to coarse-grained sandstones and fine-grained calcareous sandstones with flaser and wavy bedding intercalated with shales and siltstones. Gamma ray readings (Fig. 3) can be used as proxies for sand/shale ratio with low values indicative of clean (mud-free) sandstones and high values suggestive of high mud content (shales). The San Miguel Formation records thin post-glacial transgressive deposits that are overlain by thick, stacked regressive deltaic packages (Buatou et al., 2007). The lowermost transgressive interval consists of laminated siltstones and thin-bedded fine- and very fine-grained sandstones with parallel lamination, combined-flow ripples and micro-hummocky cross-stratification. Trace-fossil diversity is high and the degree of bioturbation is variable, with some intervals intensely bioturbated (bioturbation index 4-6). These deposits record mainly sedimentation in lower-offshore to offshore-transition environments. The overlying regressive deposits consist of coarsening-upward parasequences within

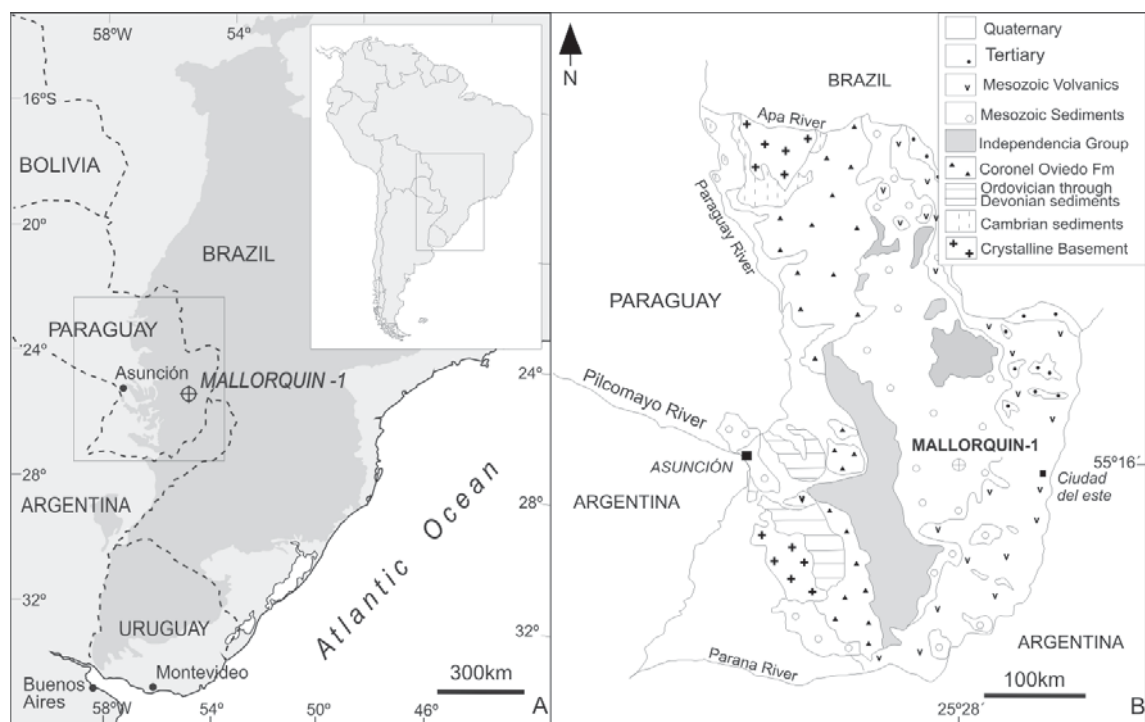


FIGURE 1 | **A)** Location of the Mallorquín-1 well (solid gray area indicates the Paraná Basin); **B)** Generalized geologic map of eastern Paraguay showing the outcrops of Independencia Group highlighted (solid grey) and Mallorquín-1 well location. The San Miguel Formation is the lowermost unit of the Independencia Group, which overlays the glacial deposits of the Coronel Oviedo Formation.

Independencia Group	Cabacua Fm.
	Tapyta Fm.
	Tacuary Fm.
	San Miguel Fm.
Coronel Oviedo Group	Coronel Oviedo Fm.

FIGURE 2 | Summary of Upper Paleozoic stratigraphy of the Paraná Basin in Paraguay.

a progradational parasequence set. These deposits consist of laminated siltstones and thin- to thick-bedded, fine- and very fine-grained sandstones with parallel lamination, combined-flow ripples, micro-hummocky and hummocky cross-stratification, and thick-bedded planar and trough cross-bedded, fine-grained sandstones. Intensity of bioturbation and trace-fossil diversity are remarkably lower than in the underlying fully marine interval. These regressive deposits record mainly sedimentation in wave-dominated deltas (encompassing prodelta, delta-front, and distributary channel facies), with subordinate tidal influence, particularly in the most proximal settings (Buatouts et al., 2007).

The San Miguel Formation has been traditionally correlated with the Rio Bonito Formation of the Brazilian sector of the basin. This correlation was mainly based on similar stratigraphic position of these two sandstone-rich units. Moreover, both units rest on the glacial interval (Coronel Oviedo Formation on the Paraguayan Basin margin, next to the Asunción Arch, and the Itararé Group in the Brazilian sector) that constitutes the initial fill of the Late Paleozoic Gondwana cycle in the Paraná Basin indicative of a similar depositional context for these units. In this study palynological assemblages were analyzed from the San Miguel Formation, recovered from three levels of the Mallorquín-1 well, located at approximately 900.00m deep (Fig. 3). The interval sampled corresponds to the maximum flooding surface that caps an almost 100m thick progradational parasequence set (cf. Van Wagoner et al., 2003)

at the bottom of the San Miguel Formation. The recognition of marine acritarchs in the palynological associations corroborates this paleoenvironmental interpretation. Thus, the lower interval of the San Miguel Formation is interpreted as deposited in a prograding wave-dominated deltaic complex with increasing tidal influence towards the top.

Fulfaro et al. (1995) published a preliminary palynological report of the San Miguel Formation. These authors suggested a Lower Permian age for this unit based on a single palynological sample from outcrops at the km 167 of the Coronel Oviedo-Yby Jahu road. Unfortunately, the precise stratigraphic location of this sample is not mentioned by Fulfaro et al. (1995). They recognized the presence of abundant pollen represented by *Potoniopsisporites* spp., *Piceapollenites* sp., *Protohaploxypinus* cf. *P. amplus*, *Vittatina subsaccata*, *V. vittifera*, *V. fasciolata* (Balme and Hennesly) Bharadwaj 1962, *V. scutata* (Balme and Hennesly) Bharadwaj 1962 and *V. costabilis*. The association was referred to the top of the Brazilian *Cannanorpollis korbaensis* Zone defined by Marques Toigo (1991) based on the presence of *Vittatina*.

Tacuary Formation

This unit consists of calcareous sandstones, shales and oolitic limestones that bear bivalves and spores. A sea-connected coastal lagoon is envisaged as a possible depositional environment for these deposits. Muff et al. (1999) studied palynological samples from cuttings of this unit that referred to the Kungurian-Kazanian. Recently, Rapalini et al. (2006) suggested for this unit a magnetization age close to 260Ma, in the late Guadalupian or early Lopingian.

Tapyta Formation

This lithostratigraphic unit includes cross-bedded sandstone and scarce conglomerate and mudstone deposited in fluvial settings.

Cabacua Formation

This unit is lithologically similar to the Tapyta Formation. The main distinction resides in the higher sand/shale ratio of the Cabacua Formation, suggesting a high-sinuosity fluvial environment.

MATERIALS AND METHODS

Five palynological assemblages were analyzed from the San Miguel Formation, recovered from three levels of slim cores from the Mallorquín-1 well, located at 904.00, 903.73, and 903.12m deep. The palynological samples were processed using conventional physico-chemical tech-

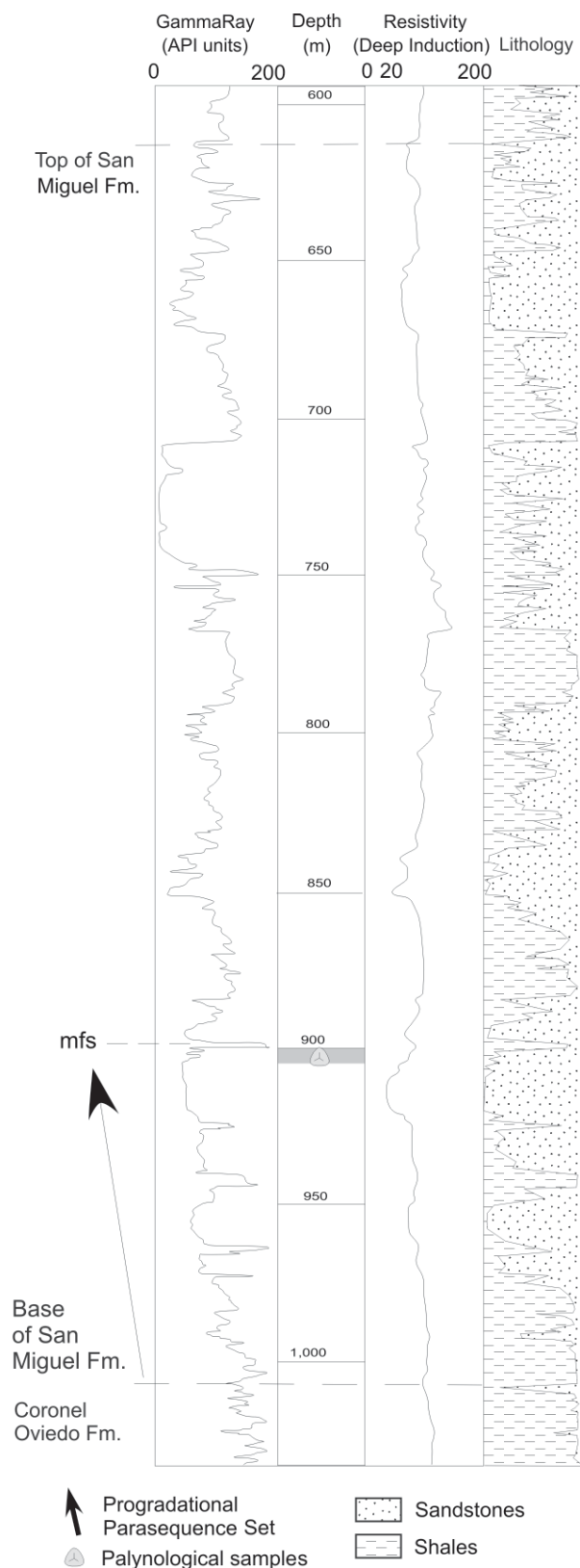


FIGURE 3 | San Miguel Formation section penetrated by Mallorquín-1 well showing the basal progradational parasequence set and the location of the sampled interval at the maximum flooding surface (mfs). See text for further details.

niques for retrieval and concentration of palynomorphs. The photographs were taken with a Nikon digital sight DS-Fi1 connected to an Olympus BX 51 binocular microscope. All illustrated specimens are deposited in the Palynological Collection of the Museo Argentino de Ciencias Naturales “Bernardino Rivadavia” (BA Pal), and are identified with England Finder coordinates.

PALYNOLOGICAL RESULTS

The associations studied comprise a total of 15 spore and 55 pollen species, together with 3 species of acritarchs and 1 of *incertae sedis*. They are dominated by taeniate pollen grains with a subordinated presence of non-taeniate bisacate pollen grains. Spores are a minor component, represented mainly by monolete spores. Finally, the acritarchs are the rarest components of the palynoflora.

The species recognized are listed below and shown on Figures I to IV that can be consulted in the Appendix of the electronic version of this paper, available at www.geologica-acta.com where also description and comments on the species with open or doubtful specific assignment are provided.

Spores

- Apiculatasporites parviapiculatus* AZCUY 1975 (Fig. I.A)
- Apiculatisporis* sp. (Fig. I.B)
- Cyclogranisporites* sp. (Fig. I.C)
- Horriditriletes uruguaiensis* (MARQUES-TOIGO) ARCHANGELSKY and GAMERRO 1979 (Fig. I.D)
- Kendosporites robustus* STEPHENSON 2008 (Fig. I.N-O)
- Laevigatosporites vulgaris* (IBRAHIM) IBRAHIM 1933 (Fig. I.F)
- Leiotriletes adnatus* (KOSANKE) POTONIÉ and KREMP 1955 (Fig. I.E)
- Leiotriletes virkii* TIWARI 1965 (Fig. I.G)
- Leiotriletes* sp. (Fig. I.H)
- Lophotriletes discordis* GUTIÉRREZ and CÉSARI 1988 (Fig. I.I)
- Lophotriletes intermedius* AZCUY 1975 (Fig. I.J)
- Reticulatisporites* sp. (Fig. I.K)
- Spelaeotriletes ybertii* (MARQUES-TOIGO) PLAYFORD and POWIS 1979 emend. PLAYFORD, DINO and MARQUES-TOIGO 2001 (Fig. I.L)
- Striatosporites heyleri* (DOUBINGER) PLAYFORD and DINO 2000 (Fig. I.LL-M)
- Verrucosisorites insuetus* PLAYFORD and DINO 2000 (Fig. I.P-S)

Pollen Grains

- Alisporites australiensis* DE JERSEY 1962 (Fig. II.A)
- Alisporites gracilis* SEGROVES 1979 (Fig. II.B)

- Alisporites parvus* DE JERSEY 1962 (Fig. II.C)
Alisporites splendens (LESCHIK) FOSTER 1979 (Fig. II.D)
Colpisaccites granulosus ARCHANGELSKY and GAMERRO 1979 (Fig. II.E)
Cycadopites alhuampi CÉSARI, ARCHANGELSKY and VILLAR DE SEOANE 1995 (Fig. II.W)
Distriatites insolitus BHARADWAJ and SALUJHA 1964 (Fig. II.G)
Falcisporites nuthallensis (CLARKE) BALME 1970 (Fig. II.H)
Hamiapollenites andiraensis PLAYFORD and DINO 2000 (Fig. II.T)
Hamiapollenites fusiformis MARQUES-TOIGO emend. ARCHANGELSKY and GAMERRO 1979 (Fig. II.U)
Hamiapollenites karroensis (HART) HART 1964 (Fig. II.K)
Lueckisporites stenotaeniatus MENÉNDEZ 1976 (Fig. II.L)
Lueckisporites virkkiae POTONIÉ and KLAUS 1954 (Fig. II.LL-M)
Lunatisporites variesectus ARCHANGELSKY and GAMERRO 1979 (Fig. II.I)
Marsupipollenites striatus (BALME and HENNELLY) HART 1965 (Fig. IV.A)
Pakhapites fusus (BOSE and KAR) MENÉNDEZ 1971 (Fig. II.I)
Platysaccus leschikii HART 1960 (Fig. II.Q)
Platysaccus papilionis POTONIÉ and KLAUS 1954 (Fig. II.O)
Platysaccus queenslandii DE JERSEY 1962 (Fig. II.V)
Platysaccus sp. 1 (Fig. II.P)
Platysaccus sp. 2 (Fig. II.R)
Platysaccus sp. 3 (Fig. II.N)
Platysaccus sp. 4 (Fig. IV.J)
Protohaploxylinus amplus (BALME and HENNELLY) HART 1964 (Fig. II.S)
Protohaploxylinus bharadwajii FOSTER 1979 (Fig. III.A)
Protohaploxylinus jacobii (JANSONIUS) HART 1965 (Fig. III.B)
Protohaploxylinus sp. (Fig. III.D)
Protohaploxylinus sp. cf. *P. diagonalis* BALME 1970 (Fig. III.O)
Pteruchipollenites gracilis (SEGROVES) FOSTER 1979 (Fig. III.T)
Scheuringipollenites circularis CÉSARI, ARCHANGELSKY and VILLAR DE SEOANE 1995 (Fig. III.I)
Scheuringipollenites medius DIAS-FABRÍCIO 1981 (Fig. III.G)
Scheuringipollenites ovatus (BALME and HENNELLY) FOSTER 1979 (Fig. III.H)
Staurosaccites cordubensis ARCHANGELSKY and GAMERRO 1979 (Fig. II.F)
Staurosaccites quadrifidus DOLBY 1976 (Fig. III.N)
Striatoabieites anaverrucosus ARCHANGELSKY and GAMERRO 1979 (Fig. III.LL)
Striatoabieites multistriatus (BALME and HENNELLY) HART 1965 (Fig. III.K)
Striatopodocarpites fusus (BALME and HENNELLY) POTONIÉ 1958 (Fig. III.R)
Striatopodocarpites rarus (BHARADWAJ and SALUJHA) BALME 1970 (Fig. III.J)
Striatopodocarpites solitus (BHARADWAJ and SALUJHA) FOSTER 1979 (Fig. III.L)
Striatopodocarpites sp. cf. *S. cancellatus* (BALME and HENNELLY) HART 1965 (Fig. III.M)
Striatopodocarpites sp. (Fig. III.W)
Striatopodocarpites sp. cf. *S. phaleratus* (BALME and HENNELLY) HART 1965 (Fig. III.V)
Striomonosaccites ovatus BHARADWAJ 1962 (Fig. III.C)
Striomonosaccites sp. cf. *S. cicatricosus* ARCHANGELSKY and GAMERRO 1979 (Fig. III.E)
Tornopollenites toreutos MORGAN 1972 (Fig. III.U)
Trisacado indet. (Fig. III.P)
Vitreisporites microsaccus DE JERSEY 1964 (Fig. IV.E)
Vittatina corrugata MARQUES-TOIGO 1974 (Fig. III.Q)
Vittatina costabilis WILSON 1962 (Fig. IV. B, F)
Vittatina saccata (HART) PLAYFORD and DINO 2000 (Fig. III.F)
Vittatina sp. cf. *V. vittifera* (LUBER) SAMOILOVICH 1953 (Fig. IV.D)
Vittatina subsaccata SAMOILOVICH 1953 (Fig. III.S)
Vittatina wodehousei (JANSONIUS) HART 1964 (Fig. IV.C)
Weylandites lucifer (BHARADWAJ and SALUJHA) FOSTER 1975 (Fig. IV.H)
Weylandites magnus (BOSE and KAR) BACKHOUSE 1991 (Fig. IV.G)
- ### Acritarchs
- Cymatiosphaera gondwanensis* (TIWARI) BACKHOUSE 1991 (Fig. IV.K)
Gorgonisphaeridium sp. (Fig. IV.L)
Navifusa sp. (Fig. IV.LL)
- ### Incertae sedis
- Reduviasporonites chalastus* (FOSTER) ELSIK 1999 (Fig. 7, I, M, N)
- ## BIOSTRATIGRAPHY
- ### Permian palynological biozones of the Paraná Basin in Brazil
- Based on data obtained from surface and subsurface palynological samples, Souza and Marques-Toigo (2005) defined two interval biozones for the Permian successions of

the Paraná Basin in Brazil (Figs. 4 and 5): *Vittatina costabilis* and *Lueckisporites virkii*. The first appearance of the genera *Vittatina* and *Protohaploxylinus*, along with the species *Pakhapites fusus* and *Illinites unicus* determine the base of the *Vittatina costabilis* Biozone. This palynozone is well represented in the upper levels of the Itararé Group, and its upper limit is located between the uppermost levels of the Rio Bonito Formation (Holz et al., 2010). The palynological assemblages included in this biozone are composed by several species, such as *Protohaploxylinus goraiensis*, *P. limpidus*, *Illinites unicus*, *Vittatina costabilis*, *V. saccata*, *V. subsaccata*, *V. vittifera*, and *Pakhapites fusus*. The Brazilian coal seams from the middle part of the Rio Bonito Formation were recently dated giving a time range of 299±2.6 to 296±1.4 Ma (Guerra-Sommer et al., 2005).

In ascending order, the next biozone is the *Lueckisporites virkii* Biozone (Fig. 4), referred to the Early-Middle Permian by Souza and Marques-Toigo (2005). The base of this biostratigraphic unit is marked by the first appearance of species of the genus *Lueckisporites*, such as *L. virkii*, *L. densicarpus* Archangelsky and Gamarro 1979 and *L. stenotaeniatus*, together with *Weylandites lucifer*, *Protohaploxylinus hartii* Foster 1979, *P. seawardii* (Virkki) Hart 1964, *P. microcorpus* (Schaarschmidt) Clarke 1965, and *Lunatisporites variesectus*, among others (Souza and Marques-Toigo, 2005). The reference section occurs in the

Irati Formation (Fig. 4), where most palynological studies have been carried out (Dellazana, 1976; Menéndez, 1976; Picarelli et al., 1987; Premaor et al., 2006). The age of the Irati Formation is constrained to the Artinskian based on 278.4±2.2 Ma, 276.4±3.7 Ma and 279.9±4.8 Ma SHRIMP zircon datings (Santos et al., 2006; Rocha-Campos et al. 2006). The occurrence of *Lueckisporites* (*L. virkii* and *L. stenotaeniatus*) along with *Weylandites lucifer* and *Lunatisporites variesectus* in the studied samples allows a closer correlation with the *Lueckisporites virkii* Zone. The *Lueckisporites virkii* Biozone would be also represented in the Palermo and Teresina Formations and part of the Rio do Rasto Formation (Souza and Marques-Toigo, 2005; Negerato et al., 2008) (Fig. 4). However, the assemblages of Teresina Formations and part of the Rio do Rasto Formation differ from the Paraguayan palynofloras here studied by the abundance of fern monolete spores.

Biostratigraphic correlation with other records of the Parana Basin

The palynoflora found in the single sample from outcrops of the San Miguel Formation by Fúlfaro et al. (1995) can be correlated, on the basis of the presence of *Vittatina* to the *Vittatina costabilis* Biozone (= *Cannanoropollis korbaensis* Biozone, Marques Toigo, 1991). This palynological sample referred by Fúlfaro et al. (1995) to the San Miguel Formation shares only few species with the associations recovered from the samples of the Mallorquín well, such as: *Vittatina subsaccata*, *V. vittifera*, and *V. costabilis*. The absence of the diagnostic species found in the Mallorquín samples as *Lueckisporites virkii*, *L. stenotaeniatus*, and *Weylandites lucifer* suggests an older age for the palynoflora studied by Fulfaro et al. (1995), perhaps related to a lower stratigraphic location of the sample. But this assumption seems uncertain considering that the samples of the Mallorquín came from the lower section of the unit.

The presence of several diagnostic species in the studied assemblages allows correlation with other palynological associations described along Paraná Basin (Fig. 5). In Argentina, Russo et al. (1980) proposed three palynozones for the Upper Paleozoic of the Chaco-Paraná Basin (=Paraná Basin), namely (in ascending order): *Potoniesporites-Lunbladisporea*, *Cristatisporites*, and *Striatites* Palynozones. Later, some authors modified this scheme (Vergel, 1993; Césari et al., 1995; Archangelsky et al., 1996). The presence of *Hamiapollenites fusiformis* and *Lunatisporites variesectus*, *Staurosaccites cordubensis*, *Lueckisporites virkii*, *Striomonosaccites cicatricosus*, *Colpisaccites granulosus* in the San Miguel Formation, suggests a better correlation with the *Striatites* Palynozone. This biozone is assigned to the Kungurian?-Kazanian-Guadalupian (Gutiérrez et al., 2003).

PARANA BASIN		
Passa Dois Group	Rio do Rastro Formation	<i>Lueckisporites</i> Zone
	Teresina Formation	
	Serra Alta Formation	
	Irati Formation	
Guata Group	Palermo Formation	<i>Vittatina costabilis</i> Zone
	Rio Bonito Formation	

FIGURE 4 | Stratigraphic summary of the Paraná Basin.

(1)	Gradstein et al. 2004		Paraná Basin			Amazonas Basin (5)	Main species San Miguel Formation
			Brazil (2)	Uruguay (3)	Argentina (4)		
Late	Lopingian	Changhsing 254	Lueckisporites Biozone	Striatoabieites anaverrucosus - Strauosaccites cordubensis Biozone	Striatites Biozone	Tornopollenites toreutos Biozone	Lueckisp. virkhae Tornopol. toreutos Verrucos. insuetus Reduviasp. chalastus
		Wuchiapingian 260					
Middle	Guadalupian	Capitanian 266					
		Wordian 268					
		Roadian 271					
Early	Cisuralian	Kungurian 276	Cristatisporites inconstans - Caheniasaccites ovatus Biozone	Cristatisporites Biozone	Vittatina costabilis Biozone		
		Artinskian 284					
		Sakmarian 295					
		Asselian 299					

FIGURE 5 | Correlation of the main Permian Brazilian palynozones and stratigraphic ranges of some palynological species of the San Miguel Formation. (1) Walker and Geissman, 2009; (2) Souza, 2006; (3) Beri et al., 2004; (4) Russo et al., 1980; (5) Playford and Dino, 2000.

Beri et al. (2004) suggested an informal biozonation for the Permian successions of the Paraná Basin in Uruguay (Fig. 5). They recognized in ascending stratigraphic order the *Cristatisporites inconstans* - *Vittatina subsaccata* (IS) and *Striatoabieites anaverrucosus* - *Staurosaccites cordubensis* (AC) Biozones. The AC Palynozone is characterized by a dominance of taeniate pollen grains, such as *Lueckisporites stenotaeniatus*, *Striatopodocarpites rarus*, *S. cancellatus* and *Protohaploxylinus* spp., and it is distinguished from IS Biozone by its low proportion of spores. The palynoflora of the San Miguel Formation correlates with the AC Biozone, which was dated with radiometric methods as not older than Artinskian in age (Rocha-Campos et al., 2006).

Biostratigraphic correlation with other Permian basins

The palynological associations from the San Miguel Formation are also comparable with those referred to the *Vittatina costabilis* (Early-Middle Permian) and *Tornopollenites toreutos* (Middle-Late Permian) Zones by Playford and Dino (2000) of the Tapajós Group in Amazonas Basin, Brazil (Fig. 5). The *Vittatina costabilis* Zone is characterized by the first record of the eponymous species, along with *Vittatina vittifera*, *V. saccata*, and *V. subsaccata*. *Hamiapollenites andiraensis*, *H. fusiformis*, *Pakhapites fusus*, *P. ovatus* (Bose and Kar) Menéndez 1971, *Corisaccites alutas* Venkatachala and Kar 1966 and *Lueckisporites virkhae* are also present in this Zone. The first appearance of the eponymous species characterizes the base of the *Tornopollenites toreutos* Zone, along with the presence of *Verrucosisporites insuetus*, *Thymospora obscura* (Kosanke) Wilson and Venkatachala 1963, and *Laevigatasporites minor*. The palynoflora recovered from the San Miguel Formation is more comparable with the latter zone, based on the presence of *Tornopollenites toreutos* and *Verrucosisporites insuetus* in the studied samples (Figs. 5 and 6). Since the

age of these zones is based mainly on palynological data, new studies will be required to constrain more precisely the age. However, as mentioned above, palynofloras from the Teresina and Rio do Rasto Formations are comparable to the biozones of the Amazonas Basin. Those stratigraphic units overlie the Irati Formation (278.4±2.2 Ma, Santos et al., 2006), supporting a probable Middle-Late Permian approximately age for the biozones of the Amazon Basin, as proposed by Dino and Playford (2000).

Césari and Gutiérrez (2001) proposed a biozonation scheme for the Upper Paleozoic of central-western of Argentina. The presence of *Pakhapites fusus* and the abundance of taeniate pollen grains mark the base of the *Pakhapites fusus*-*Vittatina subsaccata* (FS) Assemblage Biozone, dated as Early Permian in age (Césari and Gutiérrez, 2001). The first appearance of species of the genus *Lueckisporites* distinguishes the *Lueckisporites*-*Weylandites* (L-W) Assemblage Biozone, which was correlated with the *Striatites* Palynozone of the Chaco-Paraná Basin (Césari and Gutiérrez, 2001) (Fig. 5). According to several radiometric ages this biozone was supposed not to be older than late Artinskian-Kungurian (Césari et al., 1995). Nevertheless, new radiometric age of 266.3±0.8 Ma (Melchor, 2000) seems to extend the age of the LW Biozone to the Capitanian. The palynoflora studied herein is correlated also with the LW Biozone.

Falcon (1975) proposed a palynological zonation for the African Karoo assemblages, and defined four major assemblage zones subdivided into eight assemblage sub-zones for the lower Karoo sequence in Zimbabwe. The Assemblage Zone IV was defined for palynological associations present in Upper Permian strata (Catuneanu et al., 2005), which is characterized by the first appearance of *Lueckisporites* spp. Anderson (1977) also recognized several palynological biozones in the northern Karoo. Among them,

Species	<i>Tornopollenites toreutos</i> Zone	<i>Lueckisporites</i> Zone
<i>Weylandites lucifer</i>		●
<i>Distriatites insolitus</i>		●
<i>Marsupipollenites striatus</i>		●
<i>Lueckisporites stenotaeniatus</i>		●
<i>Lueckisporites virkkiae</i>	●	●
<i>Vittatina saccata</i>	●	●
<i>Vittatina costabilis</i>	●	●
<i>Vittatina subsaccata</i>	●	●
<i>Tornopollenites toreutos</i>	●	●*
<i>Hamiapollenites karroensis</i>	●	●
<i>Hamiapollenites andiraensis</i>	●	
<i>Hamiapollenites fusiformis</i>	●	
<i>Verrucosiporites insuetus</i>	●	
<i>Corisaccites alutas</i>	●	

FIGURE 6 | Distribution of the main diagnostic species of the San Miguel Formation in the *Lueckisporites* (Paraná Basin) and *Tornopollenites toreutos* (Amazonas Basin) Zones. References: Souza (2006), Playford and Dino (2000), and * this paper.

Zone 3 (middle Ecca) is distinguished by the incoming of *Lueckisporites* species that are also abundant in the following Zones 4 and 5. A correlation among these South African assemblages and the Brazilian associations referred to the *Lueckisporites virkkiae* Zone, and the LW Biozone from Argentina was proposed by Césari (2007). It is difficult to compare these biozones with the Stages/Zones scheme proposed for Australia, because they are mainly based on the distribution of selected trilete spore species, which were not recognized in the assemblages from Western Gondwana. However, the Stage V proposed by Kemp et al. (1977) for Australia is characterized by a high abundance of taeniata and not taeniata pollen grains, abundant species of *Scheuringipollenites*, and the first appearance of the genus *Weylandites*. The Stage VI presents a similar composition, but has a high abundance of *Granulatisporites trisinus* Balme and Hennesly 1956. The taeniata pollen grains are dominant in the Stage VII, whereas the Stage VIII is very similar to Stage VII but shows an increase of *Weylandites*, *Vitreisporites*, and *Tigrisporites playfordi* (de Jersey and Hamilton) Foster 1979. Taking into account the abundance of taeniata pollen, the palynofloras of the San Miguel Formation are probably equivalent to the Stage VII.

DISCUSSION

The assemblages recovered from the Mallorquín well are characterized by the presence of abundant taeniata pollen and several species of constrained stratigraphic range as *Lueckisporites*, *Verrucosiporites insuetus*, *Tornopollenites toreutos* and *Reduviasporonites chalastus*, which suggest an age not older than late Cisuralian for the fossiliferous levels (Fig. 4). According to Utting et al. (1997), *Lueckisporites virkkiae* is considered to appear first in the Russian Platform in the Wordian whereas in Brazil is common in the Irati Formation dated in 278.4±2.2 (middle Artinskian) by Santos et al. (2006). Although few specimens of *Tornopollenites toreutos* were identified, this is a significant species originally described from the Early Permian of USA but recently recognized in the Irati Formation (this paper) and also in Late Permian assemblages of the Amazonas Basin (Playford and Dino, 2000) and the Colorado Basin in offshore Argentina (Balarino, 2008). *Verrucosiporites insuetus* is another distinctive species up to now only recognized in Late Permian assemblages of the Amazonas Basin (Playford and Dino, 2000). Finally, *Reduviasporonites chalastus* is an algal spore characteristic of Late Permian associations found in Australia and Argentina (Foster et al., 2002; Balarino, 2008; Zavattieri et al., 2008).

Previously, the San Miguel Formation had been correlated with the Rio Bonito Formation, based on lithologic characteristics and stratigraphic position (López-Gamundí, 2006). Buatois et al. (2007) studied the ichnofauna of the San Miguel Formation and proposed that this unit was equivalent to the Rio Bonito and Palermo Formations. The new palynological data obtained from the Mallorquín-1 well suggest a close correlation of the fossiliferous levels of the San Miguel Formation with palynological assemblages of the Palermo and Irati Formations (which is the reference section of the *Lueckisporites virkkiae* Zone). Souza (2006) pointed out that the lowermost records of the *Lueckisporites virkkiae* Zone are represented in the lower part of the Palermo Formation. However, few published data from the latter unit are known, so new palynological studies on the Palermo Formation are needed for a closer comparison.

CONCLUSIONS

The occurrence of several species of *Hamiapollenites*, *Lueckisporites* and *Vittatina* together with *Lunatisporites variesectus*, *Tornopollenites toreutos* and baccate pollen grains assigned to *Platysaccus* spp. and *Alisporites* spp. allow us to refer the assemblages recovered from San Miguel Formation to the Brazilian *Lueckisporites virkkiae* Zone (Paraná Basin). Furthermore, a correlation can be established with biozones of contiguous basins: *Tornopollenites toreutos* (Amazonas Basin, Brazil), *Striatites* (Chacoparana

Basin, Argentina), LW (Paganzo Basin, Argentina) and AC (Paraná Basin, Uruguay). Based on the abundance or tae-niate pollen comparisons are suggested with palynological assemblages of South Africa and Australia.

All of them are considered not older than Late Cisuralian in age. This new record of *Lueckisporites*-rich assemblages in South America broadens our knowledge about these Permian associations with limited stratigraphic distribution in Gondwana.

The presence of *Reduviasporonites chalastus* is noteworthy, considering its Permian stratigraphic range constrained to the Capitanian-Chansighian in Argentina, Australia, China, Russia, Saudi Arabia, United Kingdom and Austria (Foster et al., 2002; Zavattieri et al., 2008).

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APPENDIX

SYSTEMATIC PALAEOONTOLOGY

Anteturma Proximegerminantes POTONIÉ, 1970
 Turma Triletes REINSCH emend. DETTMANN, 1963
 Suprasubturma Acavatitriletes DETTMANN, 1963
 Subturma Azonotriletes LUBER emend. DETTMANN,
 1963
 Infraturma Laevigati BENNIE and KIDSTON emend.
 POTONIÉ, 1956

GENUS *Leiotriletes* NAUMOVA ex ISHCENKO emend.
 POTONIÉ and KREMP, 1954

Type species. *Leiotriletes sphaerotriangulus* (LOOSE)
 POTONIÉ and KREMP, 1954.

Leiotriletes sp.
 Figure I.H

Description. Spores radial, trilete. Amb triangular, with slightly concave sides and rounded apices. Laesurae straight, length one-half of spore radius. Exine laevigate, 0.8µm thick.

Dimensions. Equatorial diameter: 41–46µm (2 specimens).

Comparisons. *Leiotriletes virkii* differs in having shorter laesurae and thinner exine.

Infraturma Apiculati BENNIE and KIDSTON emend.
 POTONIÉ, 1956
 Subinfraturma Granulati DYBOVA and JACHOWICZ,
 1957
 GENUS *Cyclogranisporites* POTONIÉ and KREMP, 1954

Type species. *Cyclogranisporites leopoldii* (KREMP)
 POTONIÉ and KREMP, 1954.

Cyclogranisporites sp.
 Figure I.C

Description. Spores radial, trilete. Amb subcircular. Laesurae straight, length three-quarters of spore radius. Exine 0.5–0.8µm thick, bearing comprehensively distributed sculptural elements of 0.8–3µm in basal width and 0.5–1µm high, polygonal to subpolygonal in plan view, densely distributed and delineating a fine negative reticulum. Exine often folded through compression.

Dimensions. Equatorial diameter: 58 (70) 78µm (13 specimens).

Comparisons. Insufficient and badly preserved specimens prevent the establishment of a new species.

Subinfraturma Nodati DYBOVÁ and JACHOWICZ,
 1957
 GENUS *Apiculatisporis* IBRAHIM emend. POTONIÉ
 and KREMP, 1956

Type species. *Apiculatisporis aculeatus* (IBRAHIM)
 POTONIÉ, 1956.

Apiculatisporis sp.
 Figure I.B

Description. Spores radial, trilete. Amb subcircular. Laesurae straight, length three-quarters of spore radius. Exine 0.5–0.8µm thick, sculptured with sharp coni (0.8–1 in basal width and 1–2.5 high), sparsely distributed, 1–3µm apart.

Dimensions. Equatorial diameter: 52 (39) 70µm (5 specimens).

Comparisons. No closely comparable forms were found in the literature and the few specimens encountered are considered insufficient for designating them formally.

Infraturma Murornati POTONIÉ and KREMP, 1954

GENUS *Reticulatisporites* IBRAHIM emend. POTONIÉ
 and KREMP, 1954

Type species. *Reticulatisporites reticulatus* (IBRAHIM)
 IBRAHIM, 1933.

Reticulatisporites sp.
 Figure I.K

Description. Spores radial, trilete. Amb subcircular. Laesurae straight, length three-quarters of spore radius. Exine ornamented with a reticulum composed by slightly sinuous muri (1.5–2.5µm wide at base and 2–5µm high), enclosing imperfect polygonal to irregular lumina. Muri membranous and broader at base, with short projections at the intersections of muri.

Dimensions. Equatorial diameter: 61 (65) 70 µm (5 specimens).

Comparisons. *Reticulatisporites magnidictyus* Playford and Helby 1968 differs in having straighter muri enclosing a regular reticulum.

Turma Monoletes IBRAHIM, 1933
 Suprasubturma Acavatomonoletes DETTMANN, 1963
 Subturma Azonomonoletes LUBER, 1935
 Infraturma Sculptatomonoleti DYBOVÁ and
 JACHOWICZ, 1957
 GENUS *Striatosporites* BHARDWAJ emend.
 PLAYFORD and DINO, 2000

Type species. *Striatosporites major* BHARDWAJ, 1954.

Striatosporites heyleri (DOUBINGER) PLAYFORD and
 DINO, 2000
 Figure I LL-M

1977. *Laevigatosporites varistriatus* ANDERSON, plate
 80, figs. 16-22.

Comparisons. The species *Schizaeosporites microrugosus*
 proposed by Tschudy and Kosanke (1966, pag. 63, plate 1,
 figs. 19-20) seems very similar to our specimens, as well
 as those referred to *Striatosporites heyleri* (Doubringer)
 by Playford and Dino (2000), especially to the illustrated
 by these authors in plate 7, fig. 10. If this assumption is
 confirmed the epithet specific *microrugosus* will have
 priority over *heyleri*. The specimens illustrated by Anderson
 (1977) as *Laevigatosporites varistriatus* from the Permian
 of South Africa are attributable to *Striatosporites heyleri*
 (Doubringer) Playford and Dino (2000).

Anteturma Variegerminantes POTONIÉ and KREMP, 1954
 Turma Saccites ERDTMAN, 1947
 Subturma Monosaccites (CHITALEY) POTONIÉ and
 KREMP, 1954
 Infraturma Striasacciti BHARADWAJ, 1962
 GENUS *Striomonosaccites* BHARADWAJ, 1962

Type species. *Striomonosaccites ovatus* BHARADWAJ, 1962.

Striomonosaccites sp. cf. *S. cicatricosus*
 ARCHANGELSKY and GAMERRO, 1979
 Figure III.E

Comparisons. The unique specimen encountered
 possesses all the characteristics of this species but, due
 to poor preservation, its specific assignment is made
 tentatively.

Subturma Disaccites COOKSON, 1947
 Infraturma Podocarpoiditi POTONIE, THOMSON and
 THIERGART, 1950

GENUS *Platysaccus* NAUMOVA emend. POTONIÉ and
 KLAUS, 1954

Type species. *Platysaccus papilionis* POTONIÉ and
 KLAUS, 1954.

Platysaccus sp. 1
 Figure II.P

Description. Pollen grain bilateral, taeniate, slightly
 diploxytonoid. Amb broadly oval, longitudinally elongate.
 Corpus transversely oval in polar view, with two longitudinal
 folds crossed by two transverse folds. Saccus half-circle in
 outline, slightly larger than corpus, finely endoreticulate.
 Cappula breadth ca. 1/3 that of corpus, rectangular.

Dimensions. Overall breadth: 78 (90) 112µm. Corpus
 breadth: 47 (56) 72µm; length: 35 (45) 55µm. Sacci breadth:
 33 (42) 60µm; length: 34 (53) 75µm (6 specimens).

Comparisons. Any of the known species of this genus
 possesses all the characteristics of the material here
 described.

Platysaccus sp. 2
 Figure II.R

Description. Pollen grain bilateral, diploxytonoid.
 Amb broadly oval, longitudinally elongate. Corpus
 subhexagonal in polar view. Saccus exceeding a half-
 circle in outline, larger than corpus, finely endoreticulate.
 Cappula breadth ca. 1/4 that of corpus.

Dimensions. Overall breadth: 83µm. Corpus breadth:
 46µm; length: 42µm. Sacci breadth: 38µm; length: 49µm
 (1 specimen).

Comparisons. *Platysaccus rhombicus* Ottone and
 Mancuso 2006 differs by its body transversely elongated
 and rhomboidal.

Platysaccus sp. 3
 Figure II.N

Description. Pollen grain bilateral, diploxytonoid. Amb
 broadly oval, longitudinally elongate. Corpus subcircular
 to subhexagonal in polar view, with two semilunar
 longitudinal folds on each side. Saccus exceeding a half-
 circle in outline, larger than corpus, finely endoreticulate.
 Cappula breadth ca. 1/3 that of corpus.

Dimensions. Overall breadth: 78 (78) 83µm. Corpus
 breadth: 40 (47) 55µm; length: 35 (43) 48µm. Sacci breadth:
 33 (42) 52µm; length: 50 (55) 62µm (6 specimens).

Comparisons. These specimens resemble to *Limitisporites*
luandensis Bose and Maheshwari 1968 but differ in their
 smaller size.

Platysaccus sp. 4
 Figure IV.J

Description. Pollen grain bilateral, diploxytonoid. Amb
 broadly oval, longitudinally elongate. Corpus subcircular
 in polar view. Saccus subcircular in outline, larger than
 corpus, finely endoreticulate. Cappula narrow, ca. 1/7-1/6
 of the corpus.

Dimensions. Overall breadth: 53-61µm. Corpus breadth: 25-30µm; length: 23-30µm. Sacci breadth: 25-30µm; length: 30-35µm (3 specimens).

Comparisons. *Platysaccus saarensis* (Bhardwaj) Jizba 1962 resembles the specimens here studied, but differs by its smaller size. *Platysaccus papilionis* exhibits larger saccus.

Subturma *Striatiti* PANT, 1954

GENUS *Protohaploxylinus* SAMOILOVICH emend.
HART, 1964

Type species. *Protohaploxylinus latissimus* (LUBER) SAMOILOVICH, 1953.

Protohaploxylinus sp. cf. *P. diagonalis* BALME, 1970
Figure III.O

Comparisons. Although similar to *Protohaploxylinus diagonalis*, this specimen is distinguished by the corpus transversely elongated.

Protohaploxylinus sp.
Figure III.D

Description. Pollen grain bilateral, haploxylinoid. Amb broadly oval, longitudinally elongate. Corpus transversely oval in polar view. Saccus a half-circle in outline, smaller than corpus, finely endoreticulate. Cappula ca. ½ that of corpus. Proximal surface divided into four taeniate systems, each one located at 45° of the horizontal and vertical corpus axis.

Dimensions. Overall breadth: 62µm. Corpus breadth: 40µm; length: 49µm. Sacci breadth: 17µm; length 48µm (1 specimen).

Comparisons. The peculiar features of the taeniate systems of this unique specimen disallow a close comparison with previously described species.

GENUS *Striatopodocarpites* ZORICHEVA and SEDOVA
ex. SEDOVA emend. HART, 1964

Type species. *Striatopodocarpites tojmensis* SEDOVA, 1956.

Striatopodocarpites sp. cf. *S. cancellatus* (BALME and HENNELLY) HART, 1965
Figure III M

Comparisons. The single specimen identified is very similar to *Striatopodocarpites cancellatus*. Nevertheless, due to the poor preservation, the specific assignation is made with reserves.

Striatopodocarpites sp. cf. *S. phaleratus* (BALME and HENNELLY) HART, 1965
Figure III V

Comparisons. Although *Striatopodocarpites phaleratus* is very similar to our specimens, it differs in having two folds delimiting the cappula.

Striatopodocarpites sp.
Figure III W

Description. Pollen grain bilateral, diploxylinoid. Amb broadly oval, longitudinally elongate. Corpus slightly transversely oval in polar view. Proximal surface divided into 6 continuous transverse taeniate, sculptured by small verrucae, densely distributed. Saccus subcircular in outline, larger than corpus, finely endoreticulate. Cappula narrow, ca. 1/10 that of corpus.

Dimensions. Overall breadth: 52-81µm. Corpus breadth: 23-25µm; length: 29-40µm. Sacci breadth: 26-44µm; length 35-61µm (2 specimens).

Comparisons. The morphological features of the two identified specimens differ from others belonging to this characteristic Permian genus.

GENUS *Tornopollenites* MORGAN, 1972

Type species. *Tornopollenites toreutos* MORGAN, 1972

Tornopollenites toreutos MORGAN, 1972
Figure III.U

1976. *Striatoabieites* ? sp. MENÉNDEZ, p. 19; plate 3, figure 4.

Remarks. The specimens described by Menéndez (1976) from the Irati Formation are reassigned to *Tornopollenites toreutos* because they share the diagnostic characters of the species.

Turma *Plicates* NAUMOVA emend. POTONIÉ, 1960
Subturma *Costates* POTONIÉ, 1970
Infraturma *Costati* JANSONIUS, 1963
GENUS *Vittatina* LUBER 1940, SAMOILOVICH 1953
emend. WILSON, 1962

Type species. *Vittatina subsaccata* SAMOILOVICH, 1953.

Vittatina sp. cf. *V. vittifera* (LUBER) SAMOILOVICH,
1953
Figure IV D

Comparisons. These specimens exhibit the large number of taenias (14-18) characteristic of this species, but are assigned with reserve due to their poor preservation.

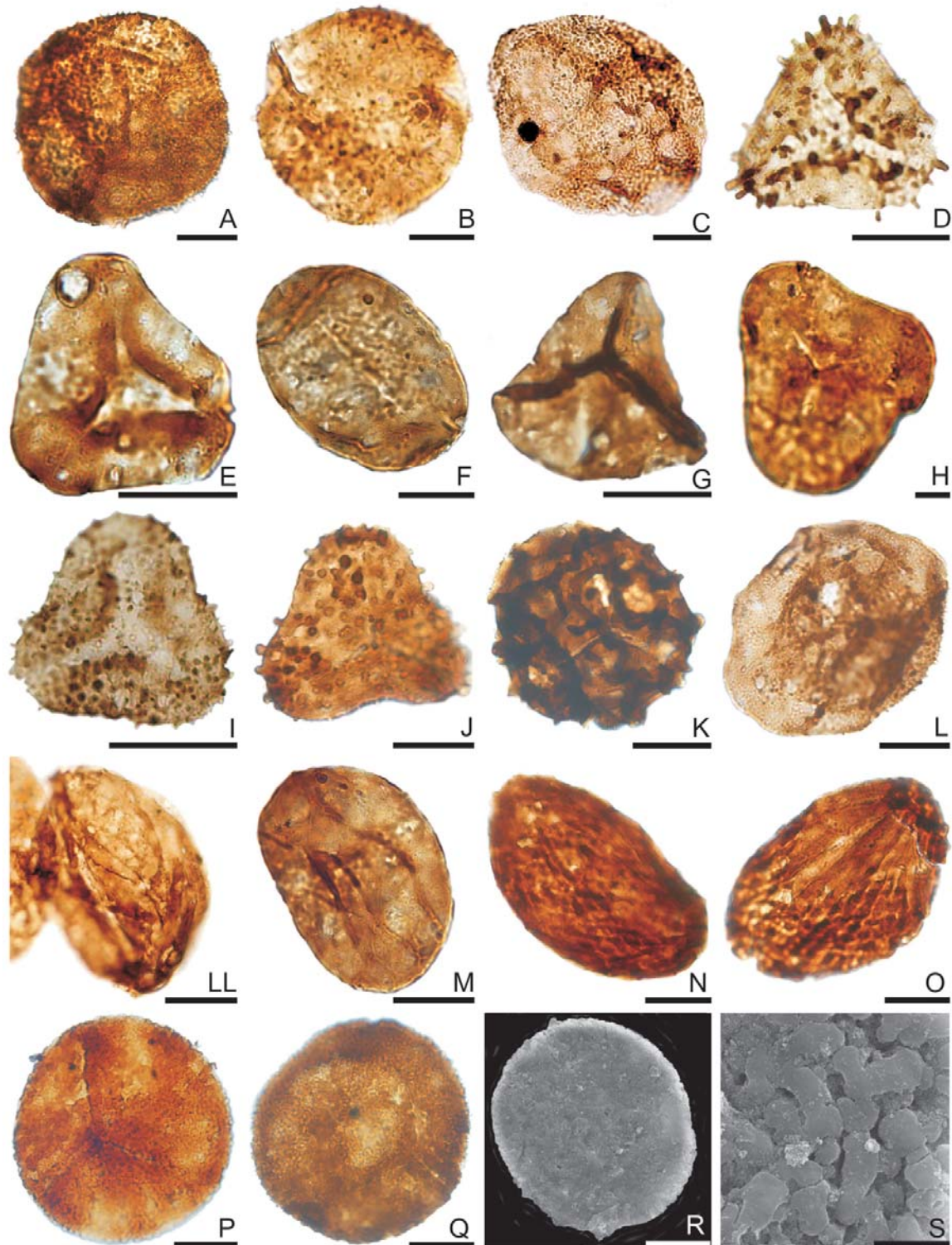


FIGURE 1 | A) *Apiculatisporis parviapiculatus* Azcuy, BA Pal 5817-2: A37/3; B) *Apiculatisporis* sp., BA Pal 5817-4: U55/2; C) *Cyclogranisporites* sp., BA Pal 5817-2: W22/3; D) *Horriditriletes uruguayensis* (Marques-Toigo) Archangelsky and Gamarro, BA Pal 5818-2: T54/0; E) *Leiotriletes adnatus* (Kosanke) Potonie and Kremp, BA Pal 5817-2: X53/3; F) *Laevigatosporites vulgaris* (Ibrahim) Ibrahim, BA Pal 5817-2: J24/3; G) *Leiotriletes virkkiae* Tiwari, BA Pal 5819-1: K35/2; H) *Leiotriletes* sp., BA Pal 5817-2: H26/4; I) *Lophotriletes discordis* Gutiérrez and Césari, BA Pal 5819-2: K31/4; J) *Lophotriletes intermedius* Azcuy, BA Pal 5819-1: Z56/3; K) *Reticulatisporites* sp., BA Pal 5818-2: C52/4; L) *Spelaeotriletes ybertii* (Marques-Toigo) Playford and Powis, BA Pal 5818-1: W45/3; LL-M) *Striatosporites heyleri* (Doubringer) Playford and Dino; LL) BA Pal 5817-3: T54/4; M) BA Pal 5817-2: 148/12; N-O) *Kendosporites robustus* Stephenson; N) BA Pal 5817-2: R46/0; O) BA Pal 5817-2: P38/2; P-S) *Verrucosiporites insuetus* Playford and Dino; P) BA Pal 5817-13: D40/1; Q) BA Pal 5817-2: F25/2; R) MEB; S) Detail of the sculpture, MEB. Scale bar: 20 μ m, except K: 5 μ m.

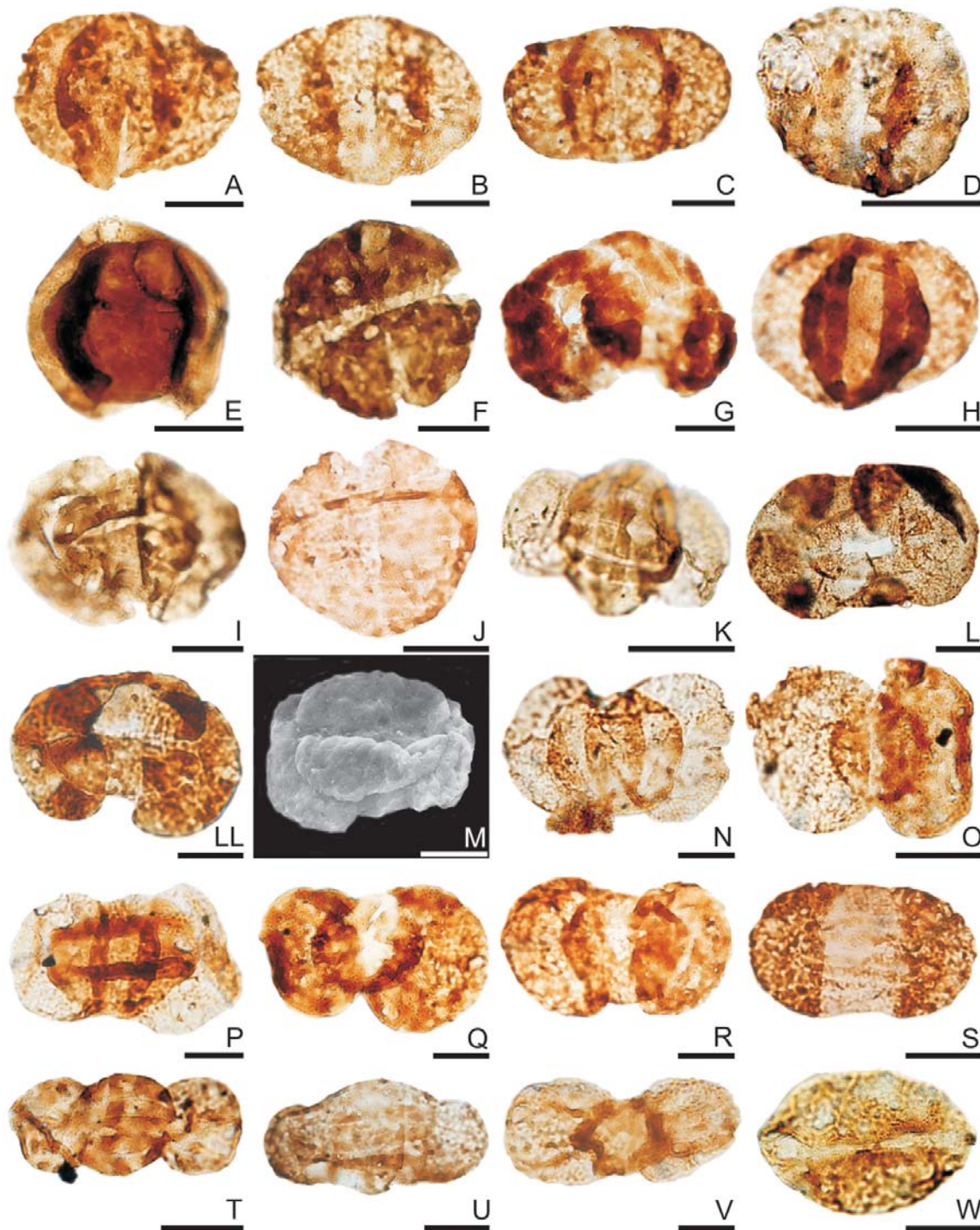


FIGURE II | A) *Alisporites australiensis* de Jersey, BA Pal 5817-3: G32/3; B) *Alisporites gracilis* Segroves, BA Pal 5817-5: L50/2; C) *Alisporites parvus* de Jersey, BA Pal 5817-2: E46/4; D) *Alisporites splendens* (Leschik) Foster, BA Pal 5817-2: G31/2; E) *Colpisaccites granulosus* Archangelsky and Gamarro, BA Pal 5818-1: D33/3; F) *Staurosaccites cordubensis* Archangelsky and Gamarro, BA Pal 5820-1: K50/4; G) *Distriatites insolitus* Bharadwaj and Salujha, BA Pal 5817-2: X22/2; H) *Falcisporites nuthallensis* (Clarke) Balme, BA Pal 5817-4: N35/3; I) *Lunatisporites varieseetus* Archangelsky and Gamarro, BA Pal 5820-1: N58/3; J) *Pakhapites fusus* (Bose and Kar) Menéndez, BA Pal 5817-7: P52/0; K) *Hamiapollenites karroensis* (Hart) Hart, BA Pal 5817-2: Q29/3; L) *Lueckisporites stenotaeniatus* Menéndez, BA Pal 5817-2: Z40/2; LL-M) *Lueckisporites virkkiae* Potonié and Klaus; LL= BA Pal 5817-6: T36/1; M= MEB; N) *Platysaccus* sp. 3, BA Pal 5817-6: M24/1; O) *Platysaccus papilionis* Potonié and Klaus, BA Pal 5817-4: M37/3; P) *Platysaccus* sp. 1, BA Pal 5817-5: H47/3; Q) *Platysaccus leschikii* Hart, BA Pal 5817-2: U45/3; R) *Platysaccus* sp. 2, BA Pal 5817-6: V49/3; S) *Protohaploxyypinus amplus* (Balme and Hennelly 1955) Hart, BA Pal 5817-6: Q40/4; T) *Hamiapollenites andiraensis* Playford and Dino, BA Pal 5817-2: L36/4; U) *Hamiapollenites fusiformis* Marques-Toigo emend. Archangelsky y Gamarro, BA Pal 5817-4: V49/2; V) *Platysaccus queslandii* de Jersey, BA Pal 5817-6: R51/1; W) *Cycadopites alhuampi* Césari et al., BA Pal 5817-2: T24/4. Scale bar: 20 μ m.

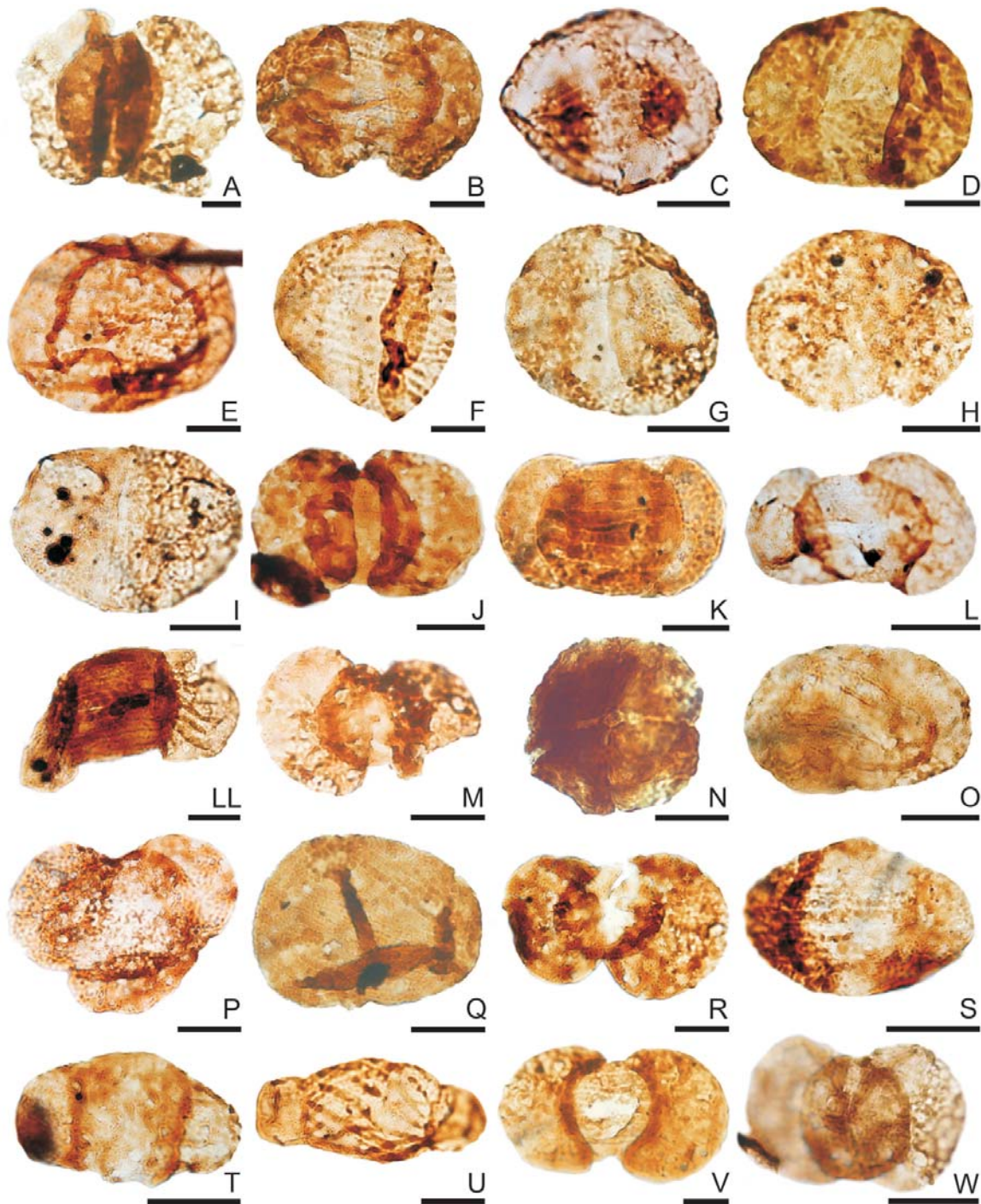


FIGURE III | A) *Protohaploxypinus bharadwajii* Foster, BA Pal 5817-3: 033/0; B) *Protohaploxypinus jacobii* (Jansonius) Hart, BA Pal 5817-6: Y50/1; C) *Striatomonosaccites ovatus* Bharadwaj, BA Pal 5819-1: Y47/3; D) *Protohaploxypinus* sp., BA Pal 5817-6: T44/0; E) *Striatomonosaccites* sp. cf. *S. cicatricosus* Archangelsky and Gamberro, BA Pal 5817-2: W45/4; F) *Vittatina saccata* (Hart) Playford and Dino, BA Pal 5817-2: L37/2; G) *Scheuringipollenites medius* Diaz Fabricio, BA Pal 5817-3: C46/2; H) *Scheuringipollenites ovatus* (Balme and Hennelly) Foster, BA Pal 5817-3: F30/2; I) *Scheuringipollenites circularis* Césari et al., BA Pal 5817-3: S43/0; J) *Striatopodocarpites rarus* (Bharadwaj and Salujha) Balme, BA Pal 5817-2: L29/3; K) *Striatobieites multistriatus* (Balme and Hennelly) Hart, BA Pal 5817-5: L46/4; L) *Striatopodocarpites solitus* (Bharadwaj and Salujha) Foster, BA Pal 5817-3: C40/3; LL) *Striatobieites anaverrucosus* Archangelsky and Gamberro, BA Pal 5817-3; M) *Striatopodocarpites* sp. cf. *S. cancellatus* (Balme and Hennelly) Hart, BA Pal 5819-3: M55/0; N) *Staurosaccites quadrifidus* Dolby, BA Pal 5821-1: Z57/2; O) *Protohaploxypinus* sp. cf. *P. diagonalis* Balme, BA Pal 5817-3: W38/0; P) Trisacado indet., BA Pal 5817-3: S53/3; Q) *Vittatina corrugata* Marques-Toigo, BA Pal 5817-3: N31/2; R) *Striatopodocarpites fusus* (Balme and Hennelly) Potonié, BA Pal 5817-3: 043/1; S) *Vittatina subsaccata* Samoilovich, BA Pal 5817-7: X40/1; T) *Pteruchipollenites gracilis* (Segroves) Foster, BA Pal 5817-6: T37/3; U) *Tornopollenites toreutos* Morgan, BA Pal 5817-60: K41/1; V) *Striatopodocarpites* sp. cf. *S. phaleratus* (Balme and Hennelly) Hart, BA Pal 5817-2: N52/2; X) *Striatopodocarpites* sp. 1, BA Pal 5817-1: L53/3. Scale bar: 20 μ m.

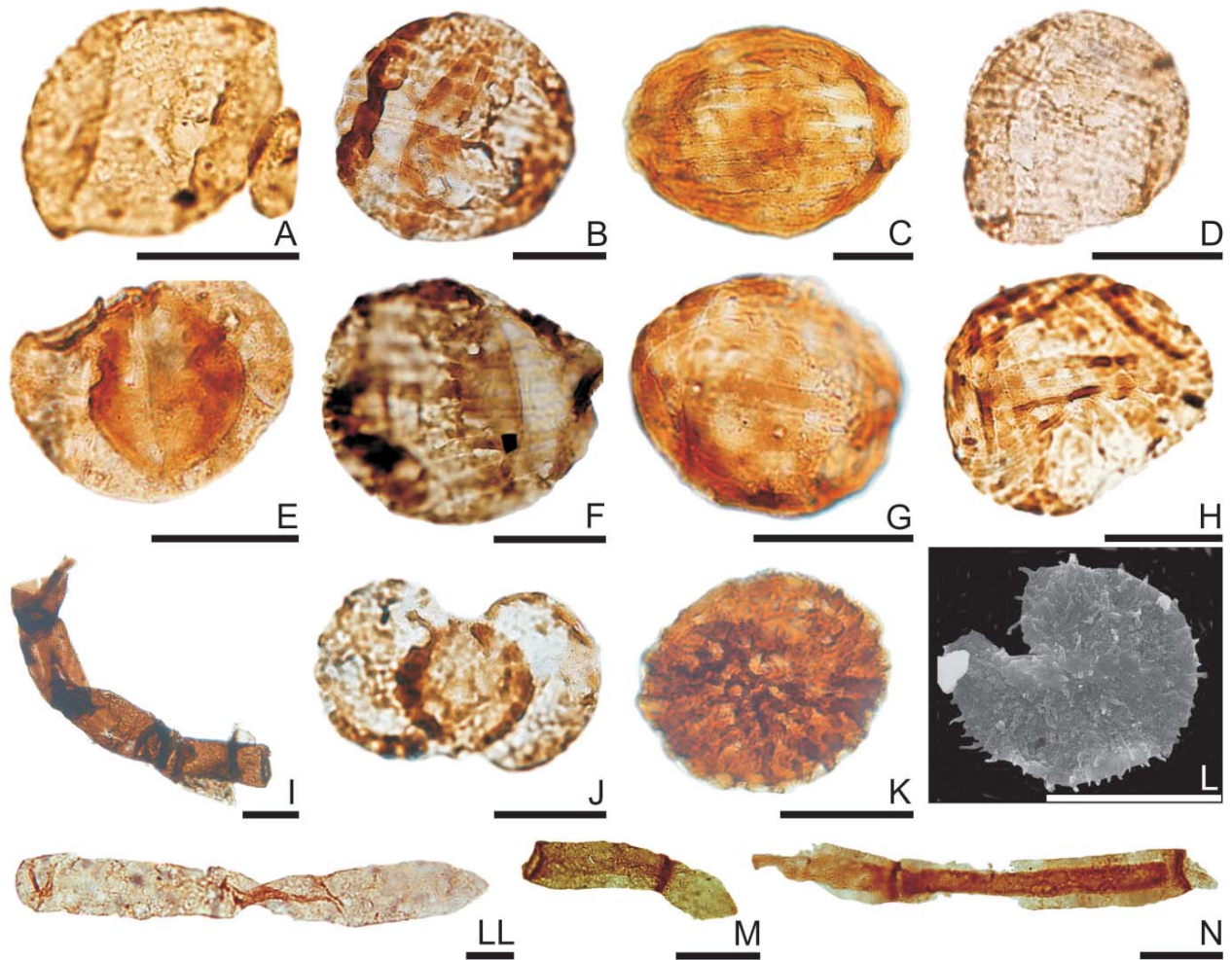


FIGURE IV | A) *Marsupipollenites striatus* (Balme and Hennelly) Hart, BA Pal 5817-4: J34/4; B) F) *Vittatina costabilis* Wilson, B) BA Pal 5817-7: 039/4; F) BA Pal 5817-7: P42/4; C) *Vittatina wodehousei* (Jansonius) Hart, BA Pal 5817-5: 024/3; D) *Vittatina* sp. cf. *V. vittifera* (Luber) Samoilovicj, BA Pal 5817-2: U43/0; E) *Vitreisporites microsaccus* de Jersey, BA Pal 5817-4: U55/2; G) *Weylandites magnus* (Bose and Kar) Backhouse, BA Pal 5817-3: S49/4; H) *Weylandites lucifer* (Bharadwaj and Salujha) Foster, BA Pal 5817-5: Q33/0; I) M-N) *Reduviasporonites chalastus* (Foster) Elsik; I, BA Pal 5817-12: E29/0; M= BA Pal 5817-11: H33/3; N= BA Pal 5817-11: G53/2; J) *Platysaccus* sp. 4, BA Pal 5817-3: Y31/3; K) *Cymatiosphaera gondwanensis* (Tiwari) Backhouse, BA Pal 5817-8: E26/3; L) *Gorgonisphaeridium* sp., MEB; LL) *Navifusa* sp., BA Pal 5817-2: BA Pal 5817-7: R51/0. Scale bar: 20µm.