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New palynological information from the Poti Formation (upper Visean) at the Roncador creek, Parnaíba Basin, northeastern Brazil

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ABSTRACT

This contribution presents the results of the palynological analysis of six surface samples of the Poti Formation cropping out at Roncador creek (Jerumenha, Piauí), northeastern Brazil. This unit unconformably overlies the upper Famennian-Tournaisian Longá Formation and is in turn unconformably overlain by the lower Pennsylvanian Piaui Formation. Carbonaceous shales and siltstones yielded a diverse assemblage of well-preserved palynomorphs, composed of 95 species: 58 indigenous spore, and 5 algal species, and 9 reworked spore and 23 reworked microplankton species mostly from Devonian strata. Three new species are described (*Verrucosisporites iannuzzii, V. roncadorense, V. souzai*). The first records for the Mississippian of Brazil (24 species) and South America (7 species) are also documented. Several age diagnostic species recorded in the Poti Formation (*Anapiculatisporites amplus, A. concinnus, Foveosporites pellucidus, Grandispora maculosa, Reticulatisporites magnidictyus, Verrucosisporites morulatus* and *Waltzispora polita*), complete with others not previously documented in subsurface deposits of this unit (*Apiculiretusispora microseta, Densosporites spinosus, Knoxisporites ruhlandi, Punctatisporites subvaricosus, Retusotriletes mirabilis* and *Tricidarisporites phippsae*), confirm a late Visean age and its correlation to the *R. magnidictyus* Melo and Loboziak Zone. Worldwide comparison of the Roncador association indicates a greater affinity with coeval palynofloras with similar paleolatitudinal position in South America, North Africa and Australia (Paracas Realm). Sedimentologic (e.g., sandstones with sigmoidal cross and wave ripple beddings) and paleontological features (e.g., plant remains and abundant terrestrial organic matter) throughout this section document a shallow, estuarine, depositional environment.

Key words: biostratigraphy, late Visean, northeastern Brazil, palynomorphs, Poti Formation.

Nueva información palinológica sobre la Formación Poti (Viseano superior) en el arroyo Roncador, Cuenca Parnaíba, noreste de Brasil

RESUMEN

*Se presenta el resultado del análisis palinológico de seis muestras de superficie de la Formación Poti expuesta en el arroyo Roncador (Jerumenha, Piauí), noreste de Brasil. Esta unidad sobreyace en discordancia a la Formación Longá (Famenniano superior-Tournaisiano) y sobre ella se dispone en discordancia la Formación Piaui (Pennsylvaniano inferior). Lutitas carbonosas y limolitas brindaron una diversa asociación de palinomorfos bien preservados, compuesta por 95 especies: 58 especies autóctonas de esporas y 5 de algas, y 9 especies de esporas y 23 especies de microplancton retrabajados principalmente de depósitos del Devónico. Se describen tres nuevas especies (*Verrucosisporites iannuzzii, V. roncadorense, V. souzai*). Se documenta el primer registro de 24 especies para el Mississippiano de Brasil y 7 especies para América del*

Sur. Entre las especies con valor estratigráfico registradas en la sección aquí estudiada Anapiculatisporites amplus, A. concinnus, Foveosporites pellucidus, Grandispora maculosa, Reticulatisporites magnidictyus, Verrucosisporites morulatus, Waltzispora polita, *junto con otras no registradas previamente en la Formación Poti* (Apiculiretusispora microseta, Densosporites spinosus, Knoxisporites ruhlandi, Punctatisporites subvaricosus, Retusotriletes mirabilis, Tricidarisporites phippsae)*, confirman una edad Viseano tardío y su correlación con la Zona R. magnidictyus (Mag) Melo y Loboziak. La comparación mundial del presente conjunto palinológico indica una gran afinidad con palinofloras coetáneas distribuidas en paleolatitudes similares en América del Sur, Norte de África y Australia (Reino Paracas). Las características sedimentológicas (e.g., areniscas con estratificación cruzada sigmoidal y ondulitas) y paleontológicas (e.g., restos de plantas y abundante materia orgánica terrestre) de la sección indican que la depositación ocurrió en un ambiente de estuario de baja profundidad.*

Palabras clave: bioestratigrafía, Formación Poti, noreste Brasil, palinomorfos, Viseano tardío.

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Introducción y metodología

La cuenca intracratónica de Parnaíba está situada en el noreste de Brasil (Fig. 1A-B), donde dos grandes ejes depositacionales con tendencia NO- SE (Lineamiento Marajó – Parnaíba, Góes y Feijó, 1994) y NE- SO (Lineamiento Transbrasiliano) son relictos de un extenso sistema de depositación del Carbonífero Inferior que se extiende más allá de los límites actuales de la cuenca.

Debido a su posición, la Cuenca de Parnaíba habría estado conectada a la cuenca de Amazonas y las cuencas de África Occidental (Góes, 1995; Milani y Thomaz Filho, 2000). Basado en evidencias palinológicas, Melo y Loboziak (2000) sugirieron la existencia de un hiato abarcando el más tardío Tournaisiano y el Visean temprano, entre las formaciones Longá y Poti (Fig. 1C). Otro hiato desde el Serpukhoviano al Pennsylvaniano más temprano (?) se reconoce entre las formaciones Piauí y Poti (Melo y Loboziak, 2003). La Formación Poti se compone principalmente de areniscas con intercalaciones menores de lutitas carbonosas y otras litologías siliciclásticas, las cuales se habrían acumulado en ambientes fluvio-deltaicos próximos a la línea de costa representando un ciclo regresivo dentro del megaciclo número 1 propuesto para Mississippiano tardío de esta cuenca (e.g., Schobbenhaus et al., 1984; Santos y Carvalho, 2009). Restos vegetales, bivalvos y palinomorfos permitieron atribuir una edad Viseano tardío a la presente unidad (Melo y Loboziak, 2000, 2003; Iannuzzi y Pfefferkorn, 2002; Santos y Carvalho, 2009; Streel et al., 2012). Entre los restos de plantas, Iannuzzi y Pfefferkorn (2002) documentaron pteridofitas ("Lepidodendropsis", Archaeocalamites*), pteridospermas (*Diplothmema, Aneimites*, "Triphyllopteris", Nothorhacopteris, ?Fryopsis, ?Sphenopteridium) y fructificaciones de pteridospermas primitivas (?*Calymmatotheca, Kegelidium, Paulophyton*). Trindade (1971) realizó el estudio de las megasporas asociadas a dicha flora (e.g.,* Lagenoisporites, Duosporites, Triletes, Setosisporites y Cystosporites*). Iannuzzi y Pfefferkorn (2002) propusieron la inclusión de la flora de la Formación Poti en el Reino Paracas, con base en la similitud de sus registros paleobotánicos y palinológicos (principalmente documentados a partir de depósitos de subsuelo), con otros conocidos de América del Sur en Perú y Bolivia (Fig. 1A-C), y unidades equivalentes del norte de Africa, India y Australia. Iannuzzi et al. (2003) definieron la Zona* Nothorhacopteris kellaybelenesis - Triphyllopteris boliviana *incluyendo los registros paleobotánicos de la Formación Poti.*

En esta contribución se presenta el resultado del análisis palinológico detallado obtenido de seis muestras de lutitas y limolitas carbonosas de un afloramiento de 5 m de espesor de la Formación Poti situado en el arroyo Roncador (Fig. 1B, 2). Cabe señalar que Dolianiti (1980) fue el primero en describir la presente localidad reportando dos especies de plantas fósiles referidas como Rhacopteris *sp. y* Triphyllopteris alvaro- albertoi. *Las mismas son reinterpretadas en este trabajo como* Nothorhacopteris *cf.* N. kellaybelenensis *y* Fedekurtzia *cf.* F. argentina*, respectivamente. Hasta la actualidad se trata del único afloramiento de la Formación Poti que ha brindado palinología y restos de plantas estudiado por Iannuzzi (1994, no publicado). Del mismo sólo fueron presentados algunos resultados en comunicaciones de congresos (Iannuzzi et al., 1993; Iannuzzi y Scherer, 1996). Iannuzzi y Pfefferkorn (2002) incluyeron solamente la lista de taxones de palinomorfos determinados de forma preliminar por Iannuzzi (1994) junto con otros registros provistos por otros autores para la Formación Poti (e.g., Daemon, 1974; Melo y Loboziak, 2000).*

Para la recuperación de palinomorfos se aplicó la metodología estándar (e.g., Traverse, 2007). La identificación de especies y microfotografías fue realizada con microscopios de luz transmitida Leitz Orthoplan y Nikon Eclipse 80i dotados con videocámaras digitales Motic (2.0 megapixels) y Pax-it (3.1 megapixels), respectivamente, pertenecientes al Laboratorio de Palinoestratigrafía de la Facultad de Ciencias Exactas y Naturales (Universidad de Buenos Aires, Argentina). Los especímenes ilustrados son identificados bajo la *referencia de la lámina correspondiente a los institutos de investigación donde son almacenadas (Laboratorio de Paleopalinología y Paleobotánica del CICYTTP, Diamante, Entre Ríos, Argentina, y Laboratorio de Palinología "Marleni Marques Toigo", Instituto de Geosciences (IGeo), Universidad Federal de Rio Grande do Sul, Porto Alegre, Brasil), seguido por las coordenadas England Finder. Estudios morfológicos de detalle fueron realizados con Microscopio Electrónico de Barrido (MEB) perteneciente al Museo de Ciencias Naturales "Bernardino Rivadavia" (MACN), en Buenos Aires (Argentina).*

Resultados y discusión

*El análisis palinológico de las muestras fértiles del arroyo Roncador reveló una diversa asociación de palinomorfos bien preservados, compuesta por 95 especies: 58 especies de esporas y 5 especies de algas autóctonas, y 9 especies de esporas y 23 especies de microplancton retrabajados principalmente de depósitos del Devónico. Tres nuevas especies son descriptas (*Verrucosisporites iannuzzii, V. roncadorense, V. souzai*) (Figs. 3-11). Se documentan también como primer registro, 24 especies para el Mississippiano de Brasil y 7 especies para América del Sur (Tabla 1, material suplementario). Fitoclastos de origen terrestre (cutículas y leños) son frecuentes en todos los niveles. La información cuantitativa obtenida de los principales grupos de palinomorfos por nivel (Fig. 12) indica que en la mayoría de los niveles, excepto uno (P7) se registran porcentajes muy similares de esporas (70-80 %) mientras que* Botryococcus *representa aproximadamente 20 %. Sólo el nivel P7 reveló un porcentaje de casi 20% de palinomorfos retrabajados mientras que en los restantes niveles está por debajo del 5 %. Entre los taxones identificados que proceden de estratos del Devónico Medio y Tardío, se encuentran numerosos acritarcas y prasinofíceas de origen marino (e.g.,* Umbellasphaeridium deflandrei, Maranhites insulatus*) y esporas de plantas terrestres (e.g.,* Emphanisporites rotatus, Grandispora pseudoreticulata, Samarisporites triangulatus*; di Pasquo et al., 2009). Otras especies tales como* Emphanisporites hibernicus *y* Cordylosporites marciae *conocidas del Devónico más tardío y Tournaisiano (Tabla 1, material suplementario), están poco representadas en este nivel, al igual que otras especies ampliamente registradas en el Tournaisiano (e.g.,* Tumulispora variverrucata, Spelaeotriletes balteatus*). Las especies más abundantes de esporas en todos los niveles corresponden a las formas de pared simple y lisa de los géneros Punctatisporites y/o Calamospora. Por su parte, el grupo de las densosporas (*Cristatisporites, Kraeuselisporites, Vallatisporites*) y las especies* Apiculiretusispora semisenta, Colatisporites decorus *y* Reticulatisporites magnidictyus *siempre están presentes en bajas frecuencias (Figs. 3A y 12). Las nuevas especies de Verrucosisporites se encuentran bien representadas en la mayoría de los niveles por especímenes aislados y tetradas (Figs. 3A, 7 y 12). Entre las especies con valor estratigráfico registradas en la Formación Poti se encuentran* Anapiculatisporites amplus, A. concinnus, Foveosporites pellucidus, Grandispora maculosa, Reticulatisporites magnidictyus, Verrucosisporites morulatus, Waltzispora polita, *las cuales permiten establecer una correlación con la Zona R. magnidictyus (Mag) Melo y Loboziak (2003). Otras especies tales como* Apiculiretusispora microseta, Densosporites spinosus, Knoxisporites ruhlandi, Punctatisporites subvaricosus, Retusotriletes mirabilis, Tricidarisporites phippsae, *no fueron registradas previamente en depósitos de la cuenca Parnaiba (Tabla 1, material suplementario). Entre ellas,* Foveosporites pellucidus, Knoxisporites ruhlandi, Tricidarisporites phippsae, Retusotriletes mirabilis y Waltzispora polita, *son taxones diagnósticos del Viseano medio-tardío conocidas principalmente en Australia (Playford, 1991; Jones y Truswell, 1992) y/o Europa (Clayton et al., 1977). Todas estas especies confirman una edad Viseano tardío para la sección aquí estudiada (Figs. 13, 14 y Tabla 1, material suplementario) e indican una gran afinidad con palinofloras coetáneas distribuidas en paleolatitudes similares del Reino Paracas (Iannuzzi y Pfefferkorn, 2002) en América del Sur (Azcuy y di Pasquo, 2005, 2006; Fasolo et al., 2006; di Pasquo, 2008b), Norte de África (Coquel et al., 1988, 1995) y Australia (Playford, 1991; Jones y Truswell, 1992). En esta contribución no se confirma la presencia de* Schopfipollenites *sp. en la Formación Poti en el arroyo Roncador tal como fuera expresado por Iannuzzi y Scherer (1996) y Iannuzzi y Pfefferkorn (2002). El análisis palinológico aquí realizado demostró que el único espécimen designado como* Schopfipollenites *sp. por Iannuzzi (1994) corresponde a una espora del género* Calamospora *sp. (Figs. 3 y 6). Por lo tanto, hasta el momento este tipo de pre-polen se registra en el Reino Paracas si bien no está presente en la cuenca Parnaíba.*

Con respecto a la flora de la presente localidad se destaca la presencia del primer registro del género Fedekurtzia en el Mississippiano tardío. Este taxón fue anteriormente erigido y reconocido sólo en los depósitos del Pennsylvaniano de Argentina (Césari, 1986). Por consiguiente, su rango se extiende al Viseano tardío. La descripción formal del material vegetal y su importancia paleogeográfica y estratigráfica se encuentra en progreso. Finalmente, en relación con la interpretación paleoambiental de la sección, las características sedimentológicas (e.g., areniscas con estratificación cruzada sigmoidal y ondulitas) y paleontológicas (e.g., restos de plantas y abundante materia orgánica terrestre) indican que la depositación ocurrió en un ambiente de estuario de baja profundidad (Fig. 2). Los palinomorfos retrabajados del Devónico y Tournaisiano registrados en un 20 % del total de la asociación en un solo nivel confirman la discordancia entre las formaciones Poti y Longá (Fig. 1C; e.g., Melo y Loboziak, 2003).

Introduction

The intracratonic Parnaíba Basin is located in northeastern Brazil (Fig. 1A-B), where two major depositional axes trending NW–SE (the Marajó-Parnaíba Lineament, after Góes and Feijó, 1994) and NE–SW (the Transbrasilian Lineament) are relics of formerly continuous Mississippian sedimentation beyond the present-day limits of the basin. Because of its location, the Parnaíba Basin was possibly connected to the Amazonas Basin and Western African basins respectively (Góes, 1995; Milani and Thomaz Filho, 2000). The Poti Formation consists mainly of sandstones with minor proportions of carbonaceous shales and other siliciclastic lithologies accumulated in fluvial to marine environmental settings that represented a regressive cycle of a first megacycle proposed for the Mississippian of this basin (e.g., Schobbenhaus *et al.*, 1984; Santos and Carvalho, 2009). Plant fossils, bivalves, and palynomorphs warranted a late Visean age for this unit (Daemon, 1974; Iannuzzi *et al.*, 2003; Iannuzzi and Scherer, 1996; Melo and Loboziak, 2000, 2003; Iannuzzi and Pfefferkorn, 2002; Santos and Carvalho, 2009; Streel *et al.*, 2012). Among the plant fossils, Iannuzzi and Pfefferkorn (2002) updated the floral composition, documenting the presence of lycopsid ("*Lepidodendropsis*") and sphenopsid (*Archaeocalamites*) stems, and primitive pteridosperm foliages (*Aneimites*, *Diplothmema*, ?*Fryopsis*, *Nothorhacopteris*, ?*Sphenopteridium*, *Triphyllopteris*) and fructifications (*Kegelidium*, *Paulophyton*, ?*Stamnostoma*). Trindade (1971) also studied the megaspores (e.g., *Lagenoisporites*, *Duosporites*, *Triletes*, *Setosisporites* and *Cystosporites*). Iannuzzi and Pfefferkorn (2002) proposed the inclusion of the flora of the Poti Formation into the Paracas realm due to its similarity to paleobotanical and palynological records from other basins in South America (Peru and Bolivia, see Fig. 1A, C), North Africa, India and Australia. Iannuzzi *et al.* (2003) defined the *Nothorhacopteris kellaybelenesis* - *Triphyllopteris boliviana* Zone including the paleofloral records of the Poti Formation (Fig. 1C). In this contribution, detailed palynological information from carbonaceous shales and siltstones of the Poti Formation exposed at Roncador creek (Fig. 1B, 2) is presented. Biostratigraphical and paleoenvironmental inferences are also addressed.

Geological setting

In the Parnaíba Basin (Fig. 1A-B), the Mississippian comprises the Longá and Poti Formations (Figs. 1C), which are best known from subsurface strata. These formations consist of sandstones, carbonaceous shales and other siliciclastic lithologies. They are subdivided within the Canindé Group, which also includes mostly Devonian to Tournaisian rock units of marine origin (e.g., Melo and Loboziak, 2003).

The Poti Formation unconformably overlies the uppermost Famennian–Tournaisian Longá Formation and is in turn unconformably overlain by the Moscovian and younger Piauí Formation which is the basal subdivision of the Balsas Group (see Melo and Loboziak, 2000). This unit, up to 320 m thick, is extensively represented, both in the subsurface of the basin and throughout its marginal outcrop belts. The lithofacies characteristics and sedimentary evolution of the Poti Formation were discussed and successively updated in several previous studies (Lima and Leite, 1978; Caputo, 1984; Della Favera, 1990; Góes and Feijó, 1994; Góes, 1995). According to these authors, different shallow marine to continental paleoenvironment arranged in a prograding succession bearing bivalve assemblages (Santos and Carvalho, 2009), were interpreted as littoral, fluvial and deltaic-estuarine deposits. Higher parts of the formation, containing more continental systems, are particularly rich in carbonized land plant megafossils (Dolianiti, 1954, 1980; Iannuzzi, 1994; Iannuzzi and Pfefferkorn, 2002; Iannuzzi *et al.*, 2006) and megaspores (Trindade, 1971). They also include very thin coal seams bearing plant fossils related to the *Nothorhacopteris kellaybelenesis - Triphyllopteris boliviana* Zone (Iannuzzi *et al.*, 2003; Fig. 1B). Previous palynological studies of this unit correspond to subsurface (cutting and cores) samples (Daemon, 1974, 1976; Melo and Loboziak, 2000, 2003 and references therein; Iannuzzi and Pfefferkorn, 2002; Streel *et al.*, 2012), except for the preliminary palynological analysis carried out by Iannuzzi (1994), later summarized without illustrations by Iannuzzi and Scherer (1996) from the same outcrop we describe here.

Based on palynological analysis, Melo and Loboziak (2000) suggested that a gap spanning the latest Tournaisian–early Visean age, separates the Longá and Poti Formations (Fig. 1C). Another gap between the Piauí and Poti formations spans the Serpukhovian-earliest Bashkirian (Pennsylvanian) (?). The former unit was constrained to the Pennsylvanian based on one core sample from a coal-exploration borehole in the southern Parnaíba Basin. These palynological assemblages bearing spores of pteridophytes and gymnosperms with monosaccate and bisaccate (taeniate and non taeniate) pollen grains, were correlated to the Moscovian or Kasimovian (younger Late Pennsylvanian), DMb or DMc Zones, documented by Césari and Gutiérrez (2001), from western Argentina and with the *I. unicus* Zone defined by Playford and Dino,

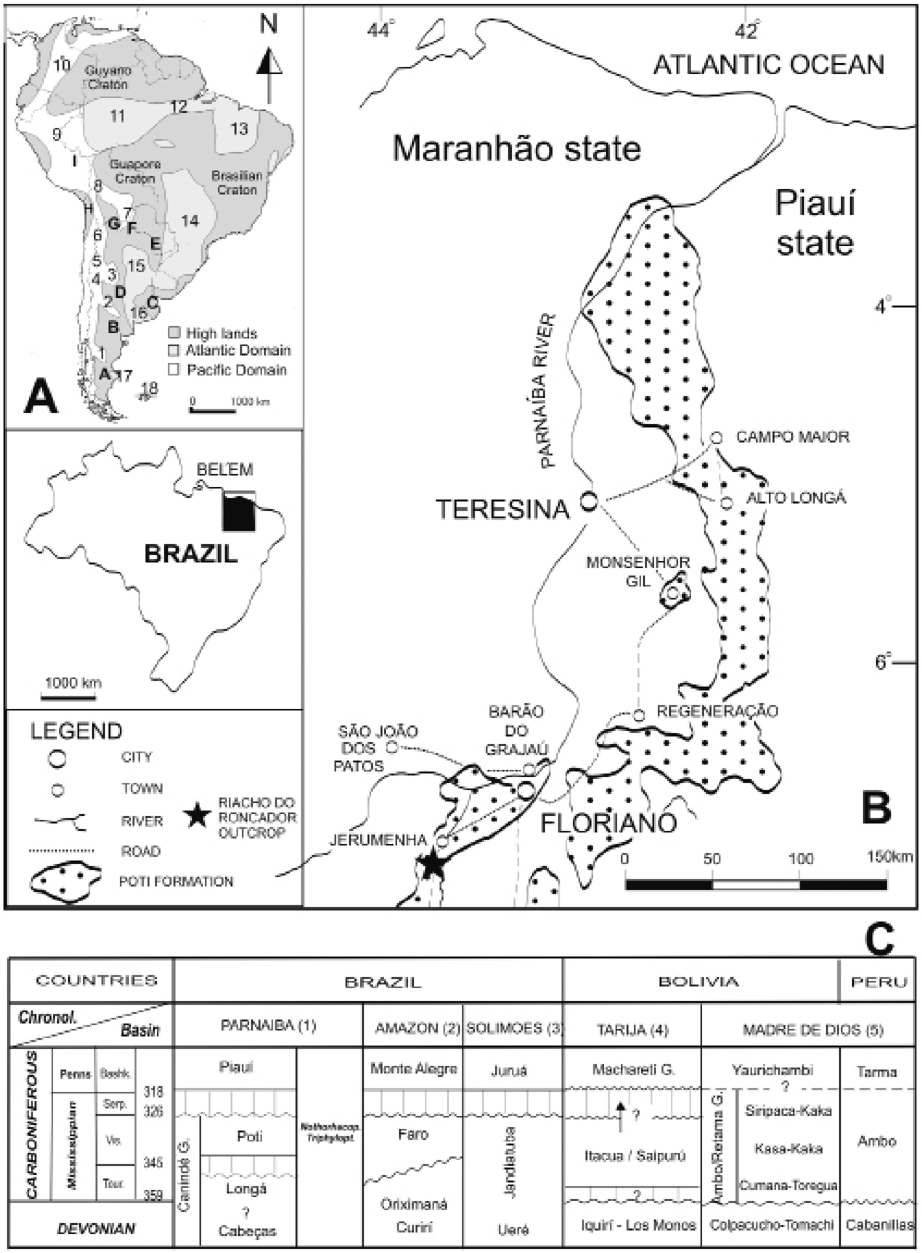

Figure. 1.A. South American basins: 1. Tepuel-Genoa, 2. San Rafael, 3. Paganzo, 4. Uspallata-Iglesia, 5. Río Blanco, 6. Arizaro, 7. Tarija, 8. Madre de Dios, 9. Ucayali-Marañón-Acre, 10. Los Llanos Orientales, 11. Solimôes, 12. Amazonas, 13. Parnaiba, 14. Paraná, 15. Chaco-Paranense, 16. Sauce Grande-Claromecó-Colorado, 17. Golondrina, 18. Falklands Islands. High lands: A. Deseado Massif, B. Somuncurá Massif, C. Río de la Plata Craton, D. Pampean Arch, E. Asunción Arch, F. Michicola Arch, G. Puna Arch, H. Arequipa Massif, I. Fitzcarrald Arch. **1.B.** Location map. **1.C.** Correlation chart of the Carboniferous stratigraphic units (formations and groups) of Brazil, Bolivia and Peru. References (see also Azcuy *et al.*, 2007): 1- Melo and Loboziak (2000, 2003) and Paleoflora Zone (Iannuzzi *et al.*, 2003), 2- Playford and Dino (2000a), Dino and Playford (2002), Playford and Melo (2012), Melo and Playford (2012), 3- Melo *et al.* (1999), Melo and Loboziak (2003), 4- di Pasquo (2007); 5- Díaz Martínez (1999), Suárez Soruco (2000), Azcuy *et al.* (2002), Azcuy and di Pasquo (2005). Legend: Penns. = Pennsylvanian; Tour. = Tournaisian; Vis. = Visean; Serp. = Serpukhovian; Bashk. = Bashkirian.

Figura 1.A. *Cuencas en América del Sur: 1. Tepuel-Genoa, 2. San Rafael, 3. Paganzo, 4. Uspallata-Iglesia, 5. Río Blanco, 6. Arizaro, 7. Tarija, 8. Madre de Dios, 9. Ucayali-Marañón-Acre, 10. Los Llanos Orientales, 11. Solimôes, 12. Amazonas, 13. Parnaiba, 14. Paraná, 15. Chaco-Paranense, 16. Sauce Grande-Claromecó-Colorado, 17. Golondrina, 18. Islas Malvinas. Terrenos elevados: A. Macizo Deseado, B. Macizo Somuncurá, C. Cratón del Río de la Plata, D. Arco Pampeano, E. Arco de Asunción, F. Arco Michicola, G. Arco de la Puna, H. Macizo de Arequipa, I. Arco Fitzcarrald.* **1.B**. *Mapa de ubicación.* **1.C.** *Esquema de correlación de unidades estratigráficas del Carbonífero (formaciones y grupos) en Brasil, Bolivia y Perú. Referencias (véase también Azcuy et al., 2007): 1- Melo y Loboziak (2000, 2003) y Zona Florística (Iannuzzi et al., 2003), 2- Playford y Dino (2000a), Dino y Playford (2002), Playford y Melo (2012), Melo y Playford (2012), 3- Melo et al. (1999), Melo y Loboziak (2003), 4- di Pasquo (2007); 5- Díaz Martínez (1999), Suárez Soruco (2000), Azcuy et al. (2002), Azcuy y di Pasquo (2005). Legend: Penns. = Pennsylvaniano; Tour. = Tournaisiano; Vis. = Viseano; Serp. = Serpukhoviano; Bashk. = Bashkiriano.*

from the upper part of the Itaituba Formation in the Amazonas Basin (Dino and Playford, 2002). Souza *et al.,* (2010) have confirmed this age on the basis of the analysis of 12 core samples from a different boreholes (1-UN-09-PI). The presence of *Raistrickia cephalata*, *Protohaploxypinus amplus*, *Lunatisporites onerosus*, *Verticipollenites* sp., *Striatopodocarpites* sp. and *Meristocorpus explicatus*, allowed the correlation of most of the studied interval with the overlying *Raistrickia cephalata* Zone defined by Playford and Dino (2000a, 2000b), in the Amazonas Basin regarded as Moscovian (Pennsylvanian) in age.

Materials

From a 5 m thick outcrop of the Poti Formation (Parnaíba Basin) located at the Roncador creek, municipality of Jerumenha, southern Piauí state (Fig. 1A-B), six carbonaceous shales and siltstones yielded diverse and abundant well preserved palynomorphs. A temporary small stream (Roncador creek), becomes easily reached during dry seasons, and its banks can be sampled. Dolianiti (1980) was the first to describe this fossiliferous locality for the Poti Formation and he reported two new taxa of plant fossils (*Triphyllopteris alvaro-albertoi* and *Rhacopteris* sp.) from there. Iannuzzi and Scherer (1996) carried on a detailed sedimentological analysis of this section shown in Figure 2. It starts with a silt/clay bed, followed by whitish medium- to fine grained sandstones with medium to large sigmoid cross-stratifications. The plant fossils studied and illustrated by Iannuzzi (1994) were recovered from thin mud drapes (1-2 centimeters thick) irregularly arranged into these bedforms. A mid section is composed of clay-siltstone beds with ripple cross-laminations that are overlain by dark gray, massive, siltstones associated with fine-grained sandstones containing wave ripples and sigmoidal bedding with bimodal paleocurrents (75-90° versus 265°). Six palynological samples collected by Iannuzzi from the Poti Formation in 1992 and 1995, were productive. A first sampling programme yielded two productive samples (P6 and P7, Fig. 2). A preliminary study of these samples was reported by Iannuzzi *et al.,* (1993) and Iannuzzi (1994). A detailed analysis of these samples, together with the results of a second sampling that yielded four more productive samples (P1A, PN2, PN3 and PN3A, Fig. 2), is presented in this contribution.

Textural and structural characteristics of the basal lithofacies are interpreted as migration of 3D bedforms (tidal bundles) in tidal channels. A regressive character of the estuarine system along this section is marked by upward fining beds (Fig. 2). The Piaui Formation (Fig. 2) unconformably overlies the Poti Formation and is composed of whitish medium- to conglomeratic- grained sandstones in lenticular beds. They are interpreted as part of a braided river system. The entry of fluvial deposits into the basin is seen at outcrop scale, and they occur as a sequence boundary (SB). However, due to the local scope of the study, the cause of this discordance is speculative. Two hypotheses are possible: (1) the discordance represents a time gap of lesser magnitude than within the underlying Devonian-Mississippian sequence, or (2) the discordance is correlated to the boundary between Devonian-Mississippian and Pennsylvanian sequences, representing a significant time gap with regional expression.

Methods

A standard palynological method was carried out to obtain organic residues from the samples (Traverse, 2007). They were treated first with hydrochloric and washed to neutralization before treatment with hydrofluoric acid to remove carbonate, silica and silicates, respectively. Organic residues were sieved (mesh size of 25 μm) and finally mounted on slides with jelly-glycerin. The sample processing was undertaken at the Palynology Laboratory of the Institute of Geosciences (IG), University of São Paulo (field samples P6 and P7), the Palynology Laboratory of the "Leopoldo Américo Miguez de Mello" Center of Research (CENPES), the Laboratory of the Brazilian Petroleum Oil Company-PETROBRAS (field samples P1A, PN2, PN3, PN3A and P7), and the Palynostratigraphy Laboratory of the Faculty of Pure and Natural Sciences (FCEN), University of Buenos Aires (field samples P1A, PN2, PN3 and P6). The identification of the palynomorphs was undertaken using both *Leitz Orthoplan* and *Nikon Eclipse* 80*i* binocular transmitted light microscopes, with x1000 maximum magnification and the photomicrographs were obtained with *Motic* (2.0 megapixels) and *Pax-it* (3.1 megapixels) video camera at the Palynostratigraphy Laboratory (FCEN, UBA). The illustrated specimens were quoted with the CICYTTP-PI and MP-P acronyms corresponding to the institutions where the studied samples are stored (the Laboratories of Paleopalynology and Paleobotany at the CICYTTP, Diamante, Entre Ríos, Argentina, and of Palynology "Marleni MarquesToigo", Institute of Geosciences (IGeo), Federal University of Rio Grande do Sul, Porto Alegre, Brazil), followed by the England Finder reference. Detailed studies of the palynomorphs were illustrated under SEM and photographed with a

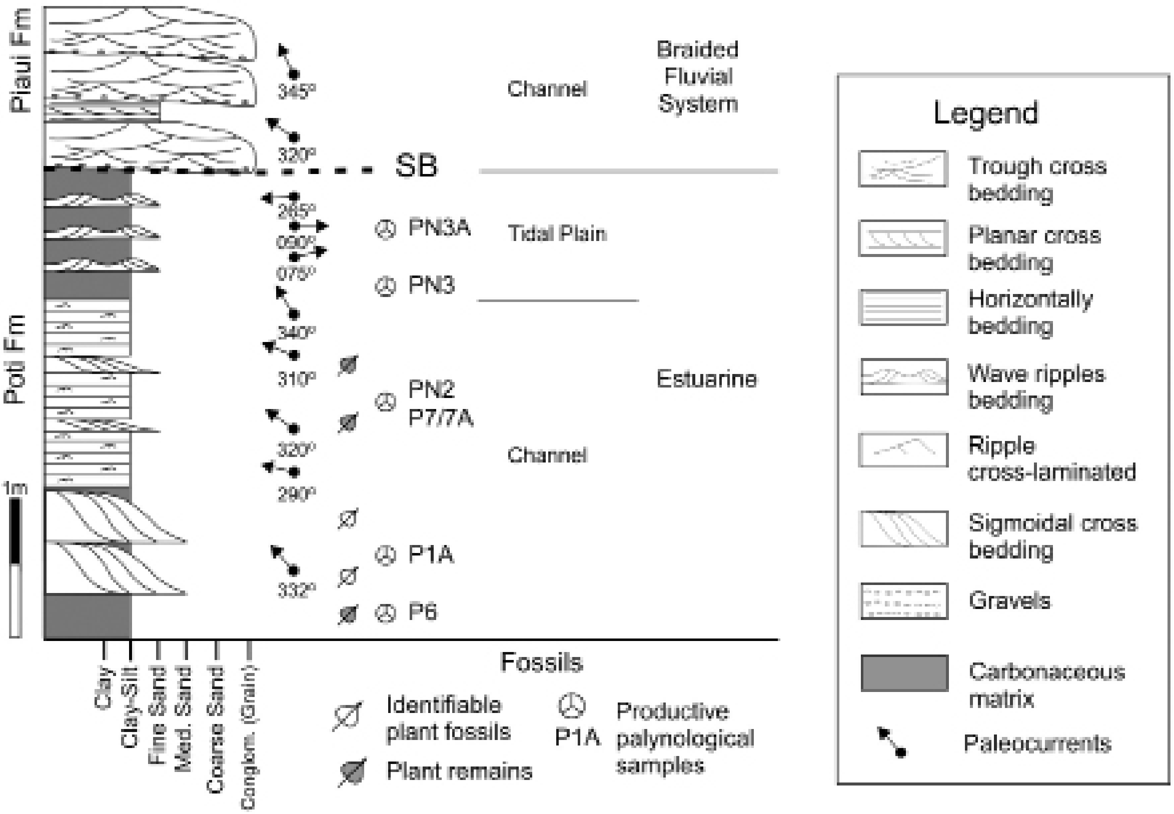

Figure 2. Stratigraphic section of the Poti Formation at Riacho do Roncador outcrop showing the location of palynological samples studied here and the palaeoenvironmental interpretation (based on Iannuzzi and Scherer, 1996).
Figura 2*. Sección estratigráfica de la Formación Poti en el perfil del Riacho do Roncador donde se muestra la ubicación de las muestras palinológicas estudiadas y la interpretación paleoambiental (basado en Iannuzzi y Scherer, 1996).*

Phillips Series XL Model 30 at the Natural Science Argentine Museum "Bernardino Rivadavia" (MACN) of Buenos Aires (Argentina). The specimens were coated with a fine film of 200-300 Å Gold-Palladium, using a sputter-coater "Termo VG Scientific SC 7620". After this study, cover slips bearing the isolated spores were removed and mounted on slides with jelly-glycerin to be re-illustrated under the light microscope. The Geological Time Scale 2013 (Cohen *et al.*, 2013) is followed in this paper.

Characteristics of the floral assemblage

Previously, the plant fossils from this locality were described by Dolianiti (1980) as *Triphyllopteris alvaro-albertoi* (Dolianiti) Rigby 1969 and *Rhacopteris* sp. Later, Césari (1986) and Sessarego and Césari (1989) reinterpreted them as *Fedekurtzia argentina* (Archangelsky) Césari 1986 and *Nothorhacopteris argentinica* Archangelsky 1983, respectively. Alternatively, Iannuzzi (1994) and Iannuzzi and Scherer (1996) reassigned the former element as a new species of the genus *Triphyllopteris*, (i.e., *T. adiantoides* n. sp.), and the second simply as *Nothorhacopteris* sp. 1. This proposal was not formally published by these authors. More recently, Iannuzzi *et al.,* (2006) and Iannuzzi and di Pasquo (2013) referred to these two forms as *Fedekurtzia* cf. *F. argentina* and *Nothorhacopteris* cf. *N. kellaybelenensis*, respectively. The last proposal is herein accepted.

The presence of a similar form to *Nothorhacopteris kellaybelenensis* (e.g., and *Nothorhacopteris* cf. *N. kellaybelenensis*) is an expected record, once this species is a key species of the Paracas realm (Iannuzzi and Pfefferkorn, 2002). However, this is the first record related to *Fedekurtzia* occurring in the latest Mississippian, a typical genus originally restricted to the Pennsylvanian deposits of Argentina (Césari, 1986). Consequently, the stratigraphic range of the genus *Fedekurtzia* is extended up to the late Visean herein. The formal description of the plant material and its paleogeographical and stratigraphical implications is in progress.

Characteristics of the palynoflora assemblages

This palynological study revealed abundant and moderately diverse palynomorphs, some fragmented and corroded but generally well preserved with discernible diagnostic features; their thermal maturity (TAI) varies between 2 and 3 according to the scale of Utting *et al.,* (in Utting and Wielens, 1992). Phytoclasts, such as tracheids and cuticular fragments, are commonly frequent. The whole assemblage is composed of 95 species, of which 58 are indigenous spores and 5 are algae, and 32 are recognized as reworked species (9 spores and 23 microplankton species) mostly from Devonian strata. The semi-quantitative data of the indigenous and reworked species, arranged in a stratigraphical order, is depicted in Figure 3A-B. Illustrations of selected species are presented in Figures 4-11 and listed in Figure 3.

Quantitative information about major groups of palynomorphs displayed in Figure 12, shows that almost all the samples except one (sample P7, Figs. 2 and 3) present quite similarly dominant (ca. 80%) percentages of spores, whereas *Botryococcus* is around 20% and reworked palynomorphs are mostly less than 5%. Sample P7 yielded a particularly noteworthy increase of the diversity and number of reworked species of marine origin, such as *Umbellasphaeridium deflandrei, Maranhites insulatus* and some typically Devonian spores (e.g., *Grandispora pseudoreticulata, Emphanisporites rotatus* and *Samarisporites triangulatus*; Figs. 3B, 10 and 11). Other species, such as *Emphanisporites hibernicus* and *Cordylosporites marciae* that appeared in the latest Devonian and continued in the Early Mississippian, are poorly represented at this level and occur along with some species that were widely recorded in Tournaisian microfloras (e.g., *Tumulispora variverrucata, Spelaeotriletes balteatus,* Figs. 3A, 8, and Chart 1 supplementary online material). High to low abundance of specimens of spore genera *Punctatisporites, Calamospora, Leiotriletes, Retusotriletes, Verrucosisporites* and *Foveosporites* are found at different levels, whereas *Apiculiretusispora semisenta, Colatisporites decorus* and *Reticulatisporites magnidictyus* are always present but in low frequency (Figs. 3A and 12). The three new species of *Verrucosisporites* here defined (*V. iannuzzii*, *V. roncadorensis*, and *V. souzai*) are well represented in almost all sample levels by tetrads and isolated specimens (Figs. 3A, 7 and 12). The densospore group (*Cristatisporites, Kraeuselisporites, Vallatisporites*) is always present in low frequency (Figs. 3A, 8 and 12).

Iannuzzi (1994) illustrated from levels P6 and P7 (Fig. 2) a list of 20 preliminary taxa: *Apiculatisporites* sp., *Auroraspora* sp., *Botryococcus* spp., *Convolutispora* sp., *Grandispora* spp., *Grandispora daemonii*, *Lycospora* sp., *Maranhites brasiliensis*, *Michrystridium* sp., *Phyllotecotriletes* sp., *Retusotriletes* sp., *Reticulatisporites* spp., *Schopfipollenites* sp., *Spelaeotriletes* spp., *Vallatisporites* sp., *Verrucosisporites* spp.. The detailed palynological analysis presented allows the reassignment of 13 of these taxa (Fig. 3).

The stratigraphical and geographic occurrences of the Mississippian species here identified are displayed in Chart 1 (supplementary online material), which is the database of the global ranges of selected species represented in Figure 13. Unpublished Abstracts or non-illustrated lists of species of Mississippian microfloras from South America (and elsewhere) were not considered for constructing the Chart 1 database.

Taxonomy of selected species

New species and other forms left in open or doubtful nomenclature, and little known species that deserve taxonomic or morphological clarifications (or when synonymies are added) are listed below. The morphological terminology is mainly in accordance with the glossary provided by Punt *et al.,* (2007), and the taxonomic rules are in agreement with the ICBN Code (Kiesling, 2002). Suprageneric citation is not included in the list of references.

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 *Calamospora* Schopf, Wilson and Bentall 1944.
Type species. *Calamospora hartungiana* Schopf, Wilson and Bentall 1944.

Calamospora sp.
Figure 6.13-15

Description. Trilete spore acavate, amb originally circular but shows oval to subcircular shapes. Laesurae indistinct, when visible is ½-1/3 of the radius of the spore. Exine 1-2 µm thick, smooth to chagrinate, frequently opened almost all along the major diameter forming a split like a "sulcus" and folds may follow

(A)

	CICYTTP-PI	581	582		583	584			
	MP-P	9739	9740	9741	9742		9743		
BA	SPORES / FIELD SAMPLE NUMBERS	6	IA	7	N2	N3	N3A	Illustration	Iannuzzi (1994)
F	*Anapiculatisporites hystricosus* Playford 1964	P	P	P		P		Fig. 4.3, 4, 8	
F	*Anapiculatisporites concinnus* Playford 1962	P	P					Fig. 4.7	
F	*Apiculiretusispora microseta* Ravn 1991	P	P	P	P	P		Fig. 4.5	?Pl. 8, 2
F	*Apiculiretusispora semisenta* (Playford) Massa, Coquel, Loboziak, Taugourdeau-Lantz 1980	P	P	P	P	P		Fig. 5.15	
S	*Calamospora microrugosa* (Ibrahim) Schopf, Wilson, Bentall 1944	A		F		F		Fig. 4.16	
L	*Colatisporites decorus* (Bharadwaj and Venkatachala) Williams in Neves, Gueinn, Clayton, Ioannides, Neville, Kruszewska 1973	P	P	P	P	P		Fig. 4.17-19	
L	*Colatisporites denticulatus* Neville in Neves, Gueinn, Clayton, Ioannides, Neville, Kruszewska 1973	P	P	P	P	P		Fig. 4.9, 10, 12	
F	*Reticulatisporites magnidictyus* (Playford, Helby) Melo, Loboziak 2000	P	P	P	P	P		Fig. 6.7, 10-12	?Pl. 8, 6
L	*Cristatisporites menendezii* (Menéndez, Azcuy) Playford 1978	P	P	P		P		Fig. 6.2, 20	
F	*Foveosporites pellucidus* Playford, Helby 1968	P	P	P	P	P		Fig. 4.13-15, 17-20	
F	*Leiotriletes inermis* (Waltz) Ischenko 1952	P	P	P	A	P	P	Fig. 4.1	
F	*Punctatisporites glaber* (Naumova) Playford 1962	P	P	P	P	P		Fig. 4.11	
F	*Punctatisporites perfrugalis* Playford 1978	A	F	F	A	F	A	Fig. 5.7, 10	
F	*Punctatisporites resolutus* Playford 1971	F	P	F	P	P		Fig. 5.8	
F	*Punctatisporites* spp.	A	P	P	P	A	P	Fig. 5.5	
F	*Punctatisporites subvaricosus* Playford 1971	P	P	P	P	P	P	Fig. 4.2, Fig. 5.8, 9, 13	
F	*Raistrickia baculosa* Hacquebard 1957	P		P				Fig. 5.1	
F	*Retusotriletes [illegible]* (Neville) Playford 1978/ *R. digressus* Playford 1978	P	P	P	P	P		Fig. 5.3, 4	
F	*Verrucosisporites gobbettii* Playford 1962	P	P	P	P	P		Fig. 5.16-19	?Pl. 8, 4
F	*Verrucosisporites morulatus* (Knox) Potonié, Kremp 1955 emend. Smith, Butterworth 1967	P	P	P	P	P		Fig. 6.5	Pl.8, 3
F	*Verrucosisporites souzai* sp.nov.	P	F	F	F	P		Fig. 7.5-7, 11-13	
F	*Verrucosisporites iannuzzii* di Pasquo sp.nov	P	F	P	F	P		Fig. 7.1-4	
F	*Lophozonotriletes* sp. cf. *Lophozonotriletes* sp. 1 in Ravn 1991	P						Fig. 6.14, 15	
F	*Convolutispora vermiformis* Hughes, Playford 1961		P	P		P		Fig. 6.3	Pl. 8, 7
L	*Cristatisporites matthewsii* Higgs, Clayton, Keegan 1988		P	P	P	P		Fig. 6.8	
L	*Densosporites spinosus* Dybová, Jachowicz 1957		P					Fig. 6.9	
L	*Densosporites regalis* (Bharadwaj, Venkatachala) Smith, Butterworth 1967		P					Fig. 6.6	
F	*Leiotriletes ornatus* Ischenko 1956		P	P		P		Fig. 5.11, Fig. 6.7	
F	*Punctatisporites aerarius* Butterworth, Williams 1958		P	P		P			
F	*Punctatisporites irrasus* Hacquebard 1957		P	P	P	P		Fig. 5.12	
F	*Retusotriletes crassus* Clayton in Clayton, Johnston, Sevastopulo, Smith 1980		P	P	P	P		Fig. 5.2	
F	*Verrucosisporites congestus* Playford 1964		P		P	P		Fig. 6.4	
F	*Waltzispora polita* (Hoffmeister, Staplin, Malloy) Smith, Butterworth 1967		P	P	P			Fig. 7.20	
S	*Calamospora* sp.			P	P	P	P	Fig. 8.13-15	Pl.8, 14
L	*Cristatisporites colliculus* Playford 1971				P	P		Fig. 8.11	
	Knoxisporites ruhlandii Doubinger, Rauscher 1966			P	P			Fig. 7.16	
L	*Cristatisporites peruvianus* Azcuy, di Pasquo 2005			P				Fig. 8.12	
L	*Cristatisporites echinatus* Playford 1962			P				Fig. 8.16	
F	*Tricidarisporites phippsiae* Playford, Satterthwait 1986			P		P		Fig. 8.1	
F	*Dibolisporites microspicatus* Playford 1978			P		P		Fig. 8.5	
L	*Grandispora maculosa* Playford Helby 1968			P				Fig. 8.2	
L	*Vallatisporites vallatus* Hacquebard 1957			P		P		Fig. 8.18	Pl. 8, 10
L	*Tumulispora variverrucata* (Playford) Staplin, Jansonius 1964			P				Fig. 8.8	
F	*Pustulatisporites papillosus* (Knox) Potonié, Kremp 1955			P				Fig. 8.21	
F	*Pustulatisporites dolbii* Higgs, Clayton, Keegan 1988			P				Fig. 8.6	
F	*Pustulatisporites gibberosus* (Hacquebard) emend. Playford 1964			P				Fig. 4.6	
F	*Raistrickia clavata* Hacquebard emend. Playford 1964			P		P		Fig. 8.1	
L	*Spelaeotriletes balteatus* (Playford) Higgs 1996			P				Fig. 8.13	
F	*Leiotriletes* spp.			P		P			
F	*Verrucosisporites depressus* Winslow 1962			P				Fig. 8.17	
F	*Verrucosisporites papulosus* Hacquebard 1957			P				Fig. 8.9	
F	*Verrucosisporites roncadorensis* sp. nov.			P		P		Fig. 7.8-10, 14, 15	
L	*Aratrisporites saharaensis* Loboziak, Clayton y Owens 1986			P				Fig. 8.3	
O	*Emphanisporites hibernicus* Clayton, Higgs, Keegan 1977			P				Fig. 8.14	
O	*Cordylosporites marciae* (Winslow) Playford, Satterthwait 1985			P				Fig. 10.14	?Pl. 8, 5
O	*Gulisporites torpidus* Playford 1964					P		Fig. 8.4	
F	*Leiotriletes tortilis* Playford 1964					P		Fig. 8.10	
F	*Anapiculatisporites amplus* Playford, Powis 1979					P		Fig. 8.19	
Chlorophycean algae	*Botryococcus* spp. (*B. braunii* Kützing 1849)	A	A	A	A	A	F	Fig. 9.6, 8-14, 16-20	Pl. 8, 15
	Brazilea scissa (Balme and Hennelly) Foster 1975				P	P		Fig. 9.3, 4	
	Chomotriletes sp. in Higgs, Clayton, Keegan 1988		P	P	P			Fig. 9.1, 2	
	Quadrisporites granulatus (Cramer) Strother 1991		P	P		P	P	Fig. 9.5, 7	
	Undetermined species			P				Fig. 9.15	

Figure 3. Semiquantitative distribution of palynomorphs in the Poti Formation at the Roncador creek. The autochthonous (Fig. 3A) and reworked species (Fig. 3B) species (with full authority) are organized in appearance stratigraphic order. Symbols refering to the relative abundances (calculated from counts of ca. 300-400 specimens per sample) are as follows: P: < 3,8 %; F: 3,8-7,0 %; A > 7,0 %. Number of illustrated specimen and botanical affinities (F= Ferns, S= Sphenophyte, L= Lycophyte, O= other group of plants after Balme, 1995), are also indicated.

Figura 3. *Distribución semicuantitativa de palinomorfos en la Formación Poti en el arroyo Roncador. Las especies autóctonas (Fig. 3A) y retrabajadas (Fig. 3B, con su autoría completa) se organizan en orden de aparición estratigráfica. Los símbolos utilizados para las abundancias relativas (calculadas con base en conteos de ca. 300-400 especímenes por muestra) son los siguientes: P: < 3,8 %; F: 3,8-7,0 %; A > 7,0 %. Además se indican los números de los especímenes ilustrados y sus afinidades botánicas (F= Helechos, S= Esfenofita, L= Licofita, O= otros grupos de plantas, según Balme, 1995).*

(B)

MP-P	9739	9740	9741	9742		9743		
CICYTTP-PI	581	582		583	584		Illustration	Iannuzzi (1994)
Devonian reworked spore species / FIELD	8	1A	7	N2	N3	N3A		
Acinosporites eumammillatus Loboziak, Streel, Burjack			P				Fig. 10.1	
Ancyrospora langii? (Taugourdeau-Lantz) Allen			P				Fig. 10.5, 16	
Archaeozonotriletes variabilis Allen			P					
Emphanisporites rotatus McGregor emend. McGregor			P				Fig. 10.12	
Geminospora lemurata Balme emend. Playford			P					
Grandispora pseudoreticulata (Menéndez, Pöthe de Baldis) Ottone			P				Fig. 10.10, 11, 13	Pl. 8, 16
Lophozonotriletes media Taugourdeau-Lantz			P				Fig. 10.8, 9	
Samarisporites triangulatus Allen			P					Pl. 8, 18
Verrucosisporites scurrus (Naumova) McGregor and Camfield			P				Fig. 10.2	
Devonian reworked acritarchs and prasin								
Gorgonisphaeridium spp.	P	F	P	P	P	P	Fig. 10.18, Fig. 11.1, 6-7, 9-10, 12	Pl. 8, 17
Maranhites brasiliensis Brito emend. Burjack, Oliveira	P		P	P	P		Fig. 10.6, 16	
Pterospermella solis Wicander		P	P	P				
Maranhites mosesii (Sommer) Brito emend. Burjack, Oliveira			P	P			Fig. 10.17	
Maranhites spp.			P	P	P		Fig. 10.15, 21	Pl. 8, 20
Ammonidium garrasinoi Ottone			P				Fig. 10.20	
Arkonites bilixus Legault			P				Fig. 11.16	
Cymatiosphaera spp.			P		P		Fig. 10.14, Fig. 11.15	
Dictyotidium munificum (Wicander, Wood) Amenábar, di Pasquo, Azcuy			P				Fig. 10.19	
Dictyotidium spp.			P		P	P	Fig. 11.2-5	
Estiastra barbata Downie			P					
Gorgonisphaeridium ohioense (Winslow) Wicander			P					
Hemiruptia legaultii Ottone			P					
Leiosphaeridia spp.			P					
Polyedryxium ambitum Cramer			P					
Polyedryxium leptum Turner			P				Fig. 11.13, 14	
Polyedryxium tectum Deunff			P					
Polygonium barredae Ottone			P				Fig. 11.8	
Umbellasphaeridium companulatum Oliveira, Burjack			P				Fig. 10.7	
Umbellasphaeridium deflandrei (Moreau-Benoit) Jardiné et al.			P				Fig. 10.4	
Umbellasphaeridium saharicum Jardiné et al.			P				Fig. 10.3	
Veryhachium trispinosum (Eisenack) Deunff			P					
Undetermined acritarchs			F				Fig. 11.11	

Figure 3. Semiquantitative distribution of palynomorphs in the Poti Formation at the Roncador creek. The autochthonous (Fig. 3A) and reworked species (Fig. 3B) species (with full authority) are organized in appearance stratigraphic order. Symbols refering to the relative abundances (calculated from counts of ca. 300-400 specimens per sample) are as follows: P: < 3,8 %; F: 3,8-7,0 %; A > 7,0 %. Number of illustrated specimen and botanical affinities (F= Ferns, S= Sphenophyte, L= Lycophyte, O= other group of plants after Balme, 1995), are also indicated.

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this split. Detached or broken specimens along this split are common and some still preserved both proximal and distal faces attached to each other at one end of the spore.

Dimensions (14 specimens). Equatorial diameter 70–95 µm.

Remarks. The way of splitting and folding allows its separation from other species of *Calamospora* and makes this species similar to *Schopfipollenites ellipsoides* or some *Cycadopites* species. Although, the nature of the exine (simple acavate) and the presence of a trilete mark (even visible in a few specimens) confirm its assignment to the spore group. The same specimen illustrated as *Schopfipollenites* sp. by Iannuzzi (1994, Pl. 8, fig. 14) and referred as *Schopfipollenites* cf. *S. ellipsoides* by Iannuzzi and Scherer (1996) is here reassigned to this taxon and illustrated in Figure 6.13.

Comparisons. This species is similar to *Calamospora* sp. in Azcuy and di Pasquo (2005) described but not illustrated and found throughout the Ambo Formation, but the latter differs in its way of splitting in two halves, where each face is in turn, folded mimicking the *Cycadopites* species together with a relatively small diameter (less than 70 µm).

Infraturma **Retusotrileti** Streel ex Becker, Bless, Streel and Thorez 1974
Genus *Apiculiretusispora* Streel 1964 emend. Streel 1967
Type species. *Apiculiretusispora brandtii* Streel 1964.

Apiculiretusispora microseta Ravn 1991
Figure 4.5

Comparisons. This species differs from *Aneurospora greggsii* (McGregor) Streel in Becker *et al.,* 1974 (overall diameter 38-55 µm), recognized in the Ambo Formation (Azcuy and di Pasquo, 2005), mainly in not having the continuous thickened zone in the equatorial margin and a slightly lesser diameter (30-45 µm).

Infraturma **Apiculati** Bennie and Kidston emend. Potonié 1956
Subinfraturma **Nodati** Dybová and Jachowicz 1957
Genus *Tricidarisporites* Sullivan and Marshall 1966 emend. Gueinn, Neville and Williams in Neves, Gueinn, Clayton, Ioannides, Neville and Kruszewska 1973
Type species. *Tricidarisporites balteolus* Sullivan and Marshall 1966.

Tricidarisporites phippsae Playford and Satterthwait 1986
Figure 8.1

1980 *Tricidarisporites serratus* (Playford) Sullivan and Marshall 1966 (auct. non); Attar *et al.*, p. 610, pl. 1, fig. 18.

Comparisons. This species differs from similar forms such as *Diatomozonotriletes rarus* Playford 1963 (overall diameter 37-50 µm), illustrated previously from this unit by Melo and Loboziak (2000), and *Tricidarisporites serratus* (Playford) Sullivan and Marshall 1966 (spines 2-6 µm high and 2-4 µm wide of hexagonal bases), due to the uniform distal and interradial ornamentation of cones without forming a corona (1.5-5 µm high and circular bases 0.5-3.5 µm wide) and a slightly larger diameter (57-82 µm). On these grounds, the specimen illustrated as *Tricidarisporites serratus* in Attar *et al.,* (1980, pl. 1, fig. 18) is re-assigned to this taxon. For other comparisons see Playford (1978) and Playford and Satterthwait (1986).

Subinfraturma **Verrucati** Dybová and Jachowicz 1957
Genus *Verrucosisporites* Ibrahim emend. Smith and Butterworth 1967
Type species. *Verrucosisporites verrucosus* (Ibrahim) Ibrahim 1933.

Verrucosisporites iannuzzii di Pasquo sp. nov.
Figure 7.1-4

Holotype. Fig. 7.2, MP-P 9739 J5/1.
Paratypes. Fig. 7.1, MP-P 9743 T9/2; Fig. 7.3, MP-P 9742 N17/2; Fig. 7.4, CICYTTP-PI 584(SEM).

Description. Spore radial trilete, amb circular to subcircular, margin very slightly ornamented. Laesurae distinct, simple and straight, ca. 2/3 of the radius in length, often asymmetrical and off-center. Exine 1.5 – 2.5 µm thick, punctate and densely ornamented with verrucae, low and very irregular in shape (lateral and plant view), 1.2(2)4 µm wide and up to 1.2 µm high; occasionally some elements may coalesce in low numbers.

Dimensions (65 specimens). Equatorial diameter 30-50 □m.

Derivatio nominis. Dedicated to Dr. Roberto Iannuzzi, a well-known paleobotanist and collector of the material that allowed the discovery of this new taxon.

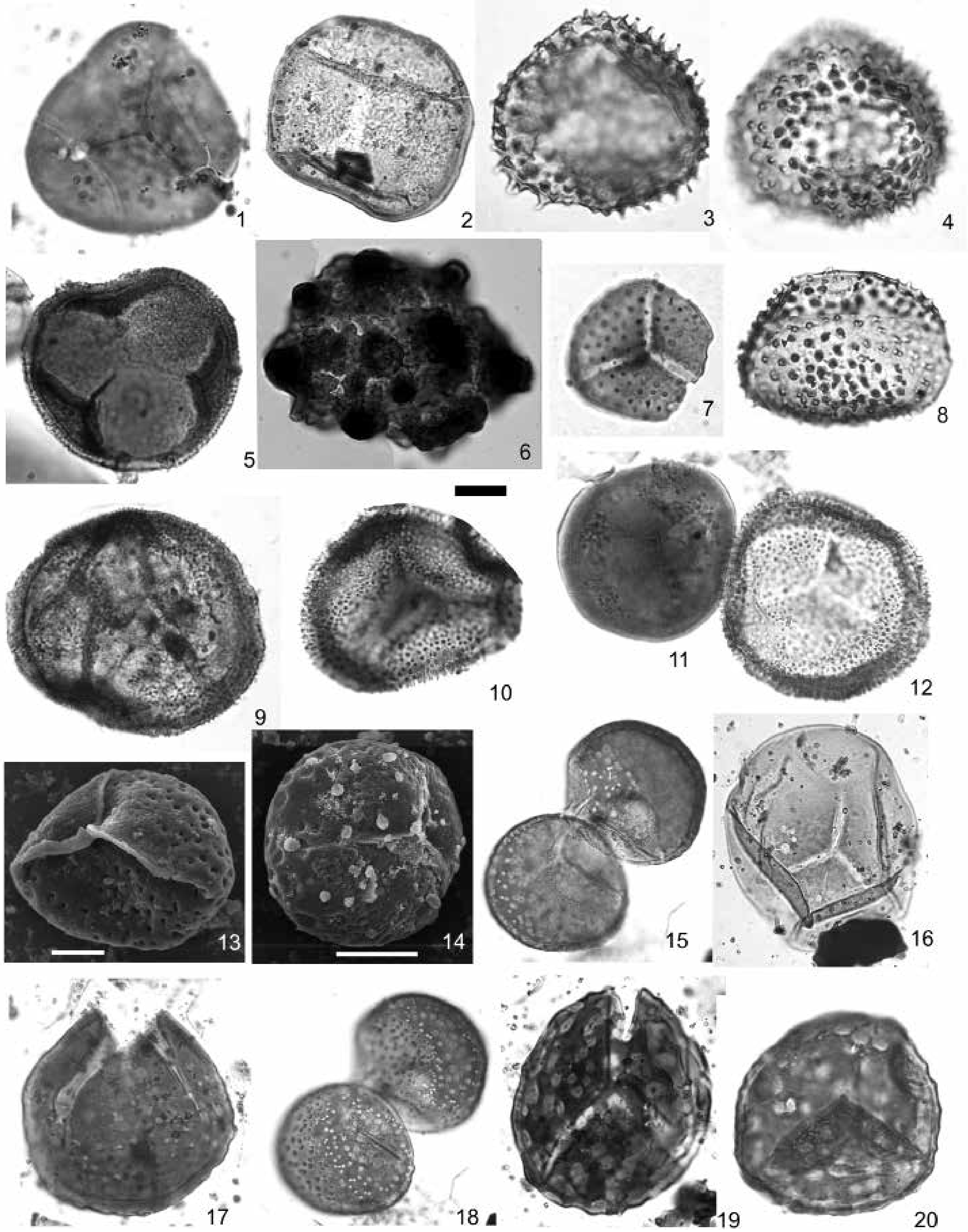


Figure 4. Autochthonous species in the assemblage of the Poti Formation at the Roncador creek.

Figura 4. *Especies autóctonas en la asociación de la Formación Poti en el arroyo Roncador.*

Scale bar/*Barra de escala*: 1-5, 7, 9, 13, 19, 20 = 10 µm, 6, 11, 12, 16-18 = 13,5 µm, 8= 15 µm, 10= 12 µm, 14, 15, 18= 20 µm. 1 *Leiotriletes inermis* (Waltz) Ishchenko, MP-P 9739 P35/1. 2 *Punctatisporites subvaricosus* Playford, MP-P 9739 M57/4. 3, 4 *Anapiculatisporites hystricosus* Playford, CICYTTP-Pl 582(3) D22/3. 5 *Apiculiretusispora microseta* Ravn, MP-P 9742 N18/1. 6 *Pustulatisporites gibberosus* (Hacquebard) Playford, MP-P 9742 S11/0. 7 *Anapiculatisporites concinnus* Playford, CICYTTP-Pl 582(1) X57/3. 8 *Anapiculatisporites hystricosus* Playford, CICYTTP-Pl 584(1)T39/1. 9 *Colatisporites multisetus* (Luber) Avchimovitch and Turnau, CICYTTP-Pl 584(1) B22/0. 10 *Colatisporites multisetus* (Luber) Avchimovitch and Turnau, MP-P 9743 A16/3. 11 *Punctatisporites glaber* (Naumova) Playford, MP-P 9743 S14/3. 12 *Colatisporites multisetus* (Luber) Avchimovitch and Turnau, MP-P 9743 K14/3. 13-14 *Foveosporites pellucidus* Playford and Helby, CICYTTP-Pl 584(SEM). 15, 18 *Foveosporites pellucidus* Playford and Helby, MP-P 9743 R27/2. 16 *Calamospora microrugosa* (Ibrahim) Schopf *et al.*, MP-P 9739 L44/1. 17 *Foveosporites pellucidus* Playford and Helby, MP-P 9739 M53/0. 19 *Foveosporites pellucidus* Playford and Helby, MP-P 9739 V56/1. 20 *Foveosporites pellucidus* Playford and Helby, MP-P 9743 T8/2.

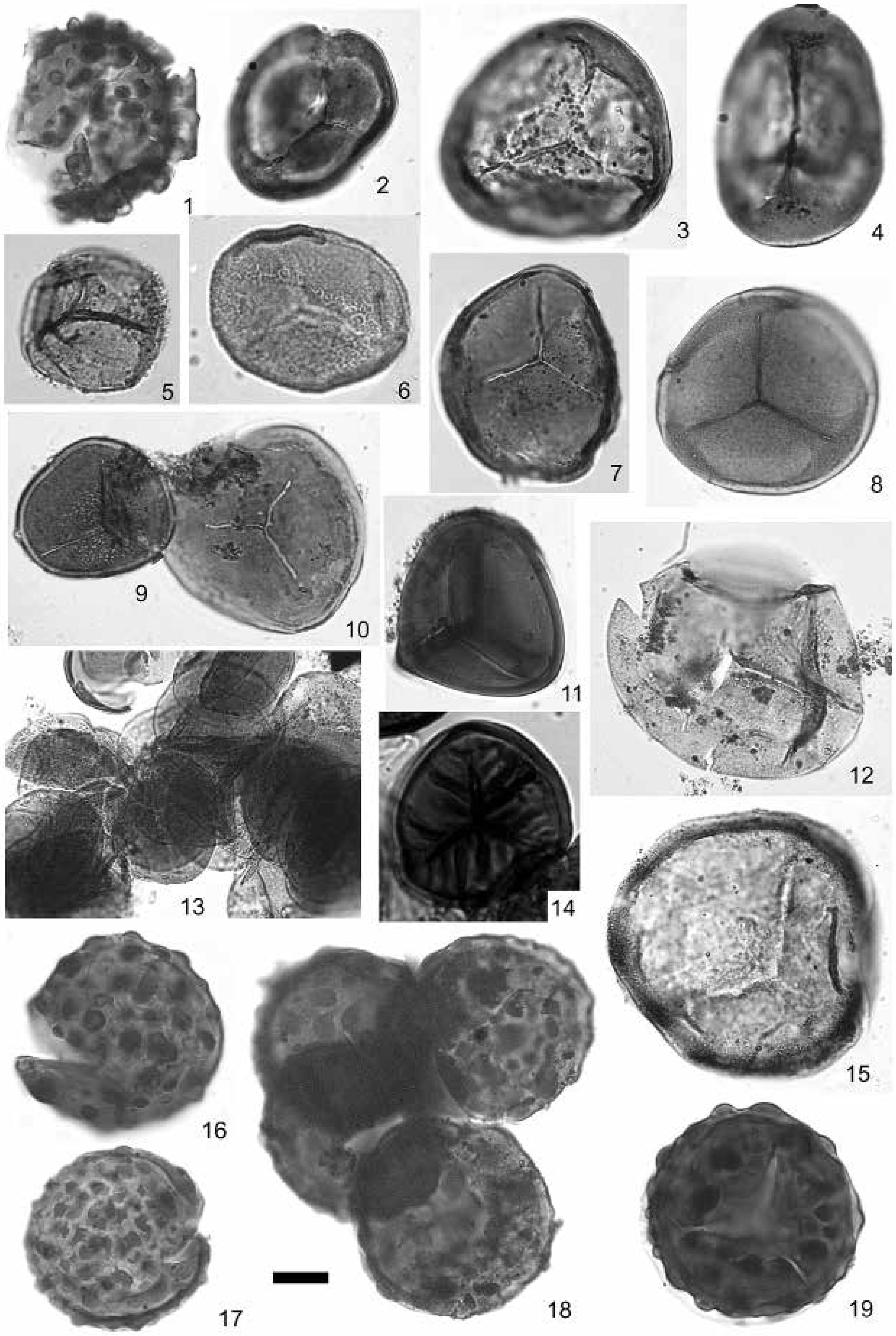


Figure 5. Autochthonous species in the assemblage of the Poti Formation at the Roncador creek.
Figura 5. *Especies autóctonas en la asociación de la Formación Poti en el arroyo Roncador.*
Scale bar/*Barra de escala*: 1, 3-6, 11, 14, 16-19 = 10 µm, 7-10, 12, 15 = 13,5 µm, 2= 15 µm, 13= 20 µm. 1 *Raistrickia baculosa* Hacquebard, MP-P 9742 R32/0. 2 *Retusotriletes crassus* Clayton in Clayton, Johnston, Sevastopulo and Smith, CICYTTP-Pl 582(1) K28/0. 3 *Retusotriletes mirabilis* (Neville) Playford / *P. digressus* Playford CICYTTP-Pl 584(1) F23/1. 4 *Retusotriletes mirabilis* (Neville) Playford / *P. digressus* Playford, MP-P 9743 J33/4. 5 *Punctatisporites* sp., MP-P 9743-A B18/0. 6 *Punctatisporites subvaricosus* Playford, MP-P 9743T9/1. 7 *Punctatisporites perfrugalis* Playford, MP-P 9741 Z27/4. 8 *Punctatisporites resolutus* Playford, MP-P 9743 S26/2. 9 *Punctatisporites subvaricosus* Playford, MP-P 9741 R31/1. 10 *Punctatisporites perfrugalis* Playford, MP-P 9741 X31/1. 11 *Leiotriletes ornatus* Ishchenko, MP-P 9742 R25/1. 12 *Punctatisporites irrasus* Hacquebard, MP-P 9742 N23/2. 13 *Punctatisporites subvaricosus* Playford, MP-P 9743 J24/3. 14 *Emphanisporites hibernicus* McGregor, MP-P 9742 S26/1. 15 *Apiculiretusispora semisenta* (Playford) Massa *et al.*, MP-P 9743 H37/3. 16 *Verrucosisporites gobbettii* Playford, MP-P 9743 G11/2. 17 *Verrucosisporites gobbettii* Playford, MP-P 9742 U24/1. 18 *Verrucosisporites gobbettii* Playford, MP-P 9742-A R32/3 (tetrad). 19 *Verrucosisporites gobbettii* Playford, MP-P 9739 O44/0.

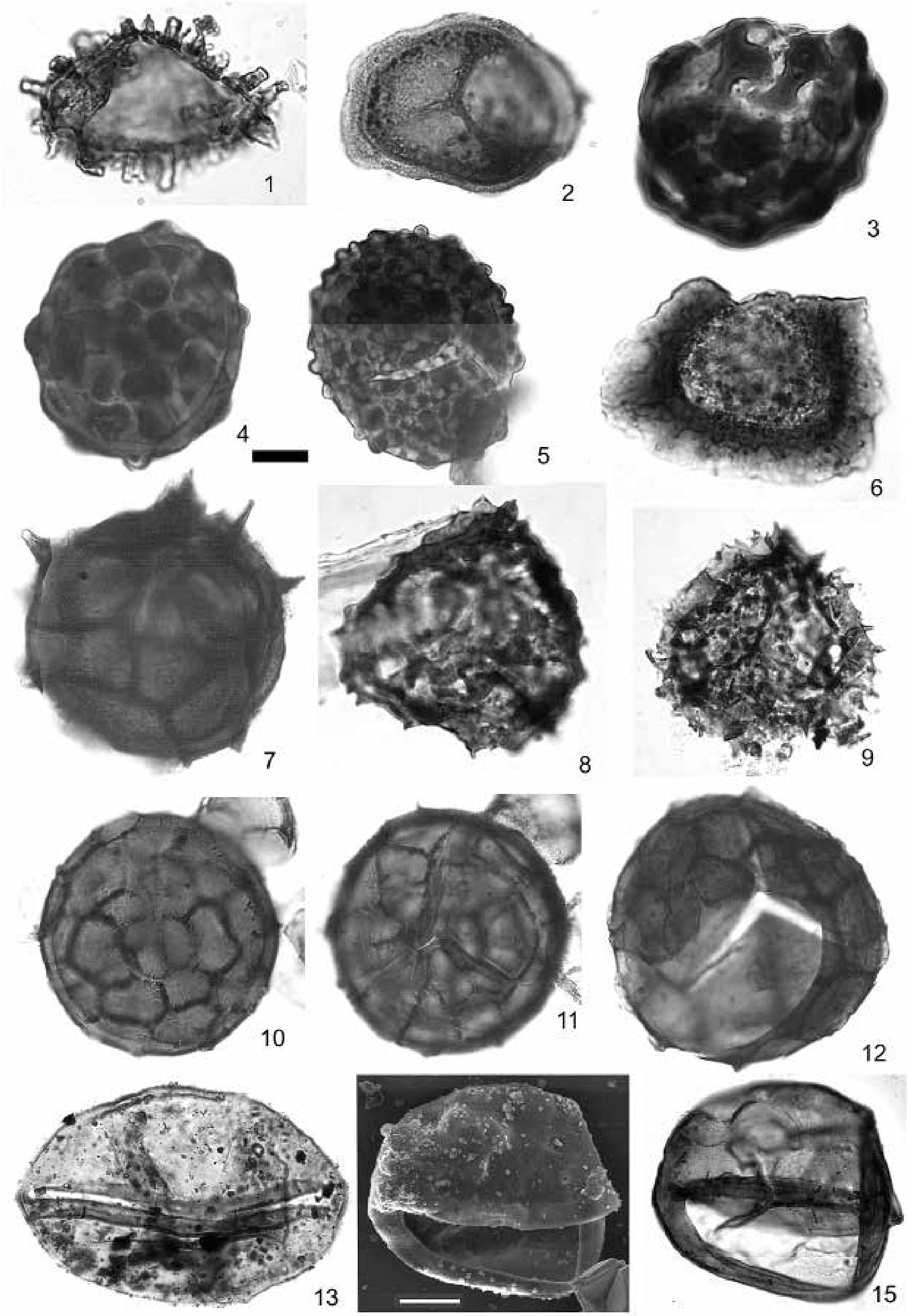


Figure 6. Autochthonous species in the assemblage of the Poti Formation at the Roncador creek.
Figura 6. *Especies autóctonas en la asociación de la Formación Poti en el arroyo Roncador.*
Scale bar/*Barra de escala*: 1-3, 5-6, 8= 10 µm, 4, 9, 12= 13,5 µm, 13= 15 µm, 7, 10-11, 14-15 = 20 µm.
1 *Raistrickia clavata* Hacquebard, MP-P 9743 Y12/2. 2 *Grandispora maculosa* Playford and Helby, MP-P 9742-A W31/4. 3 *Convolutispora vermiformis* Hughes and Playford, CICYTTP-Pl 582(1) J55/0. 4 *Verrucosisporites congestus* Playford, MP-P 9743 K13/3. 5 *Verrucosisporites morulatus* (Knox) Potonié and Kremp emend. Smith and Butterworth, CICYTTP-Pl 582(3) C50/1. 6 *Densosporites regalis* (Bharadwaj and Venkatachala) Smith and Butterworth, CICYTTP-Pl 582(1) F36/2. 7 *Reticulatisporites magnidictyus* (Playford and Helby) Melo and Loboziak, MP-P 9743 U15/3. 8 *Cristatisporites mattheusii* Higgs *et al.*, CICYTTP-Pl 582(3) X23/4. 9 *Densosporites spinosus* Dybová and Jachowicz, CICYTTP-Pl 582(1) H52/1. 10, 11 *Reticulatisporites magnidictyus* (Playford and Helby) Melo and Loboziak, MP-P 9743 N31/2. 12 *Reticulatisporites magnidictyus* (Playford and Helby) Melo and Loboziak, CICYTTP-Pl 582(1) P41/2. 13 *Calamospora* sp., MP-P 9742-1 Y58/0.
14 *Calamospora* sp., CICYTTP-Pl 584(SEM). 15 *Calamospora* sp., MP-P 9742-1 K40/2.

*Comparisons***.** This species differs from *Verrucosisporites scurrus* (Naumova) McGregor and Camfield 1982, in having smaller and less commonly fused elements. *V. bulliferus* Richardson and McGregor 1986 bears slightly larger flat-topped verrucae and *V. depressus* has rounded verrucae in plant and lateral view.

Verrucosisporites roncadorense di Pasquo sp. nov.
Fig. 7.8-10, 14, 15

Holotype. Fig. 7.10, MP-P 9743 M12/0.
Paratypes. Fig. 7.8, MP-P 9742 W27/0; Fig. 7.9, MP-P 9743 V22/4, Fig.7.14, 15, MP-P 9743 H30/2.

*Description***.** Spore radial trilete, amb circular, margin smooth to slightly modify by the ornamentation. Laesurae distinct, simple and straight, almost reaching the equator margin. Exine 2.5 – 4 μm thick loosely ornamented with 30 – 40 verrucae, 2(3)5 μm wide, 2 - 3 μm high, irregular to a somewhat hemispherical shape, mostly with a few pores. Elements arranged irregularly, two to four basal diameters apart.

Dimensions (10 specimens). Equatorial diameter 30-45 μm.

Derivatio nominis. Referred to its provenance.

Comparison. Verrucosisporites quassigobbetti Jones and Truswell 1992 and *V. gobbettii* Playford 1962 differ in having more verrucae more regular or hemispherical in-shape without a pore. *Verrucosisporites gregatus* Playford and Melo 2012, differs in having contact faces sculpture-free and wider verrucae than in our species.

Verrucosisporites souzai di Pasquo sp. nov.
Figure 7.5-7, 11-13

Holotype. Fig. 7.5, 6, MP-P 9743 R17/4.
Paratypes. Fig.7.7, 11, MP-P 9742 K16/2; Fig. 7.12, MP-P 9743 J9/2, Fig. 7.13, MP-P 9741 R37/1.

*Description***.** Spore radial trilete, amb circular to subcircular, margin smooth to very slightly ornamented. Laesurae distinct, simple and straight, ca. 2/3, often asymmetrical and off-center. Exine notably punctate, 2 – 3 μm thick, loosely ornamented with verrucae, variable in size and shape but mostly with a triangular amb, 1.2-4 μm wide and 1.2-2.5 μm high, one or two basal diameters apart. Some specimens show larger verrucae on their proximal face (see Fig. 7.7, 11).

Dimensions (78 specimens). Equatorial diameter 30-50 μm.

Derivatio nominis. In honour of a well-known palynologist from Brazil, Dr. Paulo A. Souza.

Comparisons. *Verrucosisporites verrucosus* (Ibrahim in Potonié *et al.*) Ibrahim 1933 differs in not having a punctate exine ornamented with verrucae and some rugulae and a slightly larger diameter (40-70 μm).

Subturma **Zonolaminatitriletes** Smith and Butterworth 1967
Infraturma **Cingulati** Potonié and Klaus emend. Dettmann 1963
Genus *Lophozonotriletes* Naumova emend. Potonié 1958
Type species. *Lophozonotriletes lebedianensis* Naumova 1953.

Lophozonotriletes sp. cf. *Lophozonotriletes* sp. 1 in Ravn 1991
Fig. 8.14, 15

Description. Spore radial trilete, cingulate acavate. Amb circular, margin smooth to slightly modified by the ornamentation. Laesurae distinct, simple and straight, barely extending up to the equator margin. Cingulum, 4-5 μm in width, and distal face loosely ornamented with 12 – 15 verrucae, 2(3)6 μm wide, 2 - 3 μm high, somewhat hemispherical in shape.

Remarks. Although one fairly well preserved specimen has been found that shows the main characters of the species, a better assignment is not possible.

Division **Chlorophyta** Pascher 1914
Class **Chlorophyceae** Kützing 1843
Order **Chlorococcales** (Marchand) Pascher 1915
Family **Botryococcaceae** Wille, 1909
Genus *Botryococcus* Kützing 1849
Type species. *Botryococcus braunii* Kützing 1849.

Botryococcus spp.
Figure 9.6, 8-14, 16-20

Description. Colonies with coccoid amb and conical in lateral view (Fig. 9.19, 20) with distinctive pattern of four cells are present (Fig. 9.11, 13) and several units are grouped to form colonies of different sizes. Depending on the preservation state, at least three morphologies of some botryoid colonies are recognized: 1- Showing cell-cups with "open" and thinner walls and more fibrous margins (Fig. 9.18), (typically similar to *B. braunii*), 2- cell-cups with shorter but larger cups and "closed"

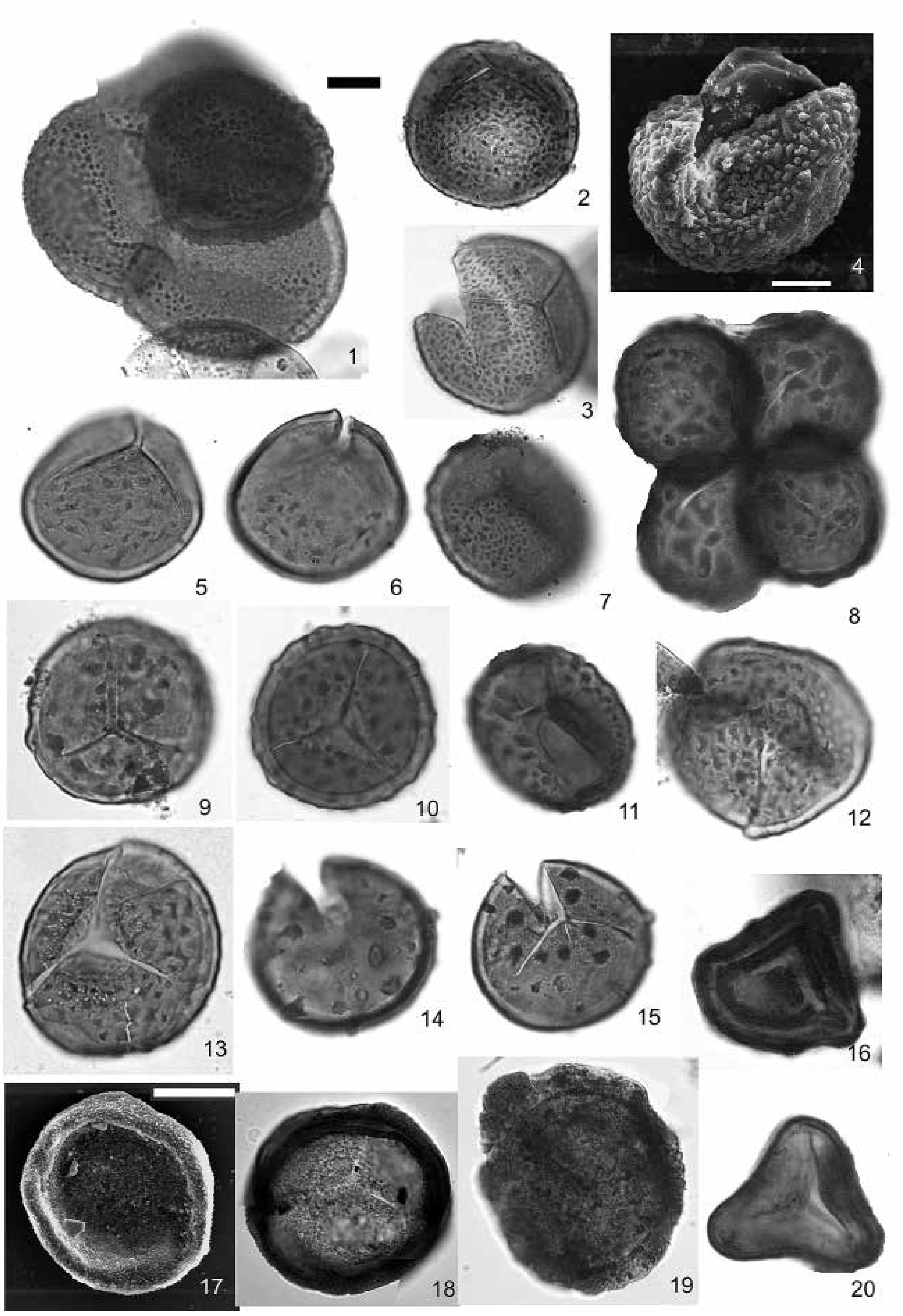


Figure 7. Autochthonous species in the assemblage of the Poti Formation at the Roncador creek.
Figura 7. *Especies autóctonas en la asociación de la Formación Poti en el arroyo Roncador.*
Scale bar/*Barra de escala*: 1-2, 4-6, 8-10, 12-13, 16, 19-20= 10 µm, 3, 7, 11, 14-15= 11,5 µm, 17-18= 13,5 µm.
1 *Verrucosisporites iannuzzii* di Pasquo sp. nov., MP-P 9743 T9/2. (35u). 2 *Verrucosisporites iannuzzii* di Pasquo sp. nov., MP-P 9739 J5/1 (holotype). 3 *Verrucosisporites iannuzzii* di Pasquo sp. nov., MP-P 9742 N17/2. 4 *Verrucosisporites iannuzzii* di Pasquo sp. nov., CICYTTP-Pl 584(SEM). 5, 6 *Verrucosisporites souzai* di Pasquo sp. nov., MP-P 9743 R17/4 (holotype). 7, 11 *Verrucosisporites souzai* di Pasquo sp. nov., MP-P 9742 K16/2. 8 *Verrucosisporites roncadorense* di Pasquo sp. nov., MP-P 9742 W27/0. 9 *Verrucosisporites roncadorense* di Pasquo sp. nov., MP-P 9743 V22/4. 10 *Verrucosisporites roncadorense* di Pasquo sp. nov., MP-P 9743 M12/0 (holotype). 12 *Verrucosisporites souzai* di Pasquo sp. nov., MP-P 9743 J9/2. 13 *Verrucosisporites souzai* di Pasquo sp. nov., MP-P 9741 R37/1. 14, 15 *Verrucosisporites roncadorense* di Pasquo sp. nov., MP-P 9743 H30/2. 16 *Knoxisporites* sp. cf. *K. ruhlandi* Doubinger and Rauscher, MP-P 9741 G30/0. 17 *Colatisporites decorus* (Bharadwaj and Venkatachala) Williams in Neves *et al.*, CICYTTP-Pl 584(SEM) escala grafica 20 um. 18 *Colatisporites decorus* (Bharadwaj and Venkatachala) Williams in Neves *et al.*, CICYTTP-Pl 584(SEM) Y62/0. 19 *Colatisporites decorus* (Bharadwaj and Venkatachala) Williams in Neves *et al.*, MP-P 9742 T16/2. 20 *Waltzispora polita* (Hoffmeister, Staplin and Malloy) Smith and Butterworth, MP-P 9742 B26/0.

or complete and thicker walls (Fig. 9.10, 11), and 3- cell-cups formed by a more tubular and longer cup (see Figs. 9.6, 9, 19, 20). Finally, there are others with a more amorphous aspect (Fig. 9.16). The 2 and 3 morphotypes seem to be the end forms of a series or group that includes some transitional specimens, and they may be closely comparable to *B. terribilis* Komárek and Marvan 1992 or *B. australis* Komárek and Marvan 1992 (living species), respectively. Additionally, a cone-in-cone structure is visible in many specimens (Fig. 9.6, 9). Possible reproductive corpuscular bodies (autospores) are attached or inside some colonies (they seem like the cells protruding from the cups in living specimens, Fig. 9.8).

Dimensions (more than 100 specimens). Overall diameter 35 - 200 µm.

Remarks. All the sample levels yielded more or less the same amount of *Botryococcus* (ca. 20% of the total palynomorphs, see Figs. 3 and 12), and different morphologies of such cell-cups of the colonies were recorded altogether in a same sample level.

Palaeoecology. *Botryococcus* indicates shallow and fresh water bodies, with low rainfall and oligotrophic water conditions. Although they also tolerate slightly brackish water (mixed palaeoenvironments), their presence in marine sediments generally indicates transportation by rivers into marine settings (Batten and Grenfell, 1996). Many species are recognized in this living genus mainly based on its morphology, size and some components of the cell and colour of the mucilaginous cover (see Komárek and Marvan, 1992). Although, some specimens are attributed to *B. braunii* in modern assemblages (e.g., Borel *et al.*, 2003), other records are not attributed to any particular species (e.g., Medeanic, 2006). In the latter case for example, Medeanic (2006) described three morphotypes, type I compared to *Botryococcus neglectus*, type II to *B. braunii*, and type III to *B. protuberans*, mainly on the basis of their cells. The modern characters used to classify this algal colony are destroyed during sedimentation processes or chemical preparation (see Jankovská and Komárek 2000, p. 61), so fossil specimens of *Botryococcus* are difficult to compare to any of these living species. However, such fossils are generally attributed to the type species *B. braunii,* mainly because the Carboniferous to Pleistocene specimens are frequently similar to this living species. Guy-Ohlson (1992) illustrated some morphological variations of the colonies similar to the ones described here, and they were tentatively attributed to different palaeoenvironmental conditions. Such variations may correspond to changes in temperature, nutrient availability, or water clarity in brackish and fresh water systems or to diverse growth states with or without preserved autospores (see also Jankovská and Komárek, 2000). Derenne *et al.,* (in Wicander *et al.*, 1996) analyzed the morphological changes in *Botryococcus* and *Gloeocapsomorpha* related to salinity variations, and they found that a higher salinity or "brackish" environment (ca. 10 g/l NaCl) allowed the development of colonies with "closed" and thicker walls more laminated at the bottom, whilst in fresh water their walls were thinner and appeared "open" with small cavities or cups. Following these observations, it is difficult to decide which of these possible explanations could be applied to our material: 1- two different species may represent fresh and brackish deposition environments, the latter being the last place of settling; 2- the same species develops different morphologies under specific palaeoenvironmental conditions (see also Colbath and Grenfell, 1995; Batten and Grenfell, 1996; Peppers and Harvey, 1997).

Occurrence. The first accurate records of *Botryococcus* are from the Mississippian (e.g., Hemer and Nygreen, 1967) whereas scarce pre-Carboniferous records correspond mostly to the Strunian sediments (e.g., Pérez Leyton, 1990) and the oldest are records from the Middle Devonian of USA and the Chigua Formation in western Argentina (see Amenábar *et al.*, 2006).

Order **Zygnematales** Borge in Pascher 1913
Genus *Chomotriletes* Naumova 1939 ex Naumova 1953
Type species. *Chomotriletes vedugensis* Naumova 1953.
Botanical affinity. See Colbath and Grenfell (1995) and Batten (1996).

Chomotriletes sp. in Higgs, Clayton and Keegan 1988
Figure 9.1, 2

Remarks. The specimens from the Poti Formation are attributed to this species due to few concentrically arranged ridges from the equator to around the middle part and the absence of ridges on both poles; some scattered small grana occur on the exine as well. Hence, this taxon differs from both the type species and *Chomotriletes multivittatus* Playford 1978.

Occurrence. It was recorded from latest Devonian to early Visean of Ireland (Higgs *et al.*, 1988).

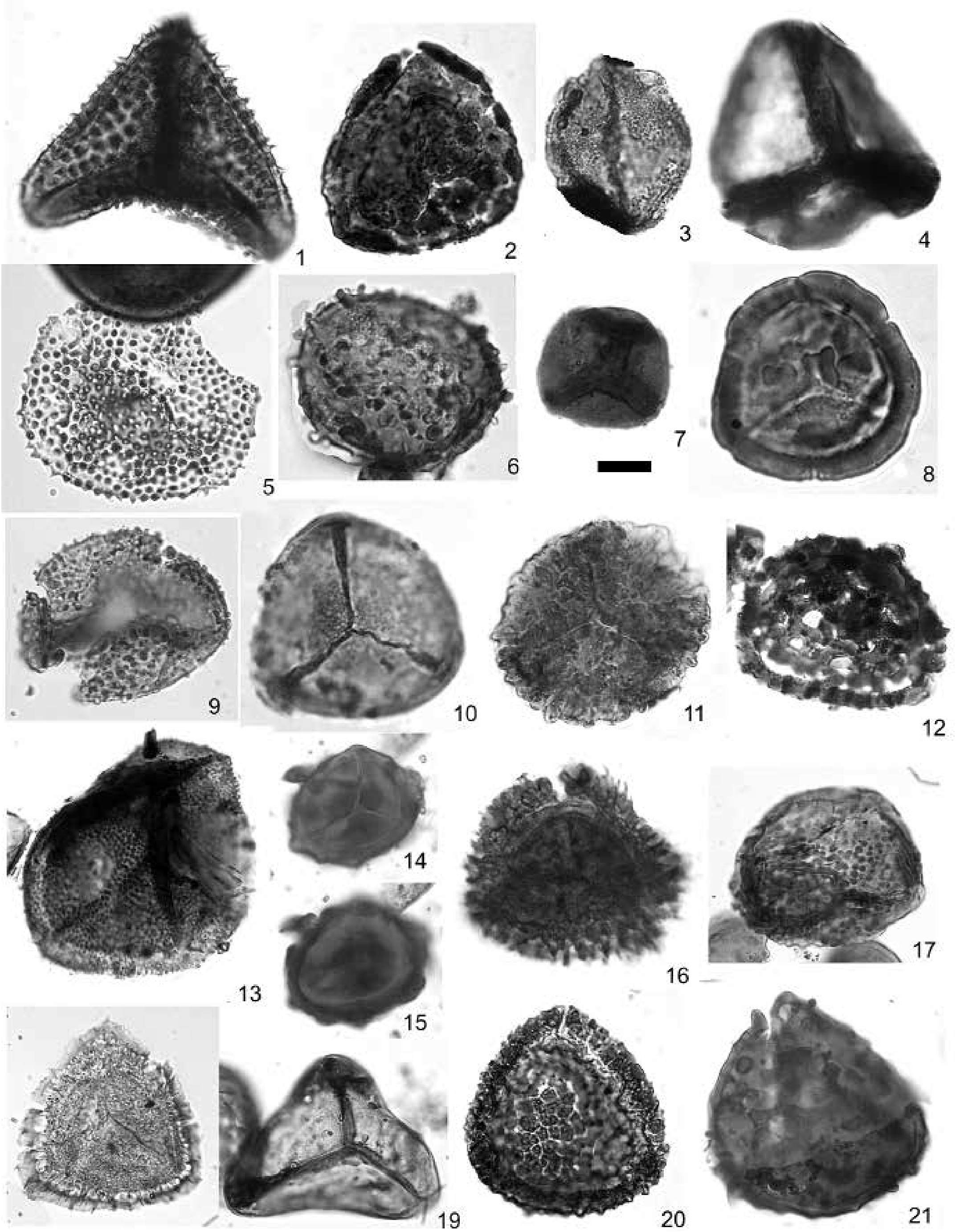


Figure 8. Autochthonous species in the assemblage of the Poti Formation at the Roncador creek.
Figura 8. *Especies autóctonas en la asociación de la Formación Poti en el arroyo Roncador.*
Scale bar/*Barra de escala*: 1-8, 10-11, 14-16, 19, 21 = 10 µm, 12-13, 17-18, 20= 13,5 µm, 9= 12 µm.
1 *Tricidarisporites phippsae* Playford and Satterthwait, MP-P 9743T12/1. 2 *Cristatisporites menendezii* (Menéndez and Azcuy) Playford, MP-P 9742 S20/1. 3 *Aratrisporites saharensis* Loboziak, Clayton and Owens, MP-P 9742 R30/4. 4 *Gulisporites torpidus* Playford, MP-P 9743 J32/1. 5 *Dibolisporites microspicatus* Playford, MP-P 9743 D8/1. 6 *Pustulatisporites dolbii* Higgs *et al.*, MP-P 9742 N24/0. 7 *Leiotriletes ornatus* Ishchenko, MP-P 9742-1Y40/0. 8 *Tumulispora variverrucata* (Playford) Staplin and Jansonius, MP-P 9742 G26/1. 9 *Verrucosisporites papulosus* Hacquebard, MP-P 9742 R29/1. 10 *Leiotriletes tortilis* Playford, MP-P 9743 S25/3. 11 *Cristatisporites colliculus* Playford, MP-P 9743 V33/0. 12 *Cristatisporites peruvianus* Azcuy and di Pasquo, MP-P 9742-A U31/1. 13 *Spelaeotriletes balteatus* (Playford) Higgs, MP-P 9742-1 M34/4. 14, 15 *Lophozonotriletes* sp. cf. *L.* sp 1 in Ravn 1991, MP-P 9739 P41/2. 16 *Cristatisporites echinatus* Playford, MP-P 9742 H27/1. 17 *Verrucosisporites depressus* Winslow, MP-P 9742 K24/2. 18 *Vallatisporites vallatus* Hacquebard, MP-P 9742 J13/0. 19 *Anapiculatisporites amplus* Playford and Powis, MP-P 9742-AT33/1. 20 *Cristatisporites menendezii* (Menéndez and Azcuy) Playford, MP-P 9743 D12/1. 21 *Pustulatisporites papillosus* (Knox) Potonié and Kremp, MP-P 9742-AY33/0.

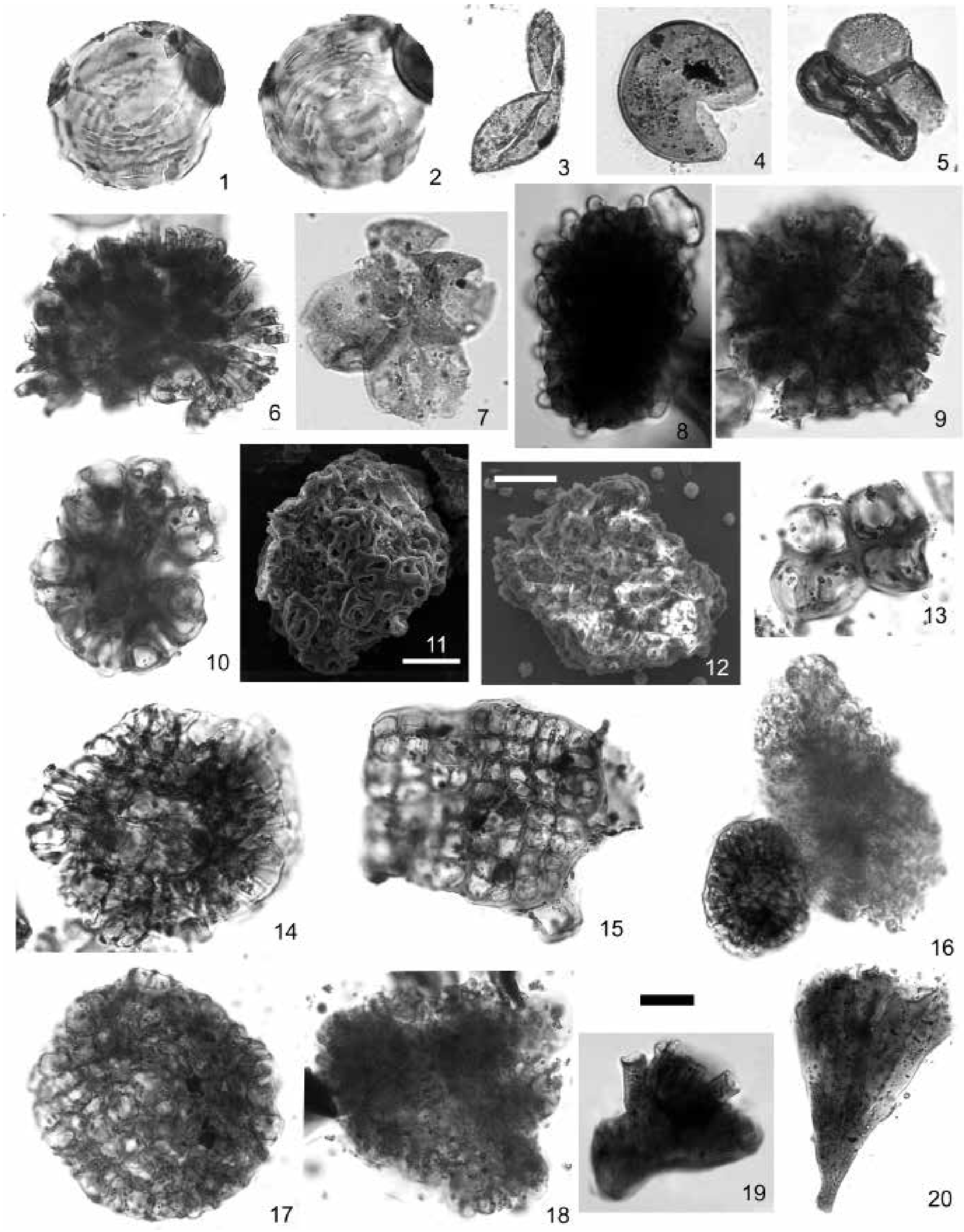


Figure 9. Autochthonous species in the assemblage of the Poti Formation at the Roncador creek.
Figura 9. *Especies autóctonas en la asociación de la Formación Poti en el arroyo Roncador.*
Scale bar/*Barra de escala*: 1, 2, 5, 15, 17, 20= 13,5 µm, 3, 4, 7-10, 13, 18, 19= 10 µm, 14= 12 µm, 6, 11-12, 16= 20 µm.
1, 2 *Chomotriletes* sp. in Higgs *et al.*, MP-P 9742 L22/3. 3 *Brazilea scissa* (Balme and Hennelly) Foster, MP-P 9743-A S34/0.
4 *Brazilea scissa* (Balme and Hennelly) Foster, MP-P 9743-A R21/2. 5 *Quadrisporites granulatus* (Cramer) Ströther, MP-P 9743-A V35/2.
6 *Botryococcus* spp., MP-P 9743 I20/4. 7 *Quadrisporites granulatus* (Cramer) Ströther, MP-P 9742 U13/1. 8 *Botryococcus* spp., MP-P 9741 V35/3. 9 *Botryococcus* spp., MP-P 9741 B23/2. 10 *Botryococcus* spp., MP-P 9742-A R31/2. 11 *Botryococcus* spp., CICYTTP-Pl 584(SEM). 12 *Botryococcus* spp., BAFC-Pl 3896(SEM). 13 *Botryococcus* spp., MP-P 9739 H55/1. 14 *Botryococcus* spp., MP-P 9743 Y9/4. 15 Indeterminate algal species, MP-P 9742-A G41/0. 16 *Botryococcus* spp., BAFC-Pl 3896(1) I26/3. 17 *Botryococcus* spp., MP-P 9739 E46/1. 18 *Botryococcus* spp., MP-P 9739 W41/1. 19 *Botryococcus* spp., MP-P 9741 S16/1. 20 *Botryococcus* spp., MP-P 9739 D48/3.

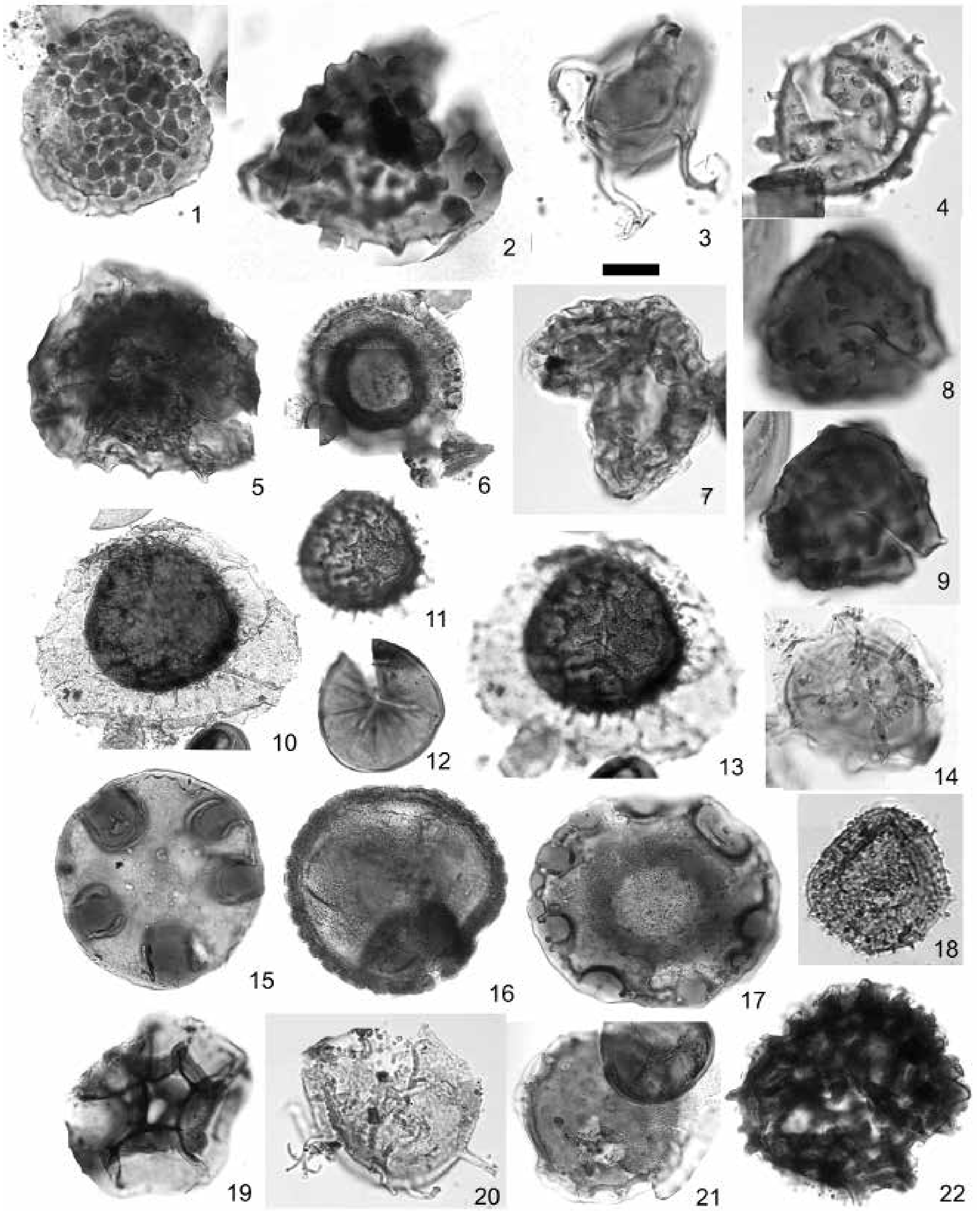


Figure 10. Reworked spores and microplankton in the assemblage of the Poti Formation at the Roncador creek.
Figura 10. *Esporas y microplancton retrabajados en la asociación de la Formación Poti en el arroyo Roncador.*
Scale bar/*Barra de escala*: 1, 7—9, 14, 18, 20= 10 µm, 2-5, 12, 22 = 13,5 µm, 15-17, 19, 21= 20 µm, 6= 40 µm, 10, 13= 25 µm, 11= 30 µm.
1 *Acinosporites eumammillatus* Loboziak, Streel and Burjack, MP-P 9742 I30/1. 2 *Verrucosisporites scurrus* (Naumova) McGregor and Camfield, MP-P 9742 F26/2. 3 *Umbellasphaeridium saharicum* Jardiné *et al.*, MP-P 9742 W16/0. 4 *Umbellasphaeridium deflandrei* (Moreau-Benoit) Jardiné *et al.*, MP-P 9742 J11/2. 5 *Ancyrospora langii?* (Taugourdeau-Lantz) Allen, MP-P 9742 L30/1. 6 *Maranhites brasiliensis* Brito emend. Burjack and Oliveira, MP-P 9742 T29/0. 7 *Umbellasphaeridium companulatum* Oliveira and Burjack, MP-P 9742 O18/3. 8, 9 *Lophozonotriletes media* Taugourdeau-Lantz, MP-P 9742 C15/2. 10, 11, 13 *Grandispora pseudoreticulata* (Menéndez and Pöthe de Baldis) Ottone, MP-P 9742 X17/4. 12 *Emphanisporites rotatus* McGregor emend. McGregor, MP-P 9742 Z18/0. 14 *Cymatiosphaera perimembrana* Staplin, MP-P 9742 X25/1. 15 *Maranhites insulatus* Brito emend. Burjack and Oliveira, MP-P 9743 N17/0. 16 *Maranhites brasiliensis* Brito emend. Burjack and Oliveira, MP-P 9742 R21/3. 17 *Maranhites mosesii* (Sommer) Brito emend. Burjack and Oliveira, MP-P 9742 P11/0. 18 *Gorgonisphaeridium* sp., MP-P 9743-AT34/1. 19 *Dictyotidium munificum* (Wicander and Wood) Amenábar *et al.*, MP-P 9742 J24/3. 20 *Ammonidium garrasinoi* Ottone, MP-P 9742 H16/1. 21 *Maranhites britoii* Stockmans and Williére, MP-P 9742 E21/3. 22 *Cordylosporites marciae* (Winslow) Playford and Satterthwait, MP-P 9742-1 Q48/0.

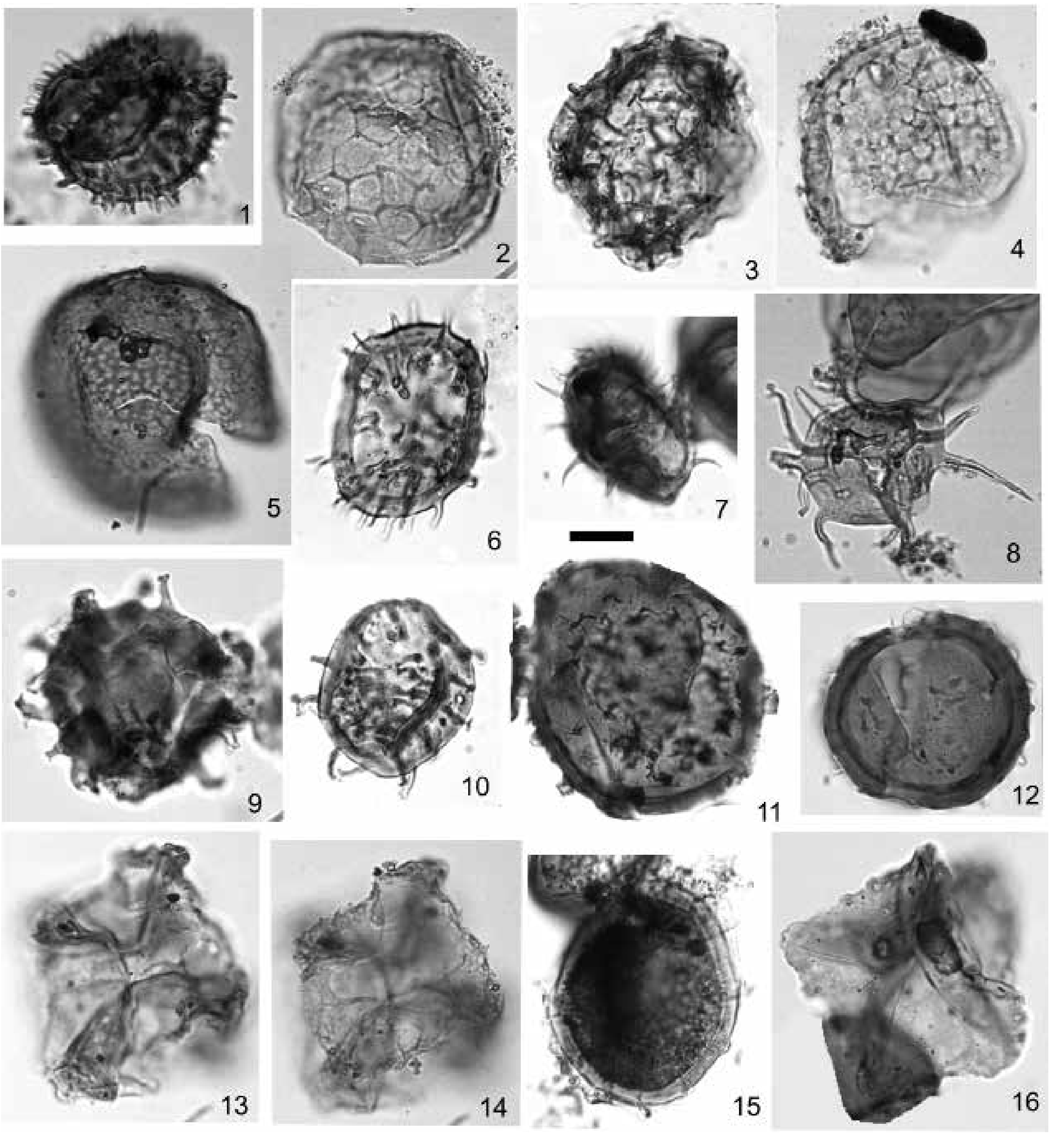


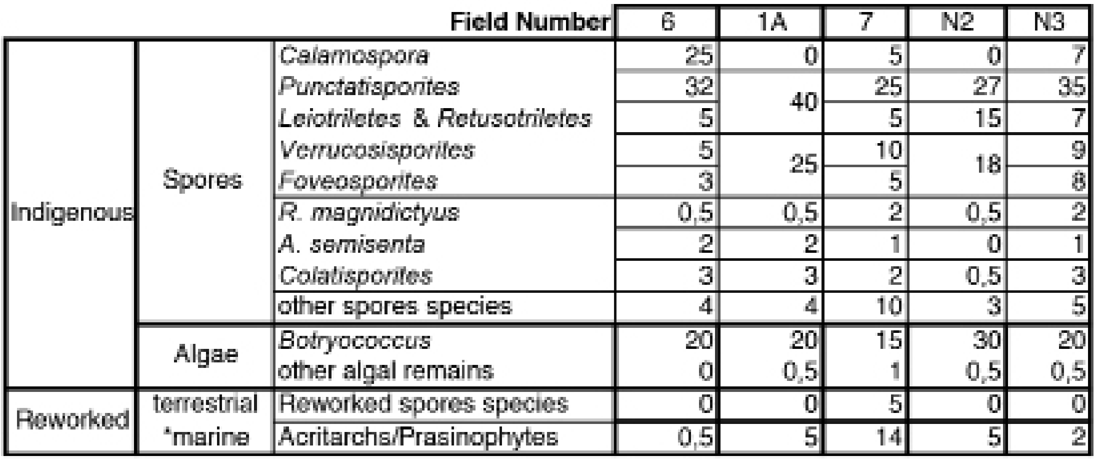
Figure 11. Reworked microplankton in the assemblage of the Poti Formation at the Roncador creek.
Figura 11. *Especies de microplancton retrabajadas en la asociación de la Formación Poti en el arroyo Roncador.*
Scale bar/*Barra de escala*: 1—7, 9-10, 12-14, 16= 10 µm, 11= 14,5 µm, 8, 15= 12 µm.
1 *Gorgonisphaeridium* sp., MP-P 9743-AY26/4. 2 *Dictyotidium* sp., MP-P 9743 D9/2. 3 *Dictyotidium* sp., MP-P 9743-A W17/1. 4 *Dictyotidium* sp., MP-P 9742 B27/0. 5 *Dictyotidium* sp., MP-P 9742 V15/2. 6 *Gorgonisphaeridium* sp., BAFC-Pl 3898-1 U20/1. 7 *Gorgonisphaeridium* sp., MP-P 9742 N27/0. 8 *Polygonium barredae* Ottone, MP-P 9742 K19/0. 9 *Gorgonisphaeridium* sp., MP-P 9742 X16/0. 10 *Gorgonisphaeridium* sp., CICYTTP-Pl 582(3) V52/3. 11 Undetermined acritarch, MP-P 9742 Z32/2. 12 *Gorgonisphaeridium* sp., MP-P 9742 E9/1. 13, 14 *Polyedryxium leptum* Turner, MP-P 9742 L16/3. 15 *Cymatiosphaera* sp., MP-P 9743 I29/2. 16 *Arkonites bilixus* Legault, MP-P 9742 J21/3.

Age and correlation

The South American Mississippian palynological record is geographically distributed in only a few locations in Brazil, Bolivia, Peru, Argentina, Chile and Colombia (Fig. 1A, Chart 1, supplementary online material). These assemblages present variable numbers of mixed Euramerican/Gondwanan species depending on their specific palaeolatitudinal occurrences and paleoenvironmental conditions (e.g., Iannuzzi and Pfefferkorn, 2002). Several quite continuous successions, mainly from the subsurface, allowed the establishment of palynological zones (e.g., Melo and Loboziak, 2003). Palynofloral correlations from South America and to some extent from other zones from Gondwana and elsewhere (Fig. 14) are possibly based on the presence of some species in common (e.g., Iannuzzi and Rösler, 2000; Azcuy and di Pasquo, 2005; Azcuy et al., 2007).

Tournaisian and early Visean palynological assemblages are documented from subsurface deposits of the Longá (Melo and Loboziak, 2003; Melo and Playford, 2012; Playford *et al.*, 2012) in the Parnaíba and the Oriximaná and Faro formations in the Amazonas basins (Melo and Loboziak, 2003; Melo and Playford, 2012; Playford and Melo, 2012), in Brazil (Fig. 1A, C). Tournaisian palynofloras are recorded from the SM-4 well in the Llanos Orientales Basin in Colombia (Dueñas and Césari, 2006). In Bolivia, early Visean palynofloras are documented in the Itacua Formation (di Pasquo, 2007, 2008a). Tournaisian and early Visean palynological assemblages are documented from the Malimán and El Ratón formations (Amenábar *et al.*, 2006, 2007; Amenábar and di Pasquo, 2008). These palynofloras share several common species with the palynoflora present in the Poti Formation studied in this paper (Chart 1, supplementary online material). Although the presence in the Poti Formation of *Reticulatisporites magnidictyus, Densosporites spinosus* and *Foveosporites pellucidus*, which are documented since the late Visean (Fig. 13), support this age for the studied assemblage but their correlation is not possible (Fig. 14).

The *Reticulatisporites magnidictyus – Verrucosisporites* sp. 85 (= *V. nitidus*) Zone was first defined by Suárez Soruco and Lobo Boneta (1983) from subsurface in Bolivia (Fig. 14), indicating a late Visean age. This age was later confirmed by the presence of the *Nothorhacopteris kellaybelenensis* Flora (Azcuy and Suárez Soruco, 1993; Iannuzzi *et al.*, 1998; Iannuzzi and Pfefferkorn, 2002; Fasolo *et al.*, 2006). Later, Melo and Loboziak (2003) defined for the first time the *R. magnidictyus* (Mag) Zone in the Amazonas Basin (Brazil). This zone was then extended to the Poti Formation of the Parnaíba and equivalent strata of the Solimões basins. Currently, the Mag Zone is restricted to the Holkerian-Asbian (mid late Visean) in Brazil and extended to the early Serpukhovian, based on the palynological assemblages documented in the Kaka Formation, in Bolivia (Fasolo *et al.*, 2006; di Pasquo, 2008b) and in the Cortaderas Formation, in the Precordillera Argentina (Pérez Loinaze, 2007). In this the latter unit, the *R. magnidictyus-V. quassigobbetti* (MQ) Zone was defined (Fig. 14) and the age was confirmed by radiometric dating (ca. 336 Ma in Césari *et al.*, 2011).



		Field Number	6	1A	7	N2	N3
Indigenous	Spores	*Calamospora*	25	0	5	0	7
		Punctatisporites	32	40	25	27	35
		Leiotriletes & Retusotriletes	5		5	15	7
		Verrucosisporites	5	25	10	18	9
		Foveosporites	3		5		8
		R. magnidictyus	0,5	0,5	2	0,5	2
		A. semisenta	2	2	1	0	1
		Colatisporites	3	3	2	0,5	3
		other spores species	4	4	10	3	5
	Algae	*Botryococcus*	20	20	15	30	20
		other algal remains	0	0,5	1	0,5	0,5
Reworked	terrestrial	Reworked spores species	0	0	5	0	0
	*marine	Acritarchs/Prasinophytes	0,5	5	14	5	2

Figure 12. Percentage of the major palynological groups including selected spore genera recognized in the assemblages of the Poti Formation at Riacho do Roncador. Sample N3A was not included due to low diversity. The asterisk refers to the discussion about indigenous and reworked origin of taxa.

Figura 12. *Porcentajes de grupos palinológicos mayores incluyendo géneros de esporas seleccionadas reconocidas en las asociaciones de la Formación Poti en el arroyo Roncador. La muestra N3A no fue incluida debido a su baja diversidad. El asterisco se refiere a la discusión sobre el origen autóctono vs. retrabajado de los taxones.*

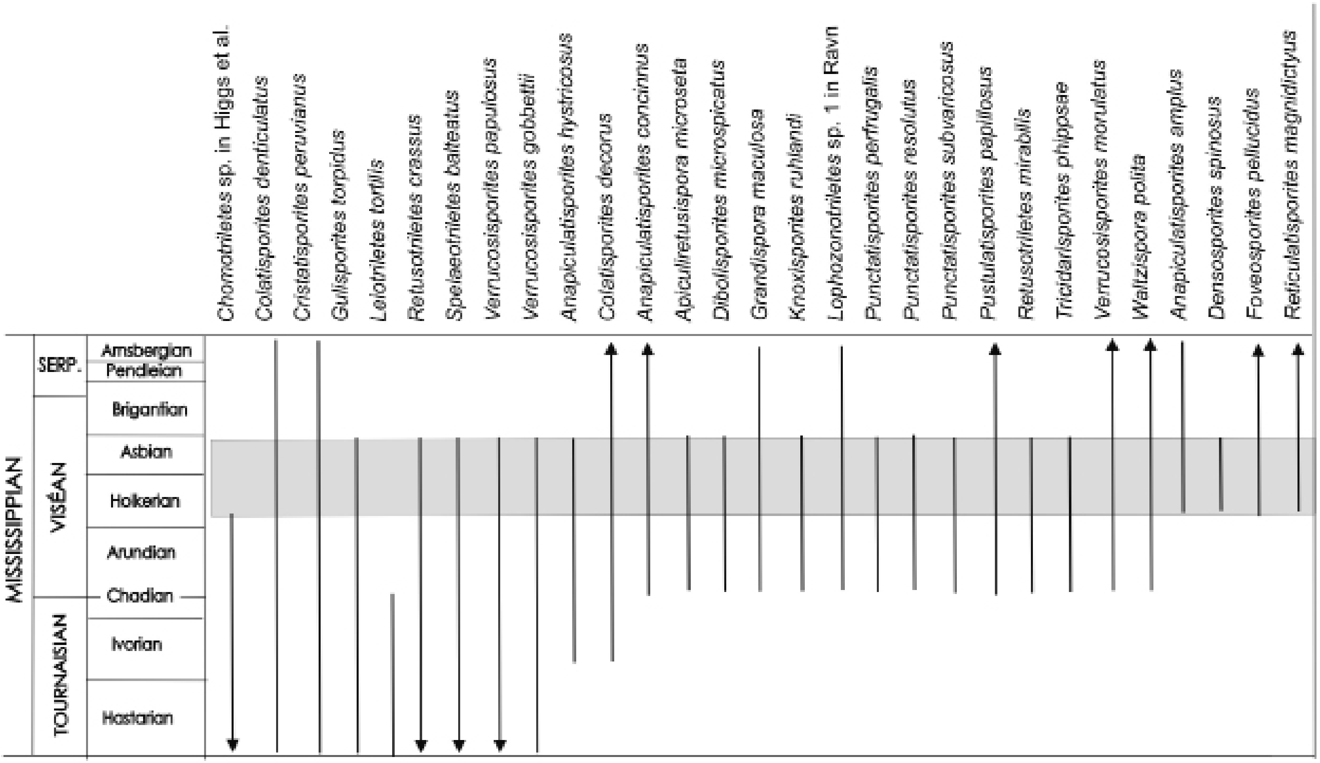


Figure 13. Stratigraphic ranges of selected species recorded in the Poti Formation at Riacho do Roncador, based on Chart 1 (supplementary online material).

Figura 13. *Rango estratigráfico de especies seleccionadas registradas en la Formación Poti en el arroyo Roncador, basado en el Cuadro 1 (material suplementario).*

The Poti Formation assemblages studied in this paper share sixteen of the 42 species with subsurface assemblages of the same stratigraphic unit analysed by Melo and Loboziak (2000), who found some age-diagnostic taxa of the late Visean (late Holkerian-Asbian) *Perotrilites tessellatus–Schulzospora campyloptera* (TC) and *Raistrickia nigra–Triquitrites marginatus* (NM), from Western Europe (Clayton *et al.*, 1977; see Fig. 14), that were not previously recognized (e.g., *Diatomozonotriletes rarus*, *Diatomozonotriletes fragilis, Kraeuselisporites dolianitii* morphon, species of *Lycospora* sp., *Perotrilites tessellatus*, *Rotaspora ergonulii, Spelaeotriletes arenaceus, S. owensii, S. triangulus* and *Vallatisporites ciliaris*; see Chart 1, supplementary online material).

Streel *et al.* (2012) recovered both Devonian and Mississippian palynomorphs from diamictites and siltstones of the Poti Formation from several wells drilled in the Tocantins River (western Parnaíba Basin). The assemblages are dated as late Visean based on several index taxa such as *Schulzospora* sp., *Raistrickia nigra*, and several species of *Spelaeotriletes* and *Densosporites.* They also illustrated ?*Schopfipollenites* sp. (Streel *et al.*, 2012, fig. 4, a-c), which should more likely be reassigned to *Spelaeotriletes*, as they show typical features of this genus such as ornamentation, a small central body and folds of the eoexine. Several Devonian species are also present and interpreted as reworking from older units. Nine long-ranging species are in common with our assemblages (see Chart 1, supplementary online material).

A late Visean age for our section at the Roncador creek is supported by the presence of common index species from the latest Visean *Grandispora maculosa* Zone (e.g. *Anapiculatisporites amplus, Foveosporites pellucidus*, *Grandispora maculosa*, *Punctatisporites subvaricosus* and *Reticulatisporites magnidictyus*) and from the late Tournaisian to mid-Visean *Anapiculatisporites largus* Zone (e.g. *Knoxisporites ruhlandi, Tricidarisporites phippsae, Retusotriletes mirabilis* and *Waltzispora polita*) documented from Australia (see Playford, 1991; Jones and Truswell, 1992; Fig. 14 and Chart 1, supplementary online material).

The *Lycospora noctuina-Knoxisporites stephanophorus* (NS) and *Schopfipollenites acadiensis-Knoxisporites triradiatus* (AT) Zones defined by Utting (1987) in Canada, are partially correlated to the R. *magnidictyus* (Mag) Zone established in Brazil (Fig. 14), as well as to the Ambo Formation in Peru (Azcuy and di Pasquo, 2005, 2006; see also Azcuy et al., 2007) and the Kaka Formation in Bolivia (Fasolo *et al.*, 2006; di Pasquo, 2008b) based on the common presence of *Schopfipollenites* and *Colatisporites decorus* (Chart 1, supplementary online information). Azcuy and di Pasquo (2005) noticed that in the Canadian associations, *Reticulatisporites magnidictyus* is absent (see also Utting and Giles, 2004; Utting *et al.*, 2010), still remaining as an exclusive species of the late Visean - early Serpukhovian of Gondwana including the Paraca floral realm (Alleman and Pfefferkorn, 1988; Iannuzzi and Pfefferkorn, 2002; Pérez Loinaze, 2007; Playford and Melo, 2012).

Moreover, the palynological analysis of the Roncador creek indicates that the specimen assigned to *Schopfipollenites* sp. by Iannuzzi (1994, see Fig. 3), is a *Calamospora* sp. (Figs. 3 and 6). Hence, *Schopfipollenites* was neither recorded in this study nor in any other palynological assemblage of the Parnaíba Basin of northeastern Brazil (Fig. 1A). This taxon has been recorded spanning the late Visean of Peru, Bolivia and northwestern Brazil (Paraca Realm) and the *Schopfipollenites acadiensis-Knoxisporites triradiatus* (AT) Zone (Fig. 14) defined by Utting (1987) in Canada (see Utting, 1987; Melo and Loboziak, 2003; Azcuy and di Pasquo, 2005; Fasolo *et al.*, 2006; di Pasquo, 2008b; Melo and Playford, 2012), and extending up to the late Carboniferous of northern Argentina, Bolivia and northwestern Brazil (Loboziak *et al.*, 1998; di Pasquo, 2002, 2003). Therefore, its oldest records are still distributed in a central western portion of South America (Bolivia, northwestern Brazil and Peru, Fig. 1A) constrained to the late Visean – Serpukhovian.

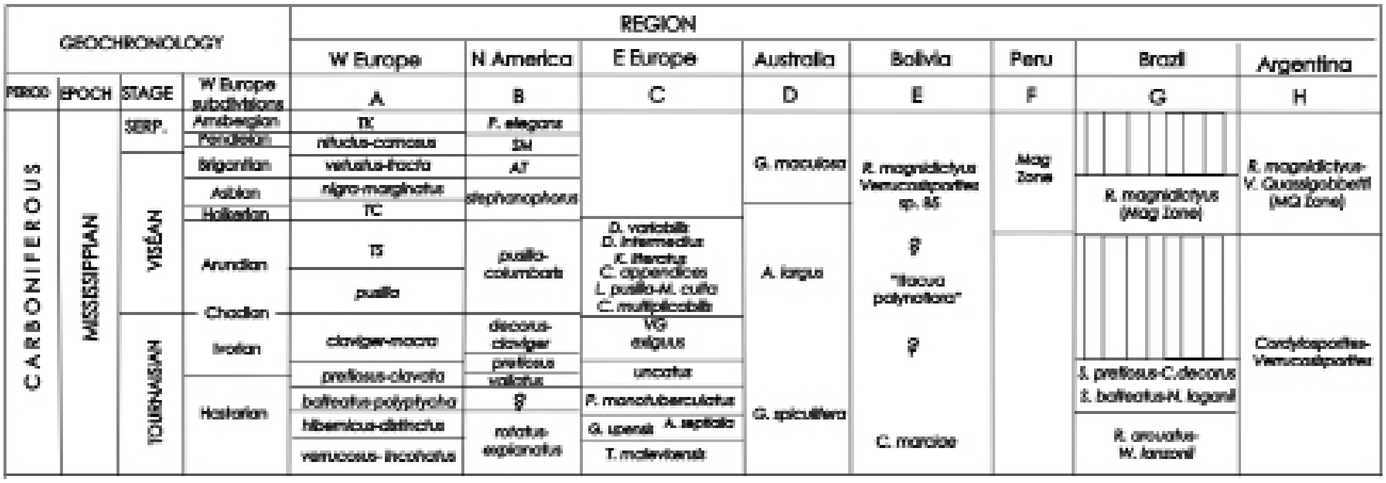


Figure 14. Biostratigraphic correlation of the Poti assemblages at Riacho do Roncador with other Mississippian biozones of Western Europe (**A**), North America (**B**), Eastern Europe (**C**), Australia (**D**), Bolivia (**E**), Peru (F), Brazil (G) and Argentina (H). The Canadian biostratigraphic zones included in North America scheme (B) are referred to *SM, AT* and *K. stephanephorus* (after Utting, 1987; Utting *et al.*, 2010). References: **A**: Clayton *et al.* (1977), Higgs *et al.* (1988); **B**: Utting and Giles (2004), Utting *et al.* (2010); **C**: Avchimovitch *et al.* (1988, 1993), Byvsheva (1997); **D**: Playford (1985, 1991); **E**: Suárez Soruco and Lobo Boneta (1983), di Pasquo (2007, 2008a, 2008b); **F**: Azcuy and di Pasquo (2005), Fasolo *et al.* (2006) di Pasquo (2008b), Azcuy *et al.* (2007); **G**: Melo and Loboziak (2003); **H**: Pérez Loinaze (2007), Césari *et al.* (2007). Abbreviations: **(W Europe)** *TS – K. triradiatus-K. stephanophorus, TC – P. tessellatus-S. camptyloptera, TK – S. triangulus-R. knoxi;* **(E Europe)** *VG – M. variomarginata-V. genuinus,* **(North America)** *SM – G. spinosa-I. magnificus, AT – S. acadiensis-K. triradiatus.*

Figura 14*. Correlación bioestratigráfica de la asociación de la Formación Poti en el arroyo Roncador con otras biozonas del Mississippiano del Oeste de Europa (***A***), América del Norte (***B***), Este de Europa (***C***), Australia (***D***), Bolivia (***E***), Perú (F), Brasil (G) y Argentina (H). La zonación de Canadá está incluida en el esquema bioestratigráfico de América del Norte (B) y sus zonas corresponden a SM, AT y K. stephanephorus según Utting (1987; Utting et al., 2010). Referencias*: **A**: *Clayton et al. (1977), Higgs et al. (1988);* **B**: *Utting y Giles (2004), Utting et al. (2010);* **C**: *Avchimovitch et al. (1988, 1993), Byvsheva (1997);* **D**: *Playford (1985, 1991);* **E**: *Suárez Soruco y Lobo Boneta (1983), di Pasquo (2007, 2008a, 2008b);* **F**: *Azcuy y di Pasquo (2005), Fasolo et al. (2006), di Pasquo (2008b), Azcuy et al. (2007);* **G**: *Melo y Loboziak (2003);* **H**: *Pérez Loinaze (2007), Césari et al. (2007). Abreviaturas:* **(W Europe)** *TS – K. triradiatus-K. stephanophorus, TC – P. tessellatus-S. camptyloptera, TK – S. triangulus-R. knoxi;* **(E Europe)** *VG – M. variomarginata-V. genuinus,* **(N America)** *SM – G. spinosa-I. magnificus, AT – S. acadiensis-K. triradiatus.*

Paleoenvironmental and paleophytogeographic approaches

Sedimentological features throughout this section reflect a depositional environment in brackish shallow estuarine facies (Iannuzzi and Scherer, 1996). The botanical affinities (see Balme, 1995) attributed to the miospores show a strong predominance of Pteridophyte and subordinated Lycophyte and Sphenophyte (see Figs. 3A and 12). Chlorophytes, mainly represented by the genus *Botryococcus*, are abundant throughout the section. The paleoecological information provided by these groups of plants corroborates physical (mainly lithological) evidence of a wholly brackish depositional environment receiving terrestrial organic matter from nearby pteridophytic land-based vegetation suggesting humid environmental conditions. Among the chlorophycean palynomorphs, the dominance of *Botryococcus* in association with amorphous kerogen and oil droplets (tapho-diagenetic feature not illustrated), suggest that the surface waters must have been sufficiently productive to allow the accumulation of organic-rich sediments. The high potential of preservation of palynomorphs falling into the hypolimnion indicates a non-turbulent oligotrophic water body where anoxic bottom conditions prevailed (Batten and Grenfell, 1996). Whether there are two different species of *Botryococcus* or only one, it is difficult to decide. The morphological diversity of this alga documented herein may reflect both fresh and brackish water bodies being the latter the final place of settling for the palynoassemblages (Colbath and Grenfell, 1995; Batten and Grenfell, 1996; Peppers and Harvey, 1997). *Brazilea* needs freshwater conditions (Colbath and Grenfell, 1995), whereas the specimens of *Botryococcus* with thick walls may suggest their growth in brackish waters under the influence of arid palaeoclimatical conditions (Guy-Ohlson, 1992).

The reworked palynomorphs are mainly documented from one sample level and are interpreted as Devonian species (Figs. 2, 3B and 10-12), supporting the erosion and the recycling of older strata into the Poti Formation (Fig. 1B-C). Species such as *Aratrisporites saharaensis*, *Emphanisporites hibernicus* and *Lophozonotriletes variverrucatus* (Fig. 10), occur in the latest Devonian/earliest Tournaisian interval and may reflect reworking from those sediments as well. This similarity was also documented in the Faro Formation by Melo and Loboziak (2003). Other species such as *Anapiculatisporites hystricosus*, *Colatisporites decorus*, *Raistrickia clavata* and *Pustulatisporites gibberosus* (see Figs. 3A, 10 and 13), may either be holdovers or reworked species from Tournaisian and early Visean? deposits (see Melo and Loboziak, 2003; Melo and Playford, 2012). Acritarchs and prasinophytes (Figs. 3B and 11) are also attributed to the recycling of Devonian units. Hence, they cannot be used to indicate a marine settling for the studied section. The presence of reworked palynomorphs especially well-represented into the mid-to upper section, suggest a slight sea level regression that caused the erosion of the underlying Devonian-Tournaisian strata. This is also confirmed by the unconformable contact between the Poti and the underlying Longá formations (Fig. 1C; see Melo and Loboziak, 2003). According to Loboziak *et al.* (1998) and Melo *et al.* (1998), similar gaps are also recorded in the Amazonas Basin, between the Oriximiná and Faro formations, as well as in the Solimões Basin, within the highly heterogeneous Jandiatuba Formation (Fig. 1C).

Streel *et al.* (2012) recovered from diamictites and siltstones of the Poti Formation from several boreholes drilled in the Tocantins River (western Parnaiba Basin), several Devonian species that are also common in the presently studied assemblage (e.g., *Grandispora pseudoreticulata* and *Samarisporites triangulatus*). They interpreted these species as derived from the reworking of older units. In contrast, Dueñas and Césari (2006) have also recovered a few marine species such as *Maranhites insulatus*, *Gorgonisphaeridum* cf. *winslowiae, Umbellasphaeridium* sp. in the subsurface Mississippian deposits of Colombia, but they were interpreted as autochthonous species, which is here considered as an incorrect interpretation.

On the other hand, paleogeographic reconstructions of South America during the late Visean have located the Parnaíba and the Amazonas basins in Brazil, and the Madre de Dios Basin in Peru and northern Bolivia between 40° and 50° S paleolatitude (Scotese, 2000). This data is in agreement with warm temperate conditions for the region where the parent flora of the late Visean-early Serpukhovian Central Gondwana or Paraca floral realm (Alleman and Pfefferkorn, 1988; Iannuzzi and Pfefferkorn, 2002) was developed (Iannuzzi and Pfefferkorn, 2002). It is characterized by humid and temperate floras with few typical plants (e.g., *Tomiodendron*, *Archaeocalamites*, *Nothorhacopteris*, *Triphyllopteris*, *Fryopsis*, *Sphenopteridium* and *Diplothmema*) that embrace a wide belt extending from the west of South America up to the east of Australia. Therefore, in view of the vast extent of this realm differences would be expected in floral composition between the distinct Gondwana regions, mainly related to changes of humidity recorded throughout this belt. In fact, the flora from the drier temperate conditions prevailing in the central parts of Gondwana showed some disparities in their palyno- and plant fossil composition (Iannuzzi and Pfefferkorn, 2002).

Therefore and according to palaeoclimatical reconstructions (see Iannuzzi and Rösler, 2000), the Parnaíba Basin would have been situated in a semi-arid climatic zone during the mid- Mississippian, distinct from phytofossiliferous areas found in Peru, Bolivia and Argentina, located in humid regions. The occurrence of a unique flora at the Roncador section consisting of some taxa restricted to the Parnaíba Basin could be explained by paleobiogeographical restrictions of these elements to northeastern Brazil owing to macroclimatic conditioning. Among the exclusive Mississippian palynomorphs in this locality, *Densosporites spinosus*, *Knoxisporites ruhlandi, Tricidarisporites phippsae* and *Retusotriletes mirabilis* are described for the first time in Brazil and/or South America and they are constrained to the middle to late Visean (Chart 1, supplementary online material), in addition, to the three new spore species that are here erected (e.g., *Verrucosisporites iannuzzii, V. souzai, V. roncadorense*). For plant fossils, *Kegelidium lamegoi* Dolianiti 1954 and *Diplothmema gothanica* (Dolianiti) Iannuzzi 2002 have been considered endemic forms of the Parnaíba Basin (Dolianiti, 1954; Iannuzzi and Pfefferkorn, 2002; Iannuzzi *et al.*, 2006), and now the presence of *Fedekutzia* cf. *F. argentina* is the first confirmed record of the genus for the Mississippian of northern South America.

As far as whether the deposition of diamictites have a glacial origin or not in the Poti Formation is concerned, as the former origin was not really demonstrated by Streel *et al*. (2012), it is not in disagreement with the warmer interglacial period related to the Paraca Realm. This is because we must consider the following facts: 1- Our section is very thin (ca. 5 m) in comparison to the ca. 26 meters of the diamictite section analysed by these authors (2012). Hence, the diamictites may represent different times of deposition during the late Visean of ca. 4 Ma (Cohen *et al*., 2013). 2-The absence of the *R. magnidictyus* in those diamictites may be related to a much shorter Milankovitch-scale glacial-interglacial oscillation (Heckel *et al*., 2007; Heckel, 2008; Birgenheier *et al*., 2009) within the major interglacial period. However, it might just be a matter of preservation or ecofaciological constraints, as interpreted by Streel *et al.* (2012). 3- In addition, tectonic movements triggering paleogeographical changes, such as elevation of mountains, cold coastal upwelling, and locally increased precipitation may play a role in modifying the degree of ice cover and the long-distance plant dispersal ("plant migration") both locally and over time during the late Visean interglacial period (Pfefferkorn *et al*., 2014).

Therefore, we conclude that, even if both the studied assemblages of the Poti Formation at the Roncador creek, and the one from the diamictite section of the Tocantins River described by Streel *et al.* (2012) are included in the same Mag Zone of late Visean age, it is likely that they are not strictly contemporaneous, i.e. they were not deposited at the same time interval. Our assemblage is more related to a normal warm interval, whilst the diamictites could have been deposited during an ice age shift into the major interglacial period.

Conclusions

Six samples of the Poti Formation at the Roncador creek yielded well-preserved indigenous palynomorphs of terrestrial provenance, including a diversity of spores (58 species) and chlorophycean algae (5 species). One level provided most of the 32 reworked species (9 spores and 23 microplankton species). Plant remains are also recorded in the lower part of this outcrop (e.g., *Fedekurtzia* cf. *F. argentina* and *Nothorhacopteris* cf. *N. kellaybelenensis*). Three new spore species, *Verrucosisporites iannuzzii* di Pasquo*, V. souzai* di Pasquo and *V. roncadorense* di Pasquo, which are well preserved and frequently represented throughout the section, are described. The analysis of the palaeogeographical and biostratigraphical distribution of the species identified in these strata proves that several Visean species are shared with palynofloras from South America and elsewhere. First records for the Mississippian of Brazil (24 species) and South America (7 species) are also documented (Chart 1, supplementary online material). Among the stratigraphically-significant species, *Anapiculatisporites amplus, A. concinnus, Apiculiretusispora microseta, Reticulatisporites magnidictyus, Foveosporites pellucidus, Grandispora maculosa, Verrucosisporites morulatus* and *Waltzispora polita* are present and confirm a late Visean age (Fig. 13). Worldwide comparison of the Roncador association indicates a superior affinity with coeval palynofloras attributed to the R. *magnidictyus* (Mag) Zone defined by Melo and Loboziak (2002) in Brazil, and other correlative palynozones, in particular Bolivia (Fasolo *et al*., 2006; di Pasquo, 2008b), northern Africa (Coquel *et al*., 1988, 1995) and Australia (Playford, 1991; Jones and Truswell, 1992) (Fig. 14 and Chart 1, supplementary online material).

Both the plant remains and the palynological records from the Poti Formation at the Roncador creek are part of the warm-temperate Paracas floral realm as discussed by Iannuzzi and Pfefferkorn (2002). The occurrence of a unique flora at the Roncador section consisting of some taxa restricted to the Parnaíba Basin may be explained by paleobiogeographical restrictions of these elements to northeastern Brazil due to macroclimatic constrainments. The presence in this location of the exclusive Mississippian palynomorphs *Densosporites spinosus*, *Knoxisporites ruhlandi, Punctatisporites subvaricosus* and *Tricidarisporites phippsae,* which are first recorded for South America and *Retusotriletes mirabilis,* and first recorded for Brazil, are age-diagnostic taxa of the middle to late Visean (Chart 1, supplementary online material) in addition to the three new spore species here erected (e.g., *Verrucosisporites iannuzzii, V. souzai, V. roncadorense*). Concerning plant fossils, *Kegelidium lamegoi* Dolianiti 1954 and *Diplothmema gothanica* (Dolianiti) Iannuzzi 2002 have been considered endemic forms of the Parnaíba Basin (Dolianiti, 1954; Iannuzzi and Pfefferkorn, 2002; Iannuzzi *et al.*, 2006), and now the presence of *Fedekutzia* cf. *F. argentina* confirms the first record of this genus in the Mississippian of northern South America. Iannuzzi *et al.,* (2003) related these floras to the late Visean - Serpukhovian *Nothorhacopteris kellaybelenesis - Triphyllopteris boliviana* Zone.

Sedimentological features throughout this section reflect brackish estuarine facies. The dominance of the algae *Botryococcus* with varied morphologies throughout the section, the plant remains found within its basal part and the presence of abundant organic matter (palynomorphs and phytoclasts), mainly within the mid- upper section, support the previous interpretation. The reworked palynomorphs from Devonian and Tournaisian rocks corroborate the unconformable contact between the Poti and its underlying Longá Formation (Melo and Loboziak, 2003).

Supplementary material

Chart 1: Stratigraphic and geographical distribution of palynomorphs recorded in the Poti Formation at Riacho do Roncador creek (Brazil). This information is freely available online at the web page of the journal http://www.igme.es/boletin/

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