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Acta Palaeobotanica 58(1): 3–26, 2018
DOI: 10.2478/acpa-2018-0002

e-ISSN 2082-0259
ISSN 0001-6594

The palynology of the Ordóñez Formation (Pennsylvanian) in the Chacoparaná Basin, northern Argentina

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Received 27 September 2017; accepted for publication 15 March 2018

ABSTRACT. A detailed palynological analysis of the Chacoparaná Basin is presented. Thirty-one samples were recovered from boreholes YCF.CO1, YCF.CO2 and YCF.CO3, corresponding to the lower part of the Ordóñez Formation, at the Santiago Temple locality (Córdoba Province, Argentina). Three new species are described: *Calamospora fissurata* sp. nov., *Retusotriletes archangelskyi* sp. nov. and *Horriditriletes chacoparanensis* sp. nov.; *Leiotriletes malanzanensis* nov. nom., *Endosporites menendezi* nov. nom., emend. are proposed to replace *L. tenuis* Azcuy and *E. parvus* Menéndez; and the following species are proposed as new combinations: *Brevitriletes coalescens* (Menéndez & Azcuy) nov. comb., *Brevitriletes papillatus* (Menéndez & Azcuy) nov. comb., *B. sparsus* (Menéndez & Azcuy) nov. comb., *B. delicatus* (Menéndez) nov. comb. and *Indotriradites malanzanensis* (Azcuy) nov. comb. Two different associations were identified and are compared with the known biozones from the same basin and other biostratigraphical schemes for basins from central western Argentina. The palynological assemblage can be referred, in part, to the *Potonieisporites–Lundbladispora* Biozone (Chacoparaná Basin) and the *Raistrickia densa–Convolutispora muriornata* Biozone (central western basins of Argentina, latest Serpukhovian–Bashkirian).

KEYWORDS: palynology, systematics, Chacoparaná Basin, Pennsylvanian, Argentina

INTRODUCTION

The Chacoparaná Basin (Argentina) is an intracratonic basin and a continuation of the Paraná Basin sedimentation that infilled primarily during the Late Palaeozoic (Fig. 1A). The sedimentary succession commences in the Ordovician and is present in parts of the sub-surface of Paraguay, Uruguay and Brazil (see Milani et al. 1998). The basin was developed in three main cycles: the first in the Cambrian–Ordovician, the second in the Silurian–Devonian, both marine, and finally the third in the Carboniferous–Permian, the latter mainly of continental origin (Reinante et al. 2014). The sediments constituting the sequence are known from different boreholes in the Santiago del Estero, Chaco, Córdoba and Santa Fe provinces (Fig. 1B).

Geological and palaeontological information obtained from different boreholes drilled during the 1940s by YPF (Yacimientos Petrolíferos Fiscales) and YCF (Yacimientos Carboníferos Fiscales) (Padula & Mingramm 1963, 1969, Russo et al. 1980, Reinante et al. 2014) indicate that the Upper Palaeozoic sediments of the Chacoparaná Basin consist mainly of diamictites, sandstones and shales, containing rich palynological assemblages (Archangelsky et al. 1980, Russo et al. 1987, Césari et al. 1995, Archangelsky & Vergel 1996, Vergel 1998, Winn & Steinmetz 1998, Playford & Dino 2002, Antonelli & Ottone 2006).

The Chacoparaná Basin is divided into the Alhuampa sub-basin in the north and the San Cristobal–Las Breñas Oriental sub-basin in the south (Fig. 1B). In the Alhuampa

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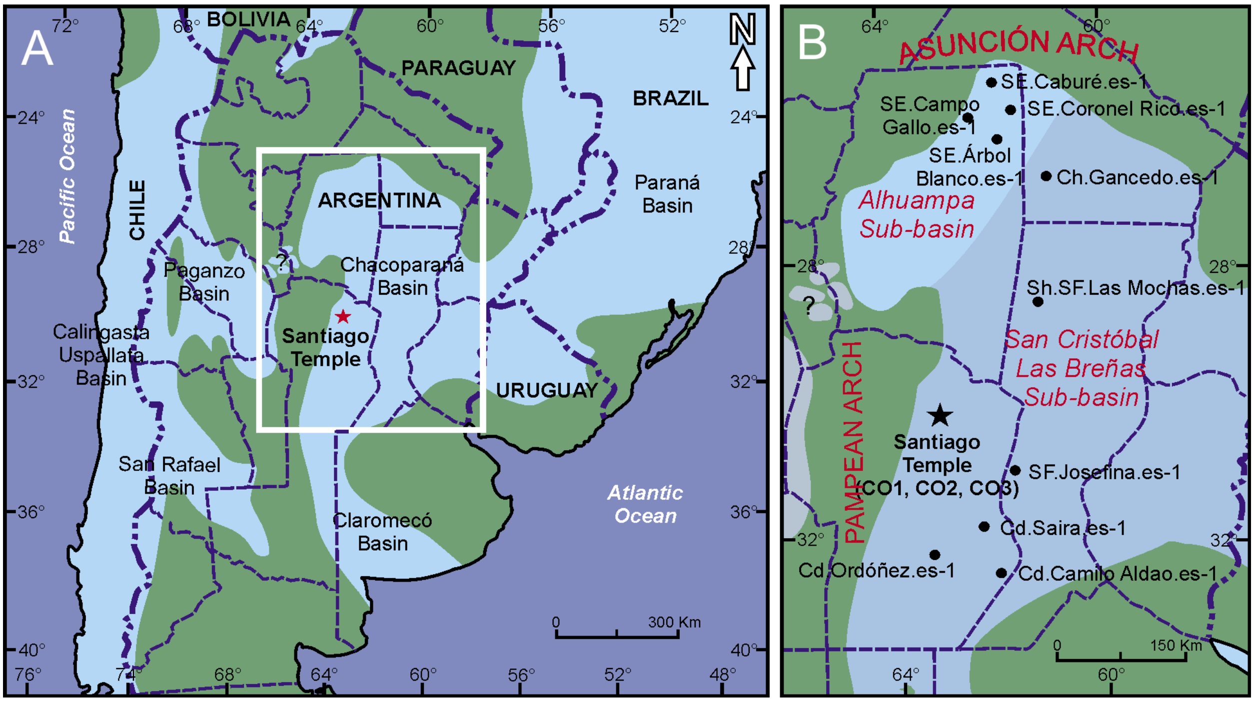

Fig. 1. **A**. Geographic location of South American Permian basins. **B**. Geographic location of the studied boreholes (Santiago Temple) and other boreholes cited in the text

sub-basin, palynomorphs recovered from the Upper Palaeozoic strata of the Árbol Blanco, Coronel Rico, Gancedo, Campo Gallo and El Caburé boreholes were published by Vergel (1987a, 1990a, b, 1993, 1998), Gutiérrez et al. (1997) and Antonelli & Ottone (2006).

Palynomorphs from the San Cristobal–Las Breñas Oriental sub-basin have been obtained from the Santiago Temple (YCF.CO1, YCF. CO2 and YCF.CO3), Ordóñez, Camilo Aldao, Saira, Josefina and Las Mochas boreholes, and these were referred to the Ordóñez and Victoriano Rodríguez formations (Archangelsky & Gamerro 1979, Archangelsky et al. 1980, Russo et al. 1980, Vergel 1986, 1987b, Césari et al. 1995, Winn & Steinmetz 1998, Playford & Dino 2002).

The boreholes from the Santiago Temple locality (31°23′40″S; 63°24′42″W, Córdoba Province) (Figs 1, 2) comprise Upper Palaeozoic strata. To date, the only palynological information from this area comes from a study by Archangelsky et al. (1980), who analysed one sample from each of the boreholes and identified a total of 26 species, tentatively correlating this assemblage with the *Potonieisporites–Lundbladispora* (PL) Biozone recognized in the Chacoparaná Basin by Russo et al. (1980) (Fig. 3). In this study we analysed 31 palynological samples from the Santiago Temple boreholes, and identified 219 forms consisting of palynomorphs and microforaminiferal species. We describe and illustrate only material that enables us to propose nomenclatural innovations (new species, new combinations, substitute names). Supplementary File 1[1] presents a commented list of all the palynological material included in this study, and illustrates only material not previously recorded in the Chacoparaná Basin.

The results make it clear that the assemblage presents a significantly more diverse microflora than originally thought, including the first record of foraminiferal linings in the Upper Palaeozoic of Argentina (Gutiérrez et al. 2016). Furthermore, the composition and distribution of this microflora allowed us to distinguish two associations (I, II).

GEOLOGICAL SETTING

The YCF.CO1, YCF.CO2 and YCF.CO3 boreholes were drilled in the Santiago Temple locality (Fig. 1B) at height of 150 metres OD (Ordnance Datum). Winn & Steinmetz (1998) stated that the strata 633.00 mbgl (metres below ground level) correspond to Tertiary–Cretaceous successions, overlying Upper Palaeozoic sediments referred to the Ordóñez Formation and

[1] Supplementary File 1 available on page http://www.botany.pl/images/ibwyd/acta_paleo/Acta_Palaeobot_58_1_Gutierrez-Balarino_Suppl_1.pdf

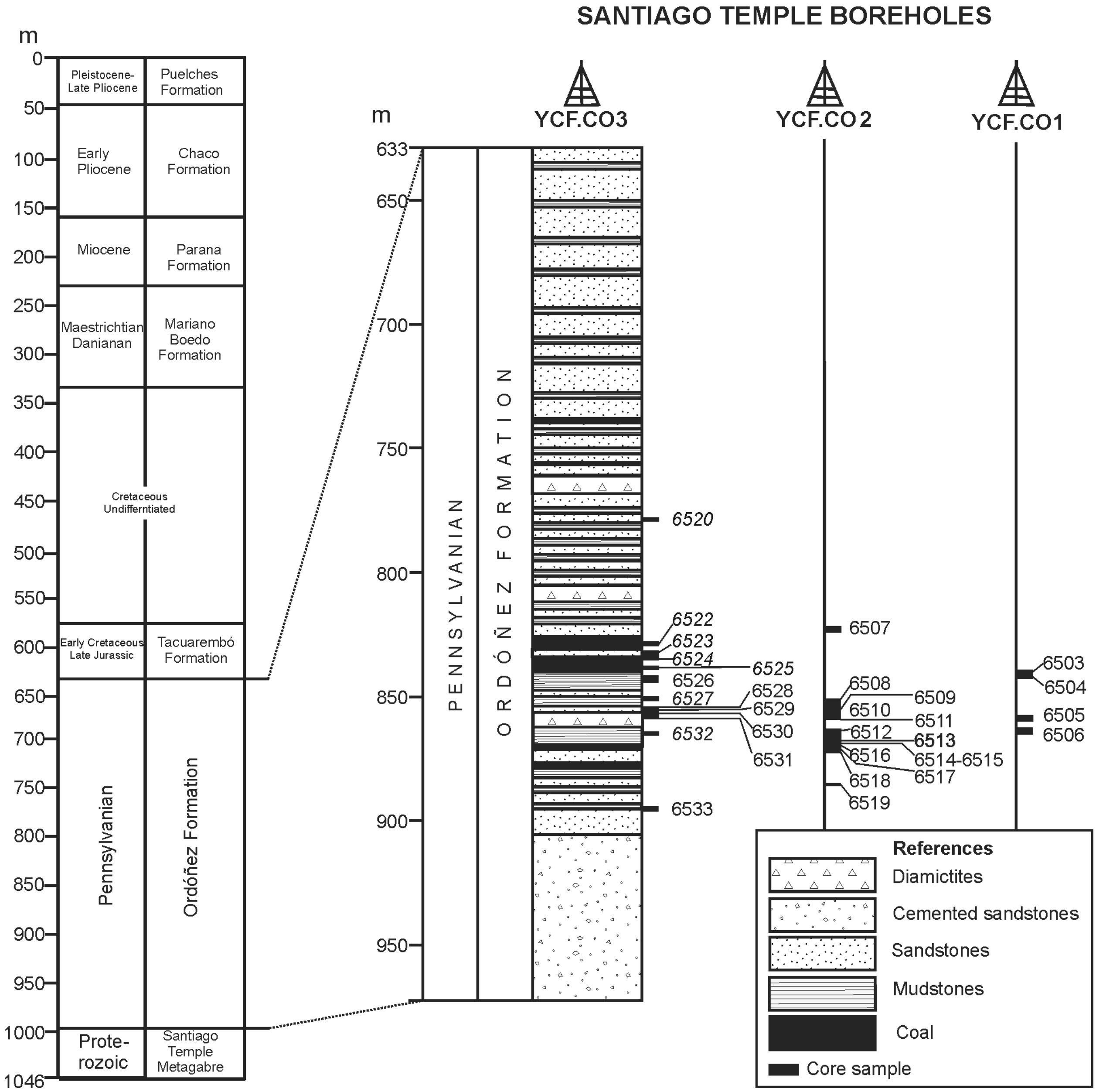

Fig. 2. Stratigraphic section in boreholes YCF.CO.1, YCF.CO2 and YCF.CO3, with studied samples (referring to BAPal acronym)

ranging from 633.00 to 990.00 mbgl. The upper section (633.00–955.00 mbgl interval) consists mainly of diamictites, sandstones, mudstones and thick coal beds, deposited in fluvial environments. The lower part (955.00–990.00 mbgl interval) is composed of extremely cemented, fine to coarse red and white micaceous sandstones. Lastly, from 990.00 to 1064.30 mbgl is crystalline basement assigned a Precambrian age (Winn & Steinmetz 1998).

In this study we analysed core samples from the 839.50–869.00 mbgl (CO1), 800.00–886.50 mbgl (CO2) and 738.00–896.75 mbgl (CO3) intervals (Fig. 2), which encompass the lower section of the Ordóñez Formation. The boreholes are very near to each other, and lithological changes were not detected between them at the same depths, so the same stratigraphic column is used in Figure 2.

MATERIAL AND METHODS

We processed the samples following the standard palynological treatment (physical disaggregation and chemical dissolution with HF and HCl; unoxidized residue then concentrated by filtration using 25 µm mesh and subsequently prepared as slides) for Palaeozoic sediments (Wood et al. 1996) at the Palaeopalynological Laboratory, Museo Argentino de Ciencias Naturales "B. Rivadavia" (MACN), Buenos Aires. Thirty-one samples were analysed for this study: 4 from the CO1 borehole, 13 from the CO2 borehole and 14 from the CO3 borehole (Tab. 1). Photographs were taken with

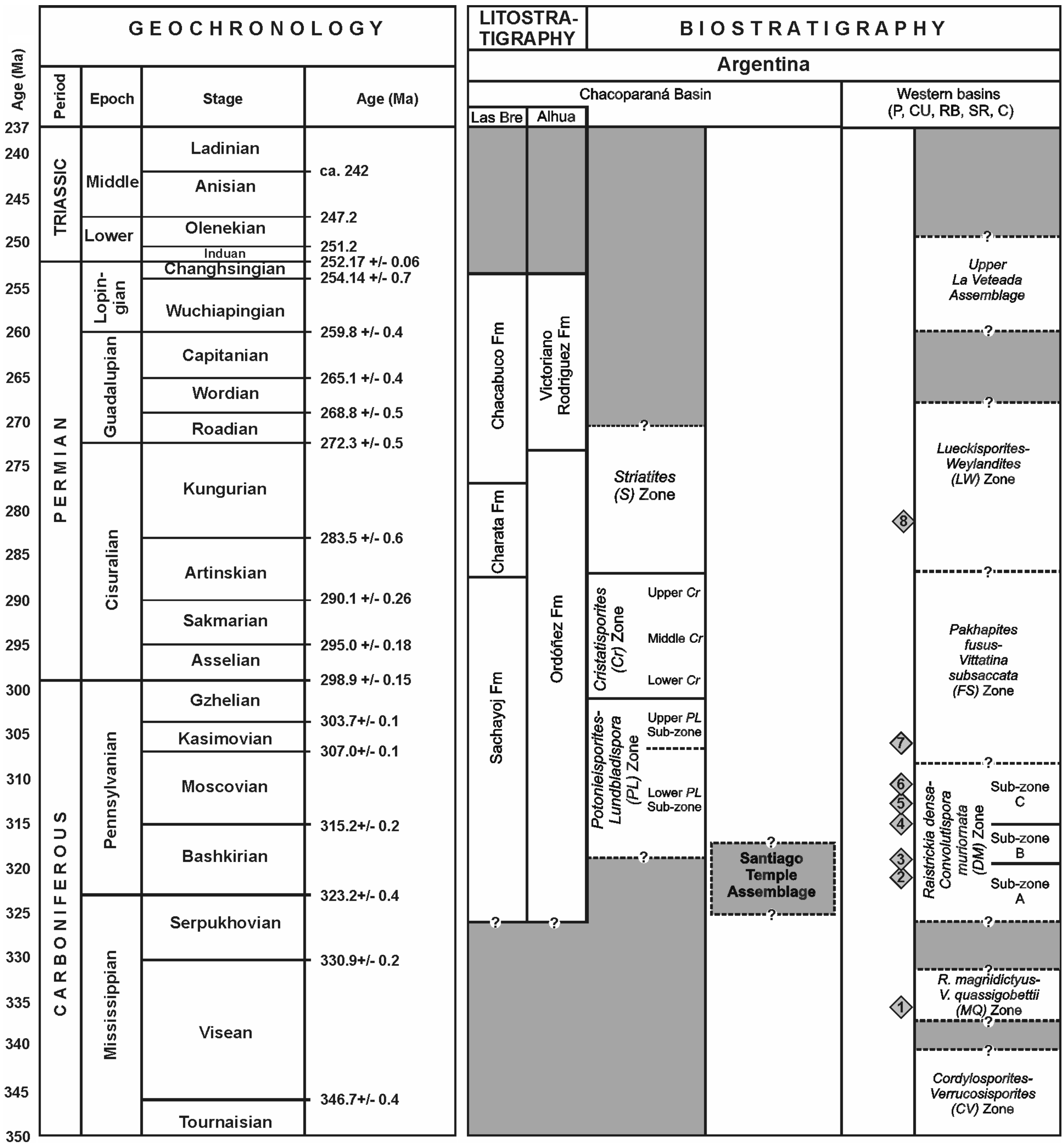

Fig. 3. Correlation of the Carboniferous-Permian palynostratigraphic units of the Chacoparaná Basin and western Argentina, according to the available radiometric data: **1**. Punta del Agua Formation, 335.99±0.06 Ma (Gulbranson et al. 2010); **2**. Jejenes Formations, 321.3±5.3 Ma (Valdez Buso et al. 2017); **3**. Lower section of the Río del Peñon Formation and Guandacol Formation, 319.57±0.09 and 318.79 0.10 Ma (Gulbranson et al. 2010); **4**. Tupe Formation, 315.46±0.07 Ma (Gulbranson et al. 2010); **5**. Tupe Formation, 312.82±0.11 Ma; **6**. Patquía Formation, 310.71±0.11, 309.89±0.08 Ma; middle Rio del Peñón Formation, 310.63±0.07 Ma (Gulbranson et al. 2010); **7**. Agua del Jagüel Formation, 307.2±5.2 Ma (Lech 2002). **8**. La Colina Formation, 295±6 Ma (Thompson & Mitchell 1972); Abbreviations: Las Bre (San Cristobal-Las Breñas Oriental sub-basin), Alhua (Alhuampa sub-basin). Selected references. Western basins (Césari & Gutiérrez 2001, Césari 2007, Pérez Loinzae 2007, Césari et al. 2011)

a Nikon DS-Fil digital camera (5 mpx resolution) fitted to a Nikon Eclipse 50i optical light microscope at the Palaeopalynological Laboratory, MACN. All illustrated palynomorphs are located with *England Finder* coordinates. The permanent repository of the samples is the Palaeopalynological Slide Collection of the aforementioned institution (numbers 6503 to 6533 BAPal). The BAPal 6531 residue was observed and photographed with a Phillips XL 30 TMP scanning electron microscope (SEM) at MACN.

Size measurements are presented as minimum (mean) maximum values. ED/id ratio refers to the Exoexine Diameter (ED)/intexine diameter (id) ratio. The relative abundance of palynomorph species identified in the present study is based on counts of 250 specimens per sample.

Table 1. Fertile samples used in this study from the Santiago Temple boreholes (YCF.CO1, CO2, CO3)

BAPal	mbgl
YCF.CO1	
6503	839.50–842.00
6504	842.00–843.25
6505	858.00–860.00
6506	862.00–864.00
YCF.CO2	
6507	823.00–826.00
6508	851.25–854.00
6509	854.00–855.50
6510	855.50–857.00
6511	857.00–859.00
6512	862.00–865.00
6513	865.00–866.00
6514	866.00–867.00
6515	867.00–870.00
6516	870.00–871.00
6517	871.00–871.75
6518	872.50–873.50
6519	885.00–886.25
YCF.CO3	
6520	778.50–779.25
6521	815.00–817.50
6522	827.50–829.25
6523	833.00–834.00
6524	834.25–836.00
6525	838.00–839.00
6526	842.00–844.00
6527	850.00–851.50
6528	853.50–856.00
6529	856.00–857.50
6530	857.50–859.00
6531	859.00
6532	865.00–866.50
6533	895.00–896.75

SYSTEMATIC PALAEONTOLOGY

TAXONOMIC INVENTORY

A total of 214 palynomorph species and 3 microforaminiferal species were identified (Supplementary File 1). The suprageneric classification of spores and pollen grains follows the criteria of Potonié & Kremp (1954) and subsequent modifications (Playford & Dettmann 1996). Reworked elements were identified on the basis of their poor state of preservation and their anomalous stratigraphic positions (see Gutiérrez et al. 1997, 2015).

SYSTEMATIC DESCRIPTIONS

Anteturma: PROXIMEGERMINANTES

Turma: TRILETES

Suprasubturma: ACAVATRILETES

Subturma: AZONOTRILETES

Infraturma: LAEVIGATI

Genus: ***Calamospora***
Schopf, Wilson & Bentall 1944

Type species: *Calamospora hartungiana* Schopf in Schopf, Wilson & Bentall 1944 [OD]

Calamospora fissurata sp. nov.

Pl. 1, figs 1–5, 8–11; Fig. 4

Paratypes. BAPal 6524(6) U43/2 (Pl. 1, fig. 1), BAPal 6522 (5) L53/3 (Pl. 1, fig. 2), BAPal 6522(4) C48/2 (Pl. 1, fig. 5), BAPal 6520(3) E33/1 (Pl. 1, fig. 8), BAPal 6527(10) O33/1 (Pl. 1, fig. 9).

Type strata. Ordóñez Formation, Chacoparaná Basin, Argentina.

Type locality. Santiago Temple, YCF.CO3, 778.50–779.25 mbgl, Córdoba Province, Argentina.

Derivatio nominis. The name refers to the subequatorial-distal “fissure” (schism) exhibited on the exine (located on the distal face at a subequatorial site), a diagnostic characteristic of the species.

Diagnosis. Spherical trilete spore; variable amb with circumpolar exinal folds. Laesurae distinct, simple, Y-arms ½ to ¾ of spore radius. Exine 1–1.5 µm thick, scabrate, with subequatorial-distal fissure (= schism) in polar view. The exinal break varies in degree, dividing the spore into two asymmetrical parts. The break line usually appears associated with conspicuous longitudinal folds.

Description. Spherical trilete spore; variable amb with numerous exinal folds (Pl. 1, figs 1, 3–5). Laesurae distinct, simple, with short branches (no bigger than ¾ of spore

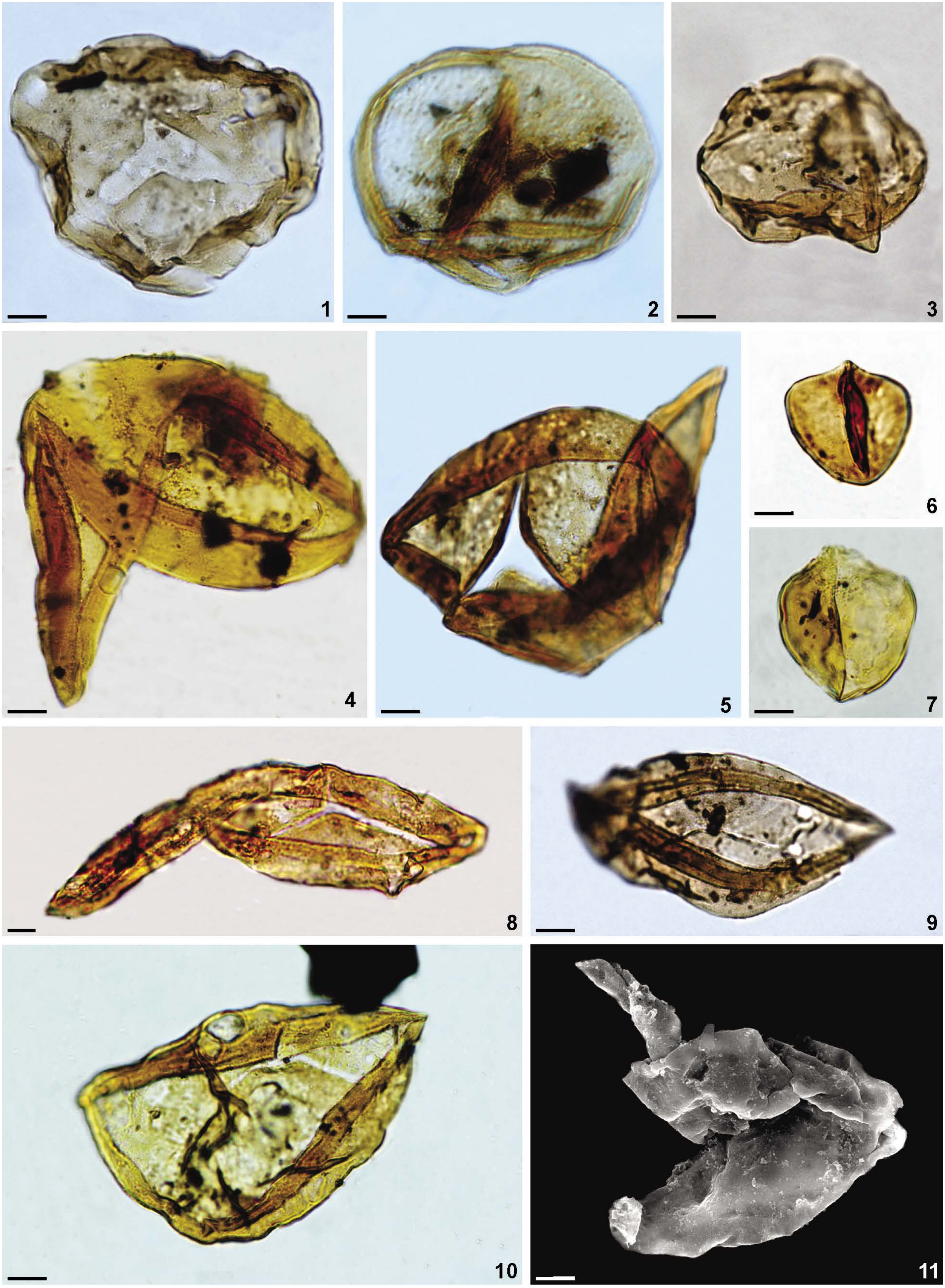

Plate 1. **1–5**, **8–11**. *Calamospora fissurata* sp. nov.; **1**. BAPal 6524(6) U43/2, paratype; **2**. BAPal 6522(5) L53/3, paratype; **3**. BAPal 6531(7) D42/4; **4**. BAPal 6509(1) S38/4; **5**. BAPal 6522(4) C48/2, paratype; **8**. BAPal 6520(3) E33/1, paratype; **9**. BAPal BAPal 6527(10) O33/1, paratype; **10**. BAPal 6516(5) G34/0; **11**. BAPal 6531 T03 f120, SEM. **6**, **7**. *Leiotriletes malanzanensis* nov. nom.; **6**. BAPal 6522(10) B37/0; **7**. BAPal 6512(9) P32/4. Scale bar = 10 µm

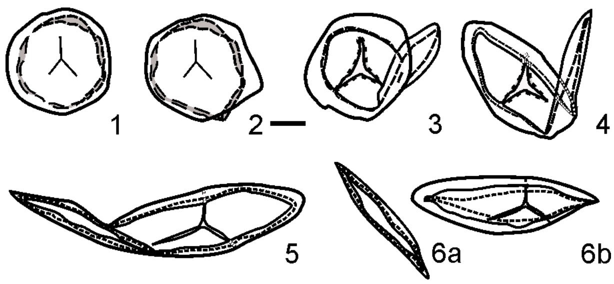

Fig. 4. *Calamospora fissurata* sp. nov. Diagram illustrating the mode of schism of the spore. The spore begins with the complete spore with the line of weakness on the sub-equatorial sector of the distal face (**1**); the exine begins to break at this site of weakness and initiates the division of the spore into two asymmetric parts (**2, 3, 4, 5**) until separated into two parts, the major part corresponding to the proximal face (**6a**) and the smaller part (**6b**) corresponding to the major part of the distal face. Scale bar = 20 μm

radius). Exine thin, scabrate, with circumpolar folds. Subequatorial line of weakness on distal face, which divides spores into two parts (see Figs 4.3–4.5), the larger being the proximal part (Pl. I, figs 4, 5, 8; Fig. 4.6b).

Discussion. The mode of exinal rupture is similar to that in the genus *Brazilea*; nevertheless, the laesurae show that it is a spore and can be referred to the genus *Calamospora*. This unique feature allows *C. fissurata* sp. nov. to be separated from the other species of *Calamospora*.

Dimensions (140 specimens). Equatorial diameter 60 (75–95) 105 μm.

Genus: ***Leiotriletes***
Naumova 1939 *ex* Ishchenko 1952
emend. R. Potonié & Kremp 1954

Type species: *Leiotriletes sphaerotriangulus* (Loose 1932) R. Potonié & Kremp 1955 [SD; Potonié & Kremp 1954, p. 120]

Leiotriletes malanzanensis nov. nom.

Pl. 1, figs 6, 7; Pl. 2, figs 1–4

Synonymy.

1975a *Leiotriletes tenuis* Azcuy, p. 14, plate I, figs 1–5.

Holotype. Azcuy (1975a, plate I, fig. 2).

Paratype. Azcuy (1975a, plate I, fig. 3).

Type strata. Malanzán Formation (Estratos Carbonosos Member), Paganzo Basin, Argentina.

Type locality. Comarca Malanzán-Loma Larga, La Rioja Argentina.

Derivatio nominis. Refers to place of origin.

Diagnosis (from Azcuy 1975a, p. 14). "Spore radial trilete, smooth margin and triangular shape. Interradial straight edges and rounded corners. Laesurae simple and straight whose rays have a length of about ⅚ the radius of the spore, ⅘ polar equatorial axis. Exine thickness not measurable, but very faint and thin (less than 1 μm). Membrane surface laevigate."

Remarks. The *tenuis* epithet was previously used by Azcuy (1975a) to name *Leiotriletes* species reported by several authors (Bolkhovitina 1953: Aptian of Azerbaijan SSR; Bhardawaj & Singh 1964: Upper Triassic of Austria). They include laevigate trilete spores with a triangular–subtriangular amb of various ages and strata (i.e. Jurassic–Palaeocene of Russia–Ukraine; Upper Permian–Lower Cretaceous of China; Mid Triassic–Lower Cretaceous of Romania and Azerbaijan; Upper Triassic of Austria; Mid Triassic of Germany, France and Italy; Permian of Czech Republic and India; see White 2006). We consider Azcuy's (1975a) name to be invalid because it has been used previously; therefore, we propose replacement of the latter with *Leiotriletes malanzanensis* nom. nov.

Infraturma: RETUSOTRILETI

Genus: ***Retusotriletes*** Naumova 1953
emend. Streel 1964

Type species: *Retusotriletes simplex* Naumova 1953 [SD; R. Potonié, 1958, p. 13].

Retusotriletes archangelskyi nov. sp.

Pl. 2, figs 5–8

Holotype. BAPal 6530(4) V40/0 (Pl. 2, fig. 5).

Paratypes. BAPal 6524(12) O29/0 (Pl. 2, fig. 6); BAPal 6518(5) C35/4 (Pl. 2, fig. 7).

Type strata. Ordóñez Formation, Chacoparaná Basin, Argentina.

Type locality. Santiago Temple, YCF.CO3, 857.50–859.00 mbgl, Córdoba Province, Argentina.

Derivatio nominis. In honour of Dr. Sergio Archangelsky, Argentinian palaeobotanist and palynologist.

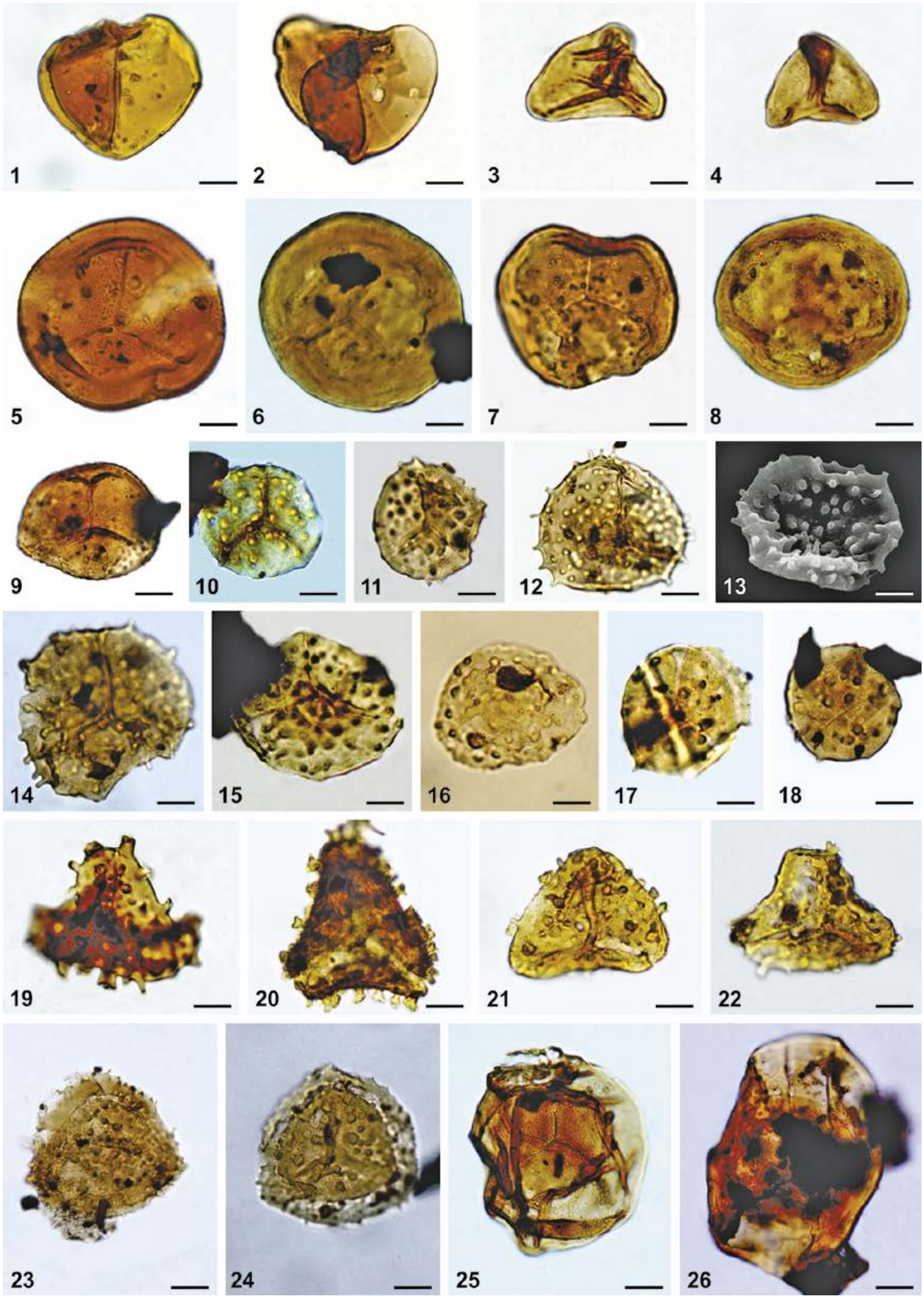

Plate. 2. **1–4**. *Leiotriletes malanzanensis* nov. nom.; **1**. BAPal 6511(8) Z49/0; **2**. BAPal 6527(7) X50/1; **3**. BAPal 6522(10) S25/3; **4**. BAPal 6522(12) F45/1; **5–8**. *Retusotriletes archangelskyi* nov. sp.; **5**. BAPal 6530(4) V40/0, holotype; **6**. BAPal 6524(12a) O29/0, paratype; **7**. BAPal 6518(5) C35/4, paratype; **8**. BAPal 6531(3) S45/4; **9**. *Apiculiretusispora ralla* (Menéndez & Azcuy 1969) Menéndez & Azcuy 1971 emend., BAPal 6530(2) G46/0; **10**, **11**. *Brevitriletes coalescens* (Menéndez & Azcuy 1973) nov. comb.; **10**. BAPal 6522(5) G26/0; **11**. BAPal 6531(3) M52/0; **12–14**. *Brevitriletes delicatus* (Menéndez 1965) nov. comb.; **12**. BAPal 6522(2) W56/0; **13**. BAPal 6531 T2 f 129, SEM; **14**. BAPal 6527(7) Q58/1; **15**, **16**. *Brevitriletes papillatus* (Menéndez & Azcuy 1971) nov. comb.; **15**. BAPal 6522(10) T23/4; **16**. BAPal 6523(3) V49/3; **17**, **18**. *Brevitriletes sparsus* (Menéndez & Azcuy 1971) nov. comb.; **17**. BAPal 6520(3) J41/0; **18**. BAPal 6529(10) S39/0; **19–22**. *Horriditriletes chacoparanensis* sp. nov.; **19**. BAPal 6522(13) X36/4, paratype; **20**. BAPal 6522(6) H51/3, holotype; **21**. BAPal 1062(3) T38/0; **22**. BAPal 6524(3) E30/0, paratype; **23**, **24**. *Indotriradites malanzanensis* (Azcuy 1975b) nov. comb.; **23**. BAPal 6527(3) Y34/3; **24**. BAPal 6529(4) S46/0.; **25**, **26**. *Endosporites menendezi* nov. nom., emend.; **25**. BAPal 6522(4) K56/2; **26**. BAPal 6532(2) F40/1. Scale bar = 10 μm

Diagnosis. Spore radial trilete; subcircular amb. Laesurae simple, length from ¾ to equator; straight. Curvaturae perfectae–imperfectae. Exine 1–2 µm thick, scabrate to infrapunctate, laevigate, thinner in contact areas. Contact area usually concave and depressed, forming thickenings at the junctions of the laesurae and the small curvaturae ridges.

Dimensions (99 specimens). Equatorial diameter 45 (56) 80 µm.

Remarks. *Retusotriletes archangelskyi* nov. sp. is distinguishable from the other species of this genus by the presence of simple laesurae, the dimensions (45–80 µm), the medium-thin exine and the relatively large contact area (ratio range ¾–1), and the slight thickening of the exine at the junctions of the laesurae and small ridges in the curvaturae.

Genus: ***Apiculiretusispora***
Streel 1964 emend. Streel 1967

Type species: *Apiculiretusispora brandtii*
Streel 1964 [OD]

Apiculiretusispora ralla (Menéndez & Azcuy 1969) Menéndez & Azcuy 1971 emend.

Pl. 2, fig. 9

Synonymy.

1969 *Anapiculatisporites? rallus* Menéndez & Azcuy, p. 88, plate II, figs J–N.

2010 *Brevitriletes levis* (Balme & Hennelly) Bharadwaj & Srivastava, Souza et al., plate 1, fig. 3.

Holotype. Menéndez & Azcuy (1969, plate II, fig. J–K).

Type strata. Lagares Formation, Paganzo Basin, Argentina.

Type locality. Paganzo, La Rioja Argentina.

Emended diagnosis. Spore radial, trilete. Amb circular or subcircular. Laesurae distinct, with rays extending to equatorial margin of spore. Imperfectly defined curvaturae. Exine smooth to microgranular on proximal face; distal face covered predominantly by pointed and blunt cones, scattered.

Dimensions (38 specimens). Equatorial diameter 28 (36.2) 48 µm; exine 1.5–1.7 µm thick; coni (in plan) 1 (1.5) 2 µm and height of 1.2–2 µm; coni separated to 1 and 1.5 of its basal diameter distance.

Remarks. The ornamentation is composed mainly of coni (sharp and blunt) which are widely spaced, features that allow separation of *Apiculiretusispora ralla* (Menéndez & Azcuy) Menéndez & Azcuy 1971 emend. from other species of the genus.

Comparison. *Retusotriletes baculiferus* Ybert (1975, p. 1, Ph. 22, 23) is similar to *Apiculiretusispora ralla*, although the sculpture includes bacula and larger elements (3–4 µm high). Revision of the type material will determine the degree of similarity between the two species.

Infraturma: APICULATI

Subinfraturma: BACULATI

Genus: ***Horriditriletes***
Bharadwaj & Salujha 1964

Type species: *Horriditriletes curvibaculosus*
Bharadwaj & Salujha 1964 [OD]

Horriditriletes chacoparanensis sp. nov.

Pl. 2, figs 19–22

1977 *Neoraistrickia baculicapillosa pars*. Pons, p. 120, plate II, fig. 14.

1980 *Neoraistrickia* sp. cf. *N. baculicapillosa* Pons; Azcuy & Jelin, plate II, fig. 13 [no description].

Holotype. BAPal 6522(13) X36/4 (Pl. 2, fig. 20).

Paratypes. BAPal 6522(6) H51/3 (Pl. 2, fig. 19), BAPal 6524(3) E30/0 (Pl. 2, fig. 22).

Type strata. Ordóñez Formation, Chacoparaná Basin, Argentina.

Type locality. Santiago Temple, YCF.CO3, 827.50–829.25 mbgl, Córdoba Province, Argentina.

Derivatio nominis. Refers to the place of origin.

Diagnosis. Spore radial, trilete. Amb triangular, concave side. Laesurae simple, may extend almost to equator. Exine 1.2 µm thick, sculptured with bacula (5 µm high; 1.2–3.5 µm basal width; ≤4 µm apical width) together with minor sharp and blunt coni and pila (≤3 µm basal width; 3.5 µm high). In the same specimen the bacula may have different types of apices (rounded, straight, blunt, acuminate, irregular lacerated and digitate).

Observations. Sculpture density is variable (12–40 projected elements around the equator). Among the bacula, those exhibiting digitate apices appear in varying numbers (few elements to ⅔ of total sculptural elements).

Dimensions (15 specimens). Equatorial diameter 42–47 µm. Bacula: 2 (3.5) 5 µm high; 1.2 (2.3) 3.5 µm basal width; 1.8 (2.8) 4 µm apical width. Coni and pila, 1.7–3 µm basal width, 2–3.5 µm height.

Comparison. Its sculpture distinguishes *Horriditriletes chacoparanensis* sp. nov. from all other species in this genus. *Raistrickia cephalata* Bharadwaj et al. 1976 shows the same sculptural elements but the amb is circular. Some specimens from the Itararé Subgroup (Paraná Basin, Brazil) referred to *Neoraistrickia baculicapillosa* Pons (1977, p. 120, plate II, figs 14–16) are comparable to *H. chacoparanensis* sp. nov. In particular, plate II, figure 14 from Pons (1977) exhibits bacula with a digitate apex, although the ornamentation of *N. baculicapillosa* is described as consisting of bacula (smooth apices), spines and capilli. A revision of the Brazilian specimens would be necessary to make a fuller comparison with the material from Santiago Temple.

Neoraistrickia sp. cf. *N. baculicapillosa* Pons in Azcuy & Jelín (1980, plate II, fig. 13) from "Estratos de Mascasín" could be referred to *H. chacoparanensis* sp. nov. because of the variable nature of the bacula.

Subinfraturma: NODATI

Genus: ***Brevitriletes***
Bharadwaj & Srivastava 1969

Type species: *Brevitriletes communis* Bharadwaj & Srivastava 1969 [OD]

Remarks. We agree with Stephenson's criteria (2004, p. 5) which maintain that *Brevitriletes* includes retusoid and anisopolar spores with a circular amb and various distal apiculate ornamentations, usually larger than 2 µm in size.

Brevitriletes coalescens
(Menéndez & Azcuy 1973) nov. comb.
Pl. 2, figs 10, 11

Basionym. *Apiculiretusispora coalescens* Menéndez & Azcuy 1973, p. 53, plate I, figs 1, 2.

Holotype. Menéndez & Azcuy (1973, plate I, fig. 1).

Description. Spore radial trilete, subcircular; laesurae sinuous and extending to equator, lips briefly developed, 2–4 µm thick. Exine 1.2–1.5 µm thick. Papillae, coni and verrucae on distal exine, arranged irregularly. Central area shows higher concentration of sculptural elements, where they fuse in pairs.

Dimensions (14 specimens). Total diameter 30 (36.3) 45 µm; papillae 1.5 (2.7) 4 × 1.5 (2.2) 3.5 µm diameter, 1.5 (2) 3.5 µm high.

Remarks. The low and wide lips, and the alignment and fusion of the sculptural elements enable separation of this species. We consider that *Brevitriletes* Bharadwaj & Srivastava is the correct generic allocation, based on its retusoid nature and elements of the ornamentation, and in being generally greater than 2 µm in size.

Brevitriletes delicatus (Menéndez 1965)
nov. comb., emend.
Pl. 2, figs 12–14

Basionym. *Apiculatisporis delictaus* Menéndez 1965, p. 54, lám. II, fig. 4.

Synonymy.

1979 *Apicuiretusispora riojana* Menéndez & González Amicón, p. 69, 71, plate I, fig. 6; plate II, fig. 1.

1985 *Apiculirestispora tuberculata* Azcuy; Césari & Gutiérrez, p. 23, 24, plate III, fig. 6.

Holotype. BA-Pal 17(10) E33/4 (Menéndez 1965, plate II, fig. 4; Menéndez & González Amicón 1979, plate I, fig. 6).

Lectotype. BA-Pal 17(2) C33/3 (Menéndez & González Amicón 1979, plate II, fig. 1) (designated here).

Type strata. Agua Colorada Formation,

Age. Pennsylvanian.

Type locality. Río Tambillos, Sierra de Famatina, La Rioja Province.

Emended diagnosis. Spore radial, trilete, anisopolar; subcircular to subtriangular amb, irregular margin due to sculpture projection. Laesurae may extend almost to equator, resolved in imperfect curvaturae. Exine ≤1 µm thick. Ornamentation is on distal face and equator, and includes predominantly ribbon-like bacula with a wide base and blunt or occasionally acuminate apex. All sculptural elements 1.5–3 µm in basal diameter and 2–5 µm in height, distributed unevenly across distal face and equator, but tighter in polar area. Proximal surface smooth to scabrate.

Dimensions (35 specimens). Total diameter 30 (37.6) 45 µm; papillae 1.5–3 µm basal diameter, 2–5 µm high.

Observations. In specimens examined by SEM (Pl. 2, fig. 13) it was observed that the ornamental elements of *Brevitriletes delicatus* (ribbon-like bacula) projecting towards the contour are generally bent or broken at their ends, while the specimens observed by LM appear folded at their apices and therefore can be interpreted as bacula, coni and/or pila.

Discussion. In work on the palynological content of the Agua Colorada Formation (La Rioja Province), Menéndez (1965, p. 54, plate II, fig. 4) proposed the species *Apiculatisporis delicatus* to include ornate spores "with sharp spines arranged irregularly and sometimes truncated projections" without specifically describing how the elements of the ornamentation are distributed (on the whole surface of the spore or only on its distal face). In a complementary study of the same material, Menéndez & González Amicón (1979, p. 69, plate I, fig. 6; plate, fig. 7) proposed *Apiculiretusispora riojana* to include anisopolar spores that have imperfect curvaturae, and the distal face and equator ornamented by a large number of "tapered blades, truncated and rounded apex cones, and to a lesser extent papillae, cones and some spines" (whose dimensions range from 1.3 to 3 µm in basal diameter and 2 to 4.6 µm in height), irregularly distributed.

Observation of the holotype of *A. delicatus* (Menéndez 1965, plate II, fig. 4; BAPal 17(10) E33/4) has allowed us to propose that the type specimen as nominated by Menéndez and González Amicón (1979, p. 69, plate I, fig. 6) is the holotype of the new species *Apiculiretusispora riojana*. Therefore we understand that the latter name is invalid according to the CNI (McNeill et al. 2012). Moreover, it has been observed that the ornamentation of the type material is dominated by ribbon-like bacula with wide bases, arranged on the distal face of the spore and equator, as described by Menéndez & González Amicón (1979). Given the distribution of the sculpture, the element dimensions and the presence of curvaturae imperfectae defining the contact areas (smooth to micro-granulate), we propose to include this species in the genus *Brevitriletes*.

Comparisons. The specimens from the Lagares Formation, referred to *Apiculiretusispora tuberculata* Azcuy by Césari & Gutiérrez (1985, p. 23, 24, plate III, fig. 6) should be included in *Brevitriletes delicatus* (Menéndez) nov. comb., owing to the type and size of the sculpture. *Brevitriletes irregularis* (Nahuys, Alpern & Ybert) Césari, Archangelsky & Seoane (1995, p. 78, plate I, fig. 5) is very similar to *B. delicatus* (Menéndez) nov. comb., although the former exhibits thin and tall lips.

Brevitriletes papillatus
(Menéndez & Azcuy 1971) nov. comb.

Pl. 2, figs 15, 16

Basionym. *Apiculiretusispora papillata* Menéndez & Azcuy 1971: 26–28, 1, plate I, fig. 1.

Synonymy.

1980 *Apiculatisporis* sp. Archangelsky, Gamerro & Leguizamón, plate 1, fig. 3. [no description]

Holotype. Menéndez & Azcuy (1971, plate I, fig. 1).

Dimensions (24 specimens). Total diameter 25 (36.1) 50 µm; papillae 1.5 (2.4) 4 × 1.2 (2.0) 3.5 µm diameter; lateral-view papillae 1.5 (2.5) 4 µm basal diameter, 1.5 (2.0) 2.5 µm high.

Remarks. *Brevitriletes papillatus* shows papillae partially fused in a group over the central area of the distal face, with small acuminate coni (papillae) and simple laesurae (Menéndez & Azcuy 1971). *Apiculatisporis* sp. illustrated by Archangelsky et al. (1980, plate 1, fig. 3) shows simple laesurae and similar sculptural elements (isolated or fused papillae).

Brevitriletes sparsus
(Menéndez & Azcuy 1971) nov. comb.

Pl. 2, figs 17, 18

Basionym. *Apiculiretusispora sparsa* Menéndez & Azcuy 1971, p. 28, plate I, figs 2–6.

Synonymy.

1990b *Apiculiretusispora sparsa*, *pars.* Menéndez & Azcuy; Vergel, p. 56, 57.

1998 *Apiculiretusispora sparsa*, *pars.* Menéndez & Azcuy; Vergel, p. 392.

Holotype. Menéndez & Azcuy (1971, plate I, fig. 2).

Dimensions (7 specimens). Total diameter 28–35 µm; exine 1.5–2 µm thick. Papillae 1.8 (2.6) 3.5 × 1.5 (2.3) 3 µm diameter.

Remarks. This species has a laevigate proximal face and a sculptured distal face with discrete mammillae and grana irregularly distributed, not projecting equatorially. Laesurae are simple. Because of its retusoidal nature, anisopolar character and the dimensions of the ornamentation elements, generally being greater than 2 µm, we locate this species within the genus *Brevitriletes* Bharadwaj & Srivastava.

At least some specimens assigned to *Apiculiretusispora sparsa* Menéndez & Azcuy (1971) by Vergel (1990b, p. 56–57, plate II, fig. 4; 1998, p. 392, plate I, fig. 7: Campo Gallo, Árbol Blanco and Gancedo boreholes) should be placed in *Brevitriletes leptoacaina* Jones & Truswell 1992. This ornamentation consists of thin spinae with wide bases, spaced apart.

Genus: ***Anulatisporites***
Potonié & Kremp 1954

Type species: *Anulatisporites annulatus* (Loose) Potonié & Kremp 1954
[SD, Potonié 1958, p. 64]

Anulatisporites famatinensis
Menéndez 1965, emend.
Pl. 3, figs 1–9

Holotype. Menéndez (1965, plate IV, fig. 2).

Lectotypes. BAPal 17(2) T38/0, BAPal 17(3) P39/0 (designated here).

Type strata. Agua Colorada Formation, Pennsylvanian.

Age. Pennsylvanian.

Type locality. Río Tambillos, Sierra de Famatina, La Rioja Province.

Emended diagnosis. Trilete microspore, spherical, round, oval to subtriangular in outline. Cingulum smooth, variable and irregular width, usually with irregular internal margin and associated with circumpolar exinal folds. Trilete mark simple, straight, of variable length, reaching equatorial margin in some specimens. Central area generally with eximal thickenings in apex that can reach ¾ of spore radius. Central area finely punctate, sometimes with some granulations; central area isolated, irregularly arranged.

Dimensions (90 specimens). Total diameter 44 (67.4) 100 × 40 (60) 85 µm. Cingulum 2 (7) 16 µm wide. Ratio cingulum: radio spore 1/3 (1/5) 1/10.

Remarks. In revising the original material, we observed that the cingulum is of variable width and has an irregular inner edge and associated exinal folds. The slide with the type specimens BAPal 17(1) (see Menéndez 1965, p. 65, plate IV, figs 1, 2) was preserved but the holotype was destroyed. We observed and measured several other specimens on different slides, allowing us to choose new type material (lectotype). Some specimens show small exinal corpuscles attached to the wall, concentrated at the poles. The same has been observed in the Santiago Temple material (see Pl. 3, figs 4, 5, 7).

Over 75% of the specimens from Santiago Temple included in this species present an exinal thickening over the centre of the central area (Pl. 3, figs 1, 2, 4). In the specimens without an exinal thickening, a cingulum with an irregular inner edge and associated secondary folds is observed (Pl. 3, figs 1, 3, 5, 6).

Suprasubturma: LAMINATITRILETES

Subturma: ZONOLAMINATITRILETES

Infraturma: CINGULICAVATI

Genus: ***Indotriradites***
Tiwari 1964 emend. Foster 1979

Type species: *Indotriradites korbaensis* Tiwari 1964 [OD]

Comments. We accept the criteria of Scheuring (1974), Foster (1979), Playford (1991), Higgs (1996) and other authors, differentiating *Kraeuselisporites* (which includes only acavate spores) from *Indotriradites* (cavate spores).

Indotriradites malanzanensis
(Azcuy 1975b) nov. comb.
Pl. 2, figs 23, 24

Basionym. *Kraeuselisporites malanzanensis* Azcuy 1975b, p. 128, 130, plate XXII, figs 144, 145; plate XXIII, figs 149, 150.

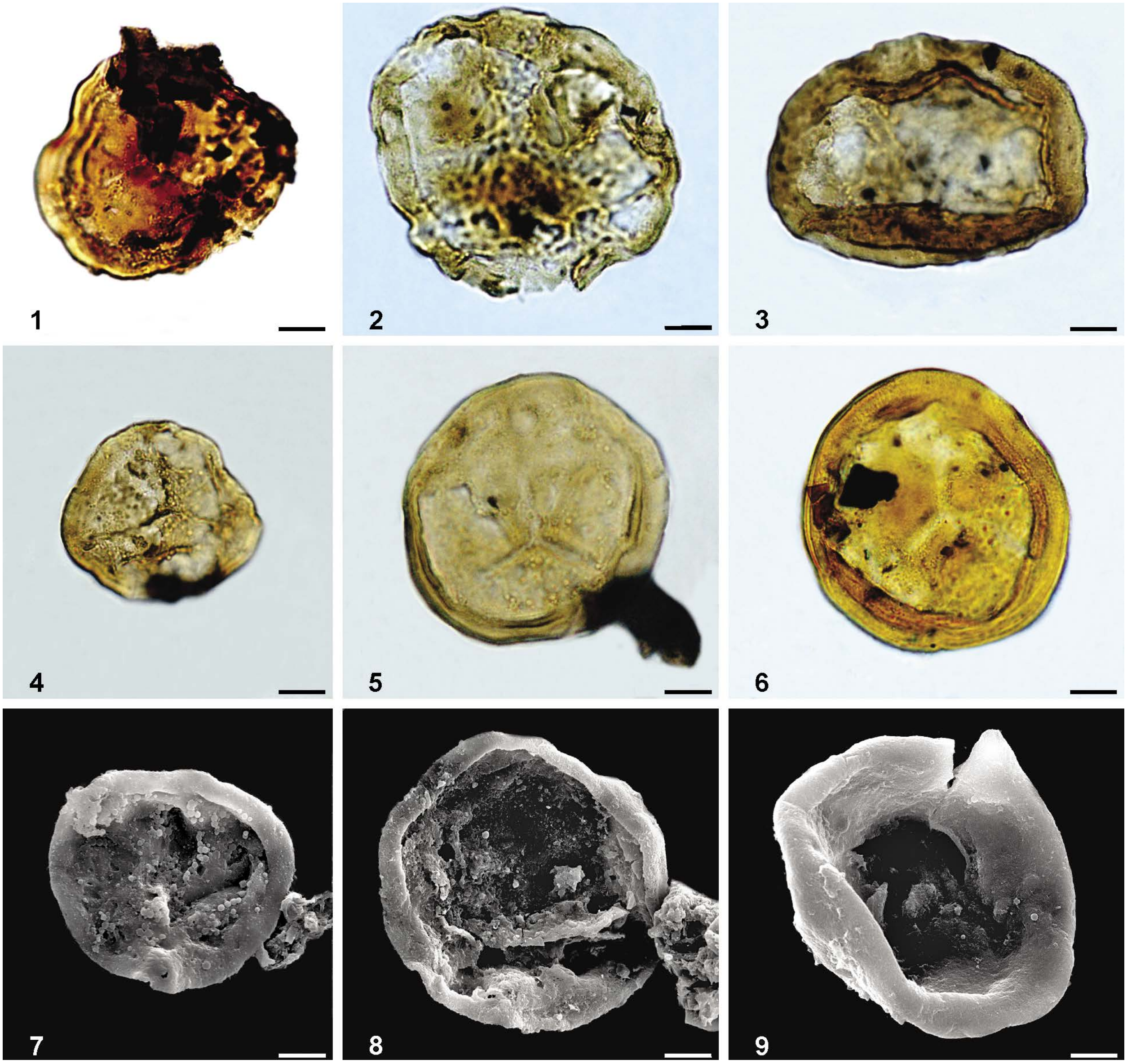

Plate 3. **1–9**. *Anulatisporites famatinensis* Menéndez 1965, emend. **1**. BAPal 6531(1) Z57/1; **2**. BAPal 6524(2) Z45/0; **3**. BAPal 6524(10) H40/3; **4**. BAPal 6531(1) K45/2; **5**. BAPal 6531(1) 32,6/114,3; **6**. BAPal 6509(1) G56/1; **7**. BAPal 6531 T05 f153, SEM; **8**. BAPal 6531 T05 f145, SEM; **9**. BAPal 6531 T03 f125, SEM. Scale bar = 10 µm

H o l o t y p e. Azcuy (1975b, plate XXII, fig. 144).

D e s c r i p t i o n. Spore radial, trilete, cavate, zonate; amb subcircular to subtriangular. Laesurae straight, extending to equatorial margin, with thin lips. Proximal face laevigate, distal face bearing biform sculptural elements and coni, 1 (1.8) 2.5 µm basal width and 2 (2.6) 4 µm height. Sculptural elements irregularly distributed, joined by their bases or widely spaced. Zone narrow (5 (8) 10 µm wide), with spaced small sculptural elements.

D i m e n s i o n s (31 specimens). Equatorial diameter 37 (50) 63 µm, central body diameter 28 (32) 38 µm, zone width 7–8 µm.

Suprasubturma: PSEUDOSACCITITRILETES

Infraturma: MONOPSEUDOSACCITI

Genus: ***Endosporites*** Wilson & Coe 1940 *ex* Schopf, Wilson & Bentall 1944

Type species: *Endosporites ornatus* Wilson & Coe 1940 [SD; Schopf et al. 1944, p. 45]

Endosporites menendezi nov. nom., emend.

Pl. 2, figs 25, 26

S y n o n y m y.

1975b *Endosporites* sp. A Azcuy, p. 147, plate XXXI, fig. 197.

2001 *Endosporites?* sp. Gutiérrez & Limarino, p. 109, fig. 7.G.

2009 *Endosporites* sp. Pérez Loinaze, p. 505, fig. 4.11.

Basionym. *Endosporites parvus* Menéndez 1965, p. 59, 60, plate V, fig. 8.

Holotype. Menéndez 1965, plate V, fig. 8.

Type strata. Agua Colorada Formation, Pennsylvanian.

Age. Pennsylvanian.

Type locality. Río Tambillos, Sierra de Famatina, La Rioja Province.

Derivatio nominis. In honour of Dr Carlos A. Menéndez†, Argentinian palaeobotanist and palynologist.

Emended diagnosis. Spores radial, trilete, cavate; amb subcircular. Laesurae simple, straight, reaching edge of central body, occasionally extending as folds over exoexine almost to spore radius. Intexine infragranular, thicker than exoexine, forming small dark central body contour conformable with amb. Exoexine infragranular and usually folded.

Dimensions (14 specimens). Equatorial diameter 45 (63) 80 × 42 (51) 70 µm, central body diameter 30 (42) 54 × 28 (37) 49 µm. Ratio DT/dcc 1.2 (1.5) 1.9 µm.

Observation of the original material studied by Menéndez (1965) allowed us to appreciate the infragranular nature of the intexine and exoexine, and higher variation in the range of general equatorial diameter (50–83 µm) and of the diameter of the central body (28–57 µm), enabling us to emend the diagnosis.

The material from Santiago Temple has a slightly larger size range (equatorial diameter 45–80 × 42–70 µm, central body diameter 30–54 × 28–49 µm) but we consider them to be the same species since they are similar in the relationship between diameters, the type of laesurae, lips, and the width and the nature of the intexine.

Before Menéndez (1965), the epithet *parvus* was used to name species of *Endosporites* by Guennel (1958) and Staplin (1960). *Endosporites? parvus* Staplin 1960 and *E. parvus* Menéndez 1965 are homonyms of *E. parvus* Guennel; therefore they are invalid. We propose *E. menendezi* as a new name to replace *E. parvus* Menéndez.

Comparisons. *Endosporites menendezi* nov. nom., emend. is differentiated from *E. parvus* Guennel (1958, p. 50–51, text-fig. 11, plate 1, figs 16–17) by its small size (equatorial diameter 30 (38) 45 µm, central body diameter 20–25 µm), the width of the central body wall being half the radius of the spore, and laesurae extending to the equatorial margin. *Endosporites? parvus* Staplin (1960, p. 33, plate 7, figs 8, 12) is distinguished from *E. menendezi* by its dimensions (equatorial diameter 24–35 µm, central body diameter 16–20 µm), the presence of a well-developed exoexine equatorial limb, the laesurae flanked by low, very narrow, irregular lips, and the central body amb being poorly discernible. The characteristics of the material referred to *Endosporites* sp. from the Malanzán Formation (Azcuy 1975b, Gutierrez & Limarino 2001, Pérez Loinaze 2009) allow their determination as *Endosporites menendezi* nov. nom., emend.

COMPOSITION OF THE PALYNOFLORA

Supplementary File 1 includes a commented list of the 214 palynomorph species and 3 microforaminiferal lining species identified in material from the Santiago Temple boreholes. The studied palynoflora includes abundant, well-preserved specimens, with dominance of spores in the associations (62.4–96%) (Supplementary File 2[2]). Completing the association are monosaccate pollen grains (2.8–22.4%), freshwater algae (0–11.6%), prasinophytes (0.8–7.6%), acritarchs (0–19.6%), bisaccate pollen grains (0–2%), monolete spores (0.4–0.8%), fungi (0–2%), striate pollen grains (0–1.2%) and microforaminiferal linings (0–0.4%).

Among the trilete spores, *Punctatisporites*, *Calamospora*, *Vallatisporites*, *Cristatisporites*, *Cyclogranisporites*, *Leiotriletes*, *Indotriradites*, *Retusotriletes*, *Apiculiretusispora* and *Brevitriletes* are the dominant forms (Supplementary File 2). Also present, but in smaller numbers, are species belonging to *Cannanoropollis*, *Potonieisporites*, *Cahenisaccites*, *Plicatipollenites* (monosaccate pollen grains), *Botryococcus* (freshwater algae), and *Leiosphaeridia* and *Brazilea* (prasinophytes).

An additional feature observed in this assemblage is the presence of redeposited

[2] Supplementary File 2 available on page http://www.botany.pl/images/ibwyd/acta_paleo/Acta_Palaeobot_58_1_Gutierrez-Balarino_Suppl_2.pdf

spores and acritarchs in many of the palynological levels, which are typical Silurian–Devonian species: *Ammonidium* spp., *Diexallophasis* spp., *Duvernaysphaera* spp., *Estiastra barbata* Downie 1963, *Cordobesia* sp. cf. *C. uruguayensis* (Machiavello) Pöthe de Baldis 1977, *Gorgonisphaeridium* spp., *Cymatiosphaera* spp., *Lophosphaeridium* spp., *Multiplicisphaeridium* spp., *Maranhites* spp., spp., *Quadrisporites granulatus* (Cramer) Strōther 1991, *Tetraporina horologia* (Staplin) Playford 1963, *Emphanisporites rotatus* (McGregor) McGregor 1973, *Auroraspora macra* Sullivan 1968, *Geminospora lemurata* Balme emend. Playford 1983, *Grandispora pseudoreticulata* (Menéndez & Pothe de Baldis) Ottone 1996 and *Cristatisporites triangulatus* (Allen) McGregor & Camfield 1982.

The lower part of the Sachayoj Formation would have been deposited in an interglacial lacustrine, fluvial environment with marine levels (Malizzia et al. 1993). These levels are documented by the presence of microforaminiferal linings (between 850.00 and 851.50 mbgl in borehole CO3) and high representation (19.2%) of the acritarch *Deusilites tenuistriatus* (between 865.00 and 866.00 mbgl in borehole CO2). These marine levels in the lower section of the Ordóñez Formation could be correlated with the first marine phases of postglacial transgression (Bashkirian) of the Terminal Glacial Stage (Limarino et al. 2014).

PALYNOSTRATIGRAPHY

Throughout the studied interval of the Ordóñez Formation, we observed no significant differences in the quantitative composition of the palynological assemblage (Supplementary Files 2 and 3[3]). However, the vertical distribution of the identified species in the Santiago Temple boreholes (Supplementary File 3) does enable us to distinguish two associations: I (between 895.00 and 833.00 mbgl, recognized in the three boreholes) and II (ranging from 827.50 and 778.50 mbgl, recognized in boreholes CO2 and CO3).

Despite the continuous distribution of many species through both associations, Association I is characterized by the exclusive presence of *Altitriletes densus*, *Converrucosisporites micronodosus*, *Convolutispora maximensis*, *Diatomozonotriletes birkheadensis*, *Endosporites menendezi*, *Foveosporites pellucidus*, *Laevigatosporites vulgaris*, *Leschikisporites chacoparanensis*, *Lophotriletes discordis*, *Raistrickia cephalata*, *R. densa*, *R. paganciana*, *Verrucosisporites quassigobetti*, *Caheniasaccites verrucosus*, *Platysaccus leschiki*, *Polarisaccites bilateralis*, *Scheuringipollenites medius*, *Striomonosaccites* sp. A and microforaminiferal linings. Association II is characterized by the appearance of *Distriatites insolitus*, *Barakarites rotatus*, *Illinites unicus* and *Protohaploxypinus goraiensis*.

AGE AND CORRELATION

Of the 217 identified species in this study, only 67 have been recorded previously in this basin (Tab. 2), 14 of which show restricted presence in the *Cristatisporites* (Cr) Biozone (*Anapiculatisporites tereteangulus*, *Brevitriletes levis*, *Caheniasaccites densus*, *Cannanoropollis janakii*, *C. perfectus*, *Convolutispora candiotensis*, *C. muriornata*, *Cristatisporites chacoparanensis*, *Dictyotidium* sp. A, *Distriatites insolitus*, *Limitisporites elongatus*, *Potonieisporites congoensis*, *Retusotriletes diversiformis*, *Verrucosisporites menendezii*), although none of them are diagnostic of this biozone (see Vergel 1993; Archangelsky & Vergel 1996). Only five species were identified in Santiago Temple as having a restricted record for the *Potonieisporites–Lundbladispora* (PL) Biozone: *Cristatisporites menendezi*, *Vallatisporites ciliaris*, *Gondwanapollis frenguelli*, *Verrucosisporites chiqueritensis* and *V. andersonii*. The first three species characterize this biozone (see Vergel 1993, Archangelsky & Vergel 1996).

Associations I and II have a generic affinity with the PL Biozone, based mainly on the presence of trilete spores (62–96%) and monosaccate pollen grains (2.8–22.4%) (see Supplementary File 2), in accordance with Vergel (1993) and Archangelsky & Vergel (1996). In addition, the absence or poor representation of bisaccate pollen grains (0–2%) and striate pollen grains (0–1.5%) in the Santiago Temple associations strengthens their separation from the *Cristatisporites* and *Striatites* (S) biozones, which are dominated by these two palynomorph groups (see Vergel 1993).

[3] Supplementary File 3 available on page http://www.botany.pl/images/ibwyd/acta_paleo/Acta_Palaeobot_58_1_Gutierrez-Balarino_Suppl_3.pdf

Table 2. Biostratigraphic distribution of the species shared between the Chacoparaná Basin and Ordónez Formation (boreholes YCF.CO1, YCF.CO2 and YCF.CO3). References: **AB** – Árbol Blanco; **CA** – Camilo Aldao; **CG** – Campo Gallo; **ER** – El Rincón; **G** – Gancedo; **J** – Josefina; **LM** – Las Mochas; **O** – Ordóñez; **S** – Saira. Biozones: **PL** (Potonieisporites-Lundbladispora), **C** (Cristatisporites), **S** (Striatites). Lower (**l**), middle (**m**), upper (**u**), basal (**b**), * (rest of the Biozone). Bibliographic references: **1** – Archangelsky & Gamerro (1979); **2** – Vergel (1986); **3** – Vergel (1987a); **4** – Vergel (1987b); **5** – Vergel (1990a); **6** – Vergel (1990b); **7** – Vergel (1993); **8** – Césari et al. (1995); **9** – Gutiérrez et al. (1997); **10** – Vergel (1998); **11** – Playford & Dino (2002); **12** – Antonelli & Ottone (2006)

Chacoparaná Basin	Boreholes	Biozones									References
		PL				Cr			S		
Species		l		u		l	m	u	b	*	
Caheniasaccites ovatus	O, CA, S, J, AB, LM, CG, G	x	x	x	x	x	x	x	x	x	1, 3, 4, 6, 7, 8, 11
Calamospora microrugosa	CA, J, AB, G, O, CG	x	x	x	x	x	x	x	x	x	1, 2, 4, 6
Cannanoropollis densus	O, CA, S, J, AB, LM, CG, G	x	x	x	x	x	x	x	x	x	1, 3, 4, 6, 7, 8
Cristatisporites inconstans	O, CA, S, J, AB, CG, LM, G	x	x	x	x	x	x	x	x	x	1, 2, 4, 6, 7, 8, 9, 11
Lundbladispora riobonitensis	J, AB, CG, LM, G	x	x	x	x	x	x	x	x	x	2, 4, 6, 7, 8, 10
Plicatipollenites densus	O, CA, S. AB, CG, LM, G, J	x	x	x	x	x	x	x	x	x	1, 4, 6, 7, 8, 11
Plicatipollenites malabarensis	O, CA, S, J, AB, CG, ER, G	x	x	x	x	x	x	x	x	x	1, 3, 4, 6, 7, 11, 12
Potonieisporites brasiliensis	O, CA, S, AB, LM, CG, G, J	x	x	x	x	x	x	x	x	x	1, 4, 6, 7, 8, 11
Potonieisporites novicus	O, CA, S, J, AB, CG, LM, G	x	x	x	x	x	x	x	x	x	1, 3, 4, 6, 7, 8, 11
Punctatisporites gretensis	O, CA, S, J, AB, CG, G	x	x	x	x	x	x	x	x	x	1, 2, 4, 6, 7, 10, 11
Brevitriletes cornutus	O, CA, S, J, AB, CG, G	x	x	x	x	x	x	x	x		1, 2, 4, 6, 7, 10
Portalites gondwanensis	J, CG, AB, G	x	x	x	x	x	x	x	x		3, 4, 6, 7
Leiotriletes tiwarii	LM, CG, AB G	x	x	x	x	x	x	x			6, 8,10
Lundbladispora braziliensis	O, CA, S, J, AB, CG, G	x	x	x	x	x	x	x			1, 2, 4, 6, 7, 10, 11
Potonieisporites neglectus	LM, O, CG	x	x				x	x			6, 7, 8, 11
Spelaeotriletes ybertii	CA, S, AB, LM, CG, G	x	x	x	x	x	x	x			1, 4, 6, 8, 10
Calamospora plicata	CG, AB, G	x	x	x	x	x	x				6, 7, 10
Gondwanapollis frenguelli	CG	x	x	x	x						6, 7
Verrucosisporites andersonii	CG, AB, G	x	x	x	x						6
Vallatisporites ciliaris	CG	x	x								6, 7, 10
Verrucosisporites chiquiritensis	LM			x							8
Cristatisporites menendezi	CG			x	x						6, 7, 10
Apiculiretusispora golatensis	AB G			x	x	x					6
Velamisporites cortaderensis	LM, CG, AB, G			x	x	x	x				6, 8, 10
Brazilea scissa	O, J, AB			x	x	x	x	x	x	x	1, 3, 6
Vallatisporites russoi	AB, G, J, O, CA, S			x	x	x	x	x	x	x	1, 6, 11
Laevigatosporites vulgaris	O, CG, AB, G			x	x		x	x	x	x	6, 7, 10, 11
Plicatipollenites trigonalis	J, LM, ER,			x	x	x	x	x	x	x	3, 6, 8, 12
Potonieisporites magnus	LM, J			x	x	x	x	x	x	x	2, 6, 8
Converrucosisporites confluens	O, CA, S, J, CG, LM, G, AB			x	x	x	x	x	x		1, 2, 6, 7, 8, 10, 11
Converrucosisporites micronodosus	O, CA, S, J, AB, CG, LM, G			x	x	x	x	x	x		1, 2, 4, 6, 7, 8, 10, 11
Granulatisporites austroamericanus	O, J, AB, LM, CG, G			x	x	x	x	x	x		1, 2, 4, 6, 8, 10, 11
Botryococcus brauni	J, CG, AB, G			x	x	x	x	x	x		6, 7
Cristatisporites crassilabratus	O, CA, S, J, AB, CG, LM, G			x	x	x	x	x	x		1, 2, 4, 6, 7, 8, 10, 11
Horriditriletes uruguaiensis	O, S, J, AB, CG, LM, G			x	x	x	x	x	x		1, 2, 4, 6, 7, 8, 10, 11
Limitisporites hexagonalis	J, LM			x	x	x	x	x	x		3, 6, 8
Polarisaccites bilateralis	O, J, AB, JM, CG, G			x	x	x	x	x	x		1, 3, 4, 6, 7, 8
Cristatisporites lestai	O, CA, S, J, LM, AB			x	x	x	x	x			1, 2, 6, 8, 10, 11
Brevitriletes sparsus	CG, AB, G			x	x	x	x	x			6, 7, 10
Cannanoropollis methae	O, CA, CG, LM, AB, G			x	x	x	x	x			1, 6, 7, 8
Deusilites ternuistriatus	AB, LM			x	x	x	x	x			9
Grossusporites microgranulatus	O, CA, S, J, CG, LM, AB			x	x	x	x	x			1, 2, 6, 7, 8, 10
Horriditriletes superbus	AB, G			x	x	x	x	x			6, 10
Leschikisporites chacoparanensis	AB, CG, G			x	x	x	x	x			5, 6, 7, 10
Retusotriletes simplex	G			x	x	x	x	x			6
Vallatisporites arcuatus	O, CA, J, AB, CG, G			x	x	x	x	x			1, 2, 4, 6, 7, 10, 11
Verrucosisporites triseccatus	AB, CG, G			x	x	x	x	x			4, 6, 7, 10
Crucisaccites latisulcatus	LM				x	x	x	x			8
Convolutispora candiotensis	O, AB, G					x	x	x			1, 6, 10
Cristatisporites chacoparanensis	O, S					x	x	x			1
Verrucosisporites menendezii	O, J					x	x	x			1, 2, 6

Table 2. Continued

Chacoparaná Basin	Boreholes	Biozones									References
Species		PL				Cr			S		
		l		u		l	m	u	b	*	
Brevitriletes levis	AB, G, J					x	x				6, 10
Convolutispora muriornata	AB, G					x	x				6
Dictyotidium sp. A	G					x	x				6
Anapiculatisporites tereteangulus	O						x				11
Caheniasaccites densus	O						x				11
Cannanoropollis janakii	O						x				11
Cannanoropollis perfectus	O						x				11
Distriatites insolitus	O						x				11
Potonieisporites congoensis	O						x				11
Retusotriletes diversiformis	O						x				11
Limitisporites elongatus	LM						x	x			7
Convolutispora ordonezii	O, S, J, LM						x	x	x	x	1, 2, 6, 8, 11
Limitisporites rectus	O						x	x	x	x	11
Convolutispora archangelskyi	O, J							x	x	x	1, 2, 6, 11
Lundbladispora areolata	LM				.			x			8

The Santiago Temple assemblages have been compared with the palynostratigraphical scheme defined for central western Argentina (Césari & Gutiérrez 2001), since the two are spatially and temporally close. These associations exhibit close similarity to the *Raistrickia densa–Convolutispora muriornata* (DM) Biozone of the above-mentioned scheme, with 37 species in common (Tab. 3). Association II shares four species with the *Fusacolpites fusus–Vittatina subsaccata* (FS) and/or *Lueckisporites–Weylandites* (LW) biozones (*Distriatites insolitus*, *Barakarites rotatus*, *Illinites unicus* and *Protohaploxypinus goraiensis*), although none of them are diagnostic of these biozones (Césari & Gutiérrez 2001).

A feature of both associations is their high similarity to the assemblages of the Paganzo Basin (170 of the 219 species identified were recorded previously in the aforementioned basin), in contrast to the low number (67) of species shared with the Chacoparaná Basin (Tabs 2, 3).

In summary, Associations I and II can be referred, at least in part, to the PL Biozone (Pennsylvanian), based on the dominance of trilete spores and monosaccate pollen grains (more than 80% of the assemblage from Santiago Temple) and the presence of *Cristatisporites menendezi*, *Vallatisporites ciliaris* and *Gondwanapollis frenguelli*. On the other hand, they are correlated with the DM Biozone (late Serpukhovian–Bashkirian) from the central western basins of Argentina (Limarino et al. 2014), given the high number of common species (37), including the characteristic *Caheniasaccites verrucosus*, *Convolutispora maximensis*, *Endosporites menendezi*, *Foveosporites pellucidus*, *Raistrickia cephalata* and *Platysaccus leschiki*.

CONCLUSIONS

Based on an analysis of 31 core samples from the YCF.CO1, YCF.CO2 and YCF.CO3 boreholes, corresponding to the lower section of the Ordóñez Formation, here we presented a new well-preserved palynofloral assemblage. This assemblage includes 135 trilete spores, 40 monosaccate pollen grains, 14 bisaccate pollen grains, 8 algae-prasinophytes, 5 bisaccate striate pollen grains, 5 monolete spores, 3 acritarchs, 3 microforaminiferal linings, 2 fungi, 1 monocolpate pollen grain and 1 plicate pollen grain species. In terms of microfloristic composition, the association is dominated by trilete spores (80.5% on average) and monosaccate pollen grains (12.7% on average). We propose three new species: *Calamospora fissurata* sp. nov., *Retusotriletes archangelskyi* sp. nov. and *Horriditriletes chacoparanensis* sp. nov. We propose *Leiotriletes malanzanensis* nov. nom and *Endosporites menendezi* nov. nom., emend. to replace *L. tenuis* Azcuy and *E. parvus* Menéndez, respectively. We established the following combinations: *Brevitriletes coalescens* (Menéndez & Azcuy) nov. comb., *B. papillatus* (Menéndez & Azcuy) nov. comb., *B. sparsus* (Menéndez & Azcuy) nov. comb., *B. delicatus* (Menéndez) nov. comb., emend. and *Indotriradites malanzanensis* (Azcuy) nov. comb. Two microflora

Table 3. Biostratigraphic distribution of the species shared between the central west Argentina basins and Ordónez Formation (YCF.CO1, YCF.CO2 and YCF.CO3 boreholes). References: **MQ** – Reticulatisporites magnidictyus-Verrucosisporites quassigobetti Interval Biozone; **DM** – Raistrickia densa-Convolutispora muriornata Assemblage Biozone; **A** – Sub-biozone A; **B** – Sub-biozone B; **C** – Sub-biozone C; **FS** – Fusacolpites fusus-Vittatina subsaccata Interval Biozone; **LW** – Lueckisporites-Weylandites Assemblage Biozone; **uLV** – Upper La Veteada Assemblage. Bibliographic references: Gutiérrez (1993), Césari et al. (1996, 2013), Gutiérrez & Césari (2000), Gutiérrez & Limarino (2001, 2006), Césari & Gutiérrez (2001), Césari & Limarino (2002), Pérez Loinaze & Césari (2004, 2012), Balarino & Gutiérrez (2006), Gutiérrez & Barreda (2006), Pérez Loinaze (2007, 2008, 2009), Vergel (2008), di Pasquo et al. (2010), Gutiérrez et al. (2010, 2011, 2014), Pérez Loinaze et al. (2010, 2011, 2014), Balarino et al. (2012, 2016), Correa et al. (2012), Archangelsky et al. (2014), Vergel et al. (2015)

Biozones North-western Argentina basins	MQ	DM			FS	LW	uLV
Species		A	B	C			
Punctatisporites resolutus	?						
Apiculatisporis variornatus	x	x	x	x	x		
Cristatisporites menendezi	x	x	x	x	x		
Retusotriletes anfractus	x	x	x	x	x		
Dibolisporites disfacies	x	x	x		x		
Indotriradites volkheimeri	x	x	x	x			
Raistrickia rotunda	x	x	x	x			
Vallatisporites ciliaris	x	x	x	x			
Raistrickia pagancia	x	x	x				
Verrucosisporites quasigobbetii	x		x				
Cyclogranisporites firmus	?	x					
Botryococcus brauni		x					
Murospora torifera		x					
Peppersites ellipticus		x					
Vallatisporites vallatus		x					
Brevitriletes coalescens		x	x				
Brevitriletes delicatus		x	x				
Convolutispora maximensis		x	x				
Endosporites menendezi		x	x				
Endosporites rhytidosaccus		x	x				
Foveosporites pellucidus		x	x				
Leiotriletes ornatus		x	x				
Microreticulatisporites punctatus		x	x				
Phyllothecotriletes aggregatus		x	x				
Potonieisporites congoensis		x	x				
Psomospora detecta		x	x				
Punctatisporites lucidulus		x	x				
Raistrickia accincta		x	x				
Rattinganispora apiculata		x	x				
Reticulatisporites asperdyctius		x	x				
Spelaeotriletes triangulus		x	x				
Anulatisporites famatinensis		x	x				
Caheniasaccites verrucosus			x				
Leiotriletes gracilis			x				
Leitriletes incospicuus			x				
Platysaccus leschiki			?				
Grandispora maculosa			x	x			
Apiculatisporis densus			x	x			
Potonieisporites marleniae				x			
Cannanoropollis trilobatus		x		x			
Anapiculatisporites concinnus		x	x	x			
Apiculiretusispora alonsoi		x	x	x			
Brevitriletes sparsus		x	x	x			
Lundbladispora irregularis		x	x	x			
Raistrickia cephalata		x	x	x			
Tricidarisporites gutii		x	x	x			
Apiculiretusispora variornata		x	x	?			
Potonieisporites densus		x	x	?			
Apiculatasporites caperatus		x	x	x	x		
Apiculatasporites parviapiculatus		x	x	x	x		
Apiculiretusispora ralla		x	x	x	x		
Brevitriletes cornutus		x	x	x	x		
Brevitriletes papillatus		x	x	x	x		
Convolutispora muriornata		x	x	x	x		
Cristatisporites chacoparanensis		x	x	x	x		
Cristatisporites crassilabratus		x	x	x	x		
Cristatisporites inconstans		x	x	x	x		
Cristatisporites lestai		x	x	x	x		
Cristatisporites rollerii		x	x	x	x		
Cristatisporites saltitensis		x	x	x	x		
Cristatisporites spinosus		x	x	x	x		
Cristatisporites stellatus		x	x	x	x		
Crucisaccites monoletus		x	x	x	x		
Foveosporites hortonensis		x	x	x	x		
Gondwanapollis frenguelli		x	x	x	x		
Grossusporites microgranulatus		x	x	x	x		
Horriditriletes curvibaculosus		x	x	x	x		
Lundbladispora riobonitensis		x	x	x	x		
Plicatipollenites densus		x	x	x	x		
Plicatipollenites trigonalis		x	x	x	x		
Portalites gondwanensis		x	x	x	x		
Potonieisporites barrelis		x	x	x	x		
Potonieisporites methoris		x	x	x	x		
Potonieisporites triangulatus		x	x	x	x		
Punctatisporites glaber		x	x	x	x		
Raistrickia densa		x	x	x	x		
Retusotriletes simplex		x	x	x	x		
Spelaeotriletes ybertii		x	x	x	x		
Tetraporina punctata		x	x	x	x		
Velamisporites cortaderensis		x	x	x	x		
Verrucosisporites patelliformis		x	x	x	x		
Ahrensisporites cristatus		x	x		x		
Brevitriletes leptoacaina		x	x		x		
Brevitriletes parmatus		x	x		x		
Costatacyclus crenatus		x	x		x		
Crucisaccites latisulcatus		x	x		x		
Gondwanapollis lenticulatus		x	x		x		
Indotriradites malanzanensis		x	x		x		
Leiotriletes corius		x	x		x		

Table 3. Continued

Biozones North-western Argentina basins	MQ	DM			FS	LW	uLV
Species		A	B	C			
Leiotriletes malanzanensis		x	x		x		
Cannanoropollis triangularis		?	x		x		
Granulatisporites varigranifer		x	x	?	?		
Navifusa variabilis		x		x	x		
Raistrickia radiosa		x	x		?		
Vallatisporites russoi		x	x		x		
Verrucosisporites chiquiritensis		?	x		?		
Lundbladispora areolata		x			x		
Cristatisporites microvacuolatus		?			x		
Gondwanapollis lenticulatus		x	x		x		
Apiculiretusispora golatensis			x		x		
Limitisporites luandensis				?	?		
Calamospora plicata					x		
Horriditriletes superbus					x		
Kraeuselisporites apiculatus					x		
Kraeuselisporites punctatus					x		
Leschikisporites chacoparanensis					x		
Limitisporites elongatus					x		
Lophotrletes lentiginosus					x		
Stellapollenites talchirensis					x		
Anapiculatisporites tereteangulus					x	x	
Barakarites rotatus					x	x	
Caheniasaccites flavatus					x	x	
Calamospora breviradiata					x	x	
Converrucosisporites confluens					x	x	
Horriditriletes ramosus					x	x	
Illinites unicus					x	x	
Polarisaccites bilateralis					x	x	
Scheuringipollenites maximus					x	x	
Scheuringipollenites medius					x	x	
Tuberisaccites varius			x	x	x	x	
Caheniasaccites elongatus			x	x	x	x	
Brevitriletes levis		x	x	x	x	x	
Caheniasaccites densus		x	x	x	x	x	
Cannanoropollis densus		x	x	x	x	x	
Cannanoropollis janakii		x	x	x	x	x	
Cannanoropollis methae		x	x	x	x	x	
Caheniasaccites ovatus		x	x	x	x	x	
Calamospora hartungiana		x	x	x	x	x	
Circumplicatipollis plicatus		x	x	x	x	x	
Cyclogranisporites microgranus		x	x	x	x	x	
Horriditriletes uruguaiensis		x	x	x	x	x	
Laevigatosporites vulgaris		x	x	x	x	x	
Leiotriletes directa		x	x	x	x	x	
Leiotriletes tiwarii		x	x	x	x	x	
Limitisporites hexagonalis		x	x	x	x	x	
Limitisporites rectus		x	x	x	x	x	
Plicatipollenites gondwanensis		x	x	x	x	x	
Plicatipollenites malabarensis		x	x	x	x	x	
Potonieisporites brasiliensis		x	x	x	x	x	
Retusotriletes diversiformis		x	x	x	x	x	
Vallatisporites arcuatus		x	x	x	x	x	
Verrucosisporites menendezii		x	x	x	x	x	
Potonieisporites magnus		x	x	x	x	x	
Potonieisporites neglectus		x	x	x	x	x	
Potonieisporites novicus		x	x	x	x	x	
Granulatisporites austroamericanus		x	x	x	x	?	
Lundbladispora braziliensis		x	x	x	x	?	
Punctatisporites gretensis		x	x	x	x	?	
Brazilea scissa		x	x		x	x	
Potonieisporites lelei		x	x		x	x	
Pteruchipollenites gracilis		x	x		x	x	
Verrucosisporites andersonii		x	x		x	x	
Lophotriletes discordis		x	?		x	?	
Convolutispora ordonezii		x	x	x		?	
Platysaccus papilionis		x			x	?	
Cannanoropollis perfectus		?			x	x	
Convolutispora candiotensis		?	?			x	
Melisphaeridium regulare		x	x	x			x
Protohaploxypinus amplus			x	x	x	x	x
Horriditriletes gondwanensis			?			x	
Distriatites insolitus				x	x		?
Protohaploxypinus goraiensis					x	x	x
Alisporites opii						x	
Convolutispora archangelskyi						x	
Limitisporites amazonensis						x	
Calamospora microrugosa						?	
Calamospora pedata						?	
Platysaccus queenslandi						?	
Verrucosisporites insuetus						?	
Meristocorpus explicatus							x

associations were recognized: Association I, from 895.00–833.00 mbgl, and identified in all three boreholes, is characterized by the exclusive presence of *Altitriletes densus*, *Converrucosisporites micronodosus*, *Convolutispora maximensis*, *Diatomozonotriletes birkheadensis*, *Endosporites menendezi*, *Foveosporites pellucidus*, *Laevigatosporites vulgaris*, *Leschikisporites chacoparanensis*, *Lophotriletes discordis*, *Raistrickia cephalata*, *R. densa*, *R. paganciana*, *Verrucosisporites quassigobetti*, *Caheniasaccites verrucosus*, *Platysaccus leschiki*, *Polarisaccites bilateralis*, *Scheuringipollenites medius*, *Striomonosaccites* sp. A and three species of microforaminiferal linings; Association II, from 827.50–778.50 mbgl in boreholes CO2 and CO3, is characterized by the appearance of *Distriatites insolitus*, *Barakarites rotatus*, *Illinites unicus* and *Protohaploxypinus goraiensis*. The palynological assemblages from Santiago Temple have greater affinity with those of central western Argentina, especially the ones described for the Paganzo Basin (*Raistrickia densa–Convolutispora muriornata* Biozone). The associations of Santiago Temple are referred partially to the *Potonieisporites–Lundbladispora* Biozone (PL), owing to the over-representation of trilete spores and monosaccate pollen grains (more than 80% of the microflora) and the presence of *Cristatisporites menendezi*, *Vallatisporites ciliaris* and *Gondwanapollis frenguelli*. Moreover, they are correlated with the *Raistrickia densa–Convolutispora muriornata* (DM) Biozone, which characterizes the late Serpukhovian–Bashkirian of central western Argentina (Fig. 3), based on sharing 37 species (including *Caheniasaccites verrucosus*, *Convolutispora maximensis*, *Endosporites menendezi*, *Foveosporites pellucidus*, *Raistrickia cephalata* and *Platysaccus leschiki*, exclusive distribution DM Biozone).

ACKNOWLEDGEMENTS

We thank G. A. Olivieri, J. P. Lovecchio and M. F. Schiuma for helpful information about the subsoil lithostratigraphy of the Santiago Temple site, Córdoba Province, and F. Tricarico for his assistance with SEM. Special thanks to S. Noetinger and B. Cariglino for invaluable comments and suggestions which helped improve the manuscript. This research was funded by Agencia Nacional de Promoción Científica y Tecnológica, Argentina (Research Grants ANPCYT-PICT 32693) and Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina (PIP Nº 0585).

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