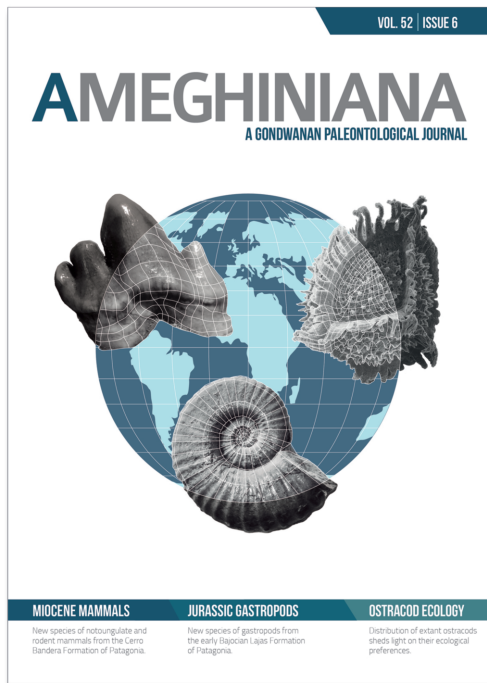




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A GONDWANAN PALEONTOLOGICAL JOURNAL



NEW PALYNOLOGICAL RECORDS FROM THE GLACIOMARINE DEPOSITS OF THE EL PASO FORMATION (LATE SERPUKHOVIAN-BASHKIRIAN) IN THE ARGENTINE PRECORDILLERA: BIOSTRATIGRAPHICAL IMPLICATIONS

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Submitted: December 1st, 2014 - **Accepted:** July 16th, 2015

To cite this article: M. Del Milagro Vergel, Gabriela A. Cisterna, and Andrea F. Sterren (2015). New palynological records from the glaciomarine deposits of the El Paso Formation (late Serpukhovian-Bashkirian) in the Argentine Precordillera: biostratigraphical implications. *Ameghiniana* 52: 613–624.

To link to this article: <http://dx.doi.org/10.5710/AMGH.16.07.2015.2860>

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NEW PALYNOLOGICAL RECORDS FROM THE GLACIOMARINE DEPOSITS OF THE EL PASO FORMATION (LATE SERPUKHOVIAN–BASHKIRIAN) IN THE ARGENTINE PRECORDILLERA: BIOSTRATIGRAPHICAL IMPLICATIONS

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Abstract. New palynological information from the El Paso Formation cropping out at the southern Sierra de Barreal (Calingasta-Uspallata Basin), San Juan Province, Argentina is presented. The palynologic assemblages were recovered from the middle to upper part of the section. Abundant trilete (75–90%) and hilate (1–5%) spore species are recognized: *Cyclogranisporites rinconadensis*, *Apiculatisporis variornatus*, *Raistrickia rotunda*, *Tricidarisorites gutii*, *Ahrensisporites* sp. cf. *A. cristatus*, *Cristatisporites stellatus*, *Indotriradites volkheimeri*, *Vallatisporites ciliaris* and *Psomospora detecta*, among others. Also, subordinate pollen grains (1.5–20%): *Circumplicatipollis plicatus*, *Costatascyclus crenatus*, *Plicatipollenites* sp. cf. *P. malabarensis*, *Potonieisporites* spp. and *Divarisaccus* sp. cf. *D. stringoplicatus*. Recycled and autochthonous acritarchs (e.g., *Cymatiogalea* sp., *Gorgonisphaeridium* sp., *Verhyachium* sp.) and Zygnematalean algae (*Tetraporina* sp., *Brazilea scisa*) with less of 2.5% are also present. We propose a late Serpukhovian–Bashkirian age, and a correlation with the Subzone A of the *Raistrickia densa-Convolutispora muriornata* (DM) Biozone to the El Paso assemblages.

Key words. Palynology. Biostratigraphy. Carboniferous. El Paso Formation. Argentine Precordillera.

Resumen. NUEVOS REGISTROS PALINOLÓGICOS EN LOS DEPÓSITOS GLACIMARINOS DE LA FORMACIÓN EL PASO (SERPUKHOVIANO TARDÍO–BASHKIRIANO), PRECORDILLERA ARGENTINA: IMPLICANCIAS BIOESTRATIGRÁFICAS. Se presenta nueva información palinológica para la Formación El Paso. Esta unidad aflora en el sector austral de la Sierra de Barreal, provincia de San Juan, Argentina (Cuenca Calingasta-Uspallata), y las asociaciones palinológicas se recuperaron de la parte media a superior de la sección. Contiene abundantes esporas trilete (75–90%) e hilate (1–5%), asignadas a *Cyclogranisporites rinconadensis*, *Apiculatisporis variornatus*, *Raistrickia rotunda*, *Tricidarisorites gutii*, *Ahrensisporites* sp. cf. *A. cristatus*, *Cristatisporites stellatus*, *Indotriradites volkheimeri*, *Vallatisporites ciliaris* y *Psomospora detecta*, entre otros. También, granos de polen subordinados (1,5–20%): *Circumplicatipollis plicatus*, *Costatascyclus crenatus*, *Plicatipollenites* sp. cf. *P. malabarensis*, *Potonieisporites* spp., *Divarisaccus* sp. cf. *D. stringoplicatus*. Acritarcos reabajados y autóctonos (e.g., *Cymatiogalea* sp., *Gorgonisphaeridium* sp., *Verhyachium* sp.) y algas Zygnematalean (*Tetraporina* sp., *Brazilea scisa*) están presentes con menos de 2,5%. Se propone una edad serpukhoviana tardía–bashkiriana y la correlación con la Subzona A de la Biozona *Raistrickia densa-Convolutispora muriornata* (DM) para las asociaciones de la Formación El Paso.

Palabras clave. Palinología. Bioestratigrafía. Carbonífero. Formación El Paso. Precordillera Argentina.

PALYNOLOGY has been recognized as a valuable tool for dating and correlating strata, particularly in the Late Paleozoic marine sequences of western Argentina, where the key faunal groups (*i.e.*, conodonts and fusulinid foraminiferids) are absent. Several localities and stratigraphic horizons have been palynologically analysed in this region, helping to clarify persistent chronostratigraphic problems in the rocks exposed in the area (*e.g.*, Césari and Gutiérrez, 2000). However,

some strata such as those of the El Paso Formation (Mésigos, 1953) herein studied had not provided until now diagnostic microfloristic records useful to assess its controversial age based on faunal evidences (Taboada, 1989, 2010; Simanaukas and Cisterna, 2001). Taboada (1989) defined the *Rugosochonetes gloucesterensis-Bulahdelia* cf. *myallensis* Biozone (late Viséan–Serpukhovian) in the El Paso Formation and placed it beneath the base of the *Levi-*

pustula levis Biozone (Serpukhovian–Bashkirian, Taboada, 2010; Taboada and Shi, 2011). Subsequently, Simanuskas and Cisterna (2001) reassigned the identified species of these brachiopod faunas and established two new associations, *i.e.*, *Aseptella-Tuberculatella* and *Rhipidomella-Micraphelia*; their affinities would have indicated a younger Late Carboniferous age.

The first palynological record from the El Paso Formation consists of a preliminary analysis of a low-diversity microfloristic assemblage from the upper section (Vergel *et al.*, 2008), without biostratigraphically diagnostic species. This assemblage was referred to Subzone A of the *Raistrickia densa-Convolutispora muriornada* (DM) Biozone (Césari and Gutiérrez, 2000), mainly because of the presence of some taxa frequent in the Late Paleozoic palynofloras from western Argentinian units (*i.e.*, Guandacol, Jejenes, Agua Colorada, Lagares and Trampeadero formations), and because of the absence of taxa characterizing older stratigraphic records.

Recent works in the fossil-bearing intervals of the El Paso Formation have yielded new collections of marine invertebrates and new samples processed for palynological analysis. The occurrence of key species in these samples allowed a re-assessment of the palynological assemblages from the El Paso Formation and its correlation with other units in western Argentinian basins.

GEOLOGICAL SETTING AND STRATIGRAPHY

Outcrops of the El Paso Formation are located in the southernmost part of Cerro Barreal, a broad North-South anticline (the Hoyada Verde Anticline) located 3 km East of the town of Barreal in San Juan Province (Fig. 1) and within the Calingasta-Uspallata Basin.

Glaciomarine deposits of this unit and those of the Hoyada Verde Formation in the core of the anticline represent one of the best records of the Pennsylvanian glacial episode in the region, widely studied by many authors (Amos and Rolleri, 1965; Frakes and Crowell, 1969; Amos and López Gamundí, 1981; González, 1981; López Gamundí, 1984, 1986; López Gamundí and Martínez, 2000). The diamic-tite-bearing successions in these two formations have been considered equivalent (Sequence I) in the context of the sequence-stratigraphic scheme provided by López Gamundí and Martínez (2003). An angular unconformity separates

the base of the El Paso Formation from the underlying rocks of the pre-Carboniferous basement of the Hilario Formation (Ordovician?) reported by Mésigos (1953). The top is overlain by the Tres Saltos Member (Pituil Formation), Sequence II of López Gamundí and Martínez (2003), separated by an erosional unconformity (Fig. 2). Two diamic-titic packages characterize the lower and upper parts of the section and between them, lies a vertical alternation of pebbly sandstones, boulder conglomerates, pebbly (dropstone) shales, sandstones, siltstones and shales (Martínez *et al.*, 1998). Two fossil-bearing intervals were identified immediately above and below the main diamic-titic package in the upper part of the section (Fig. 2). The lower level is a 30-m-thick interval of alternating mudstones and shales with fine-grained sandstones (Interval B corresponding to a trans-

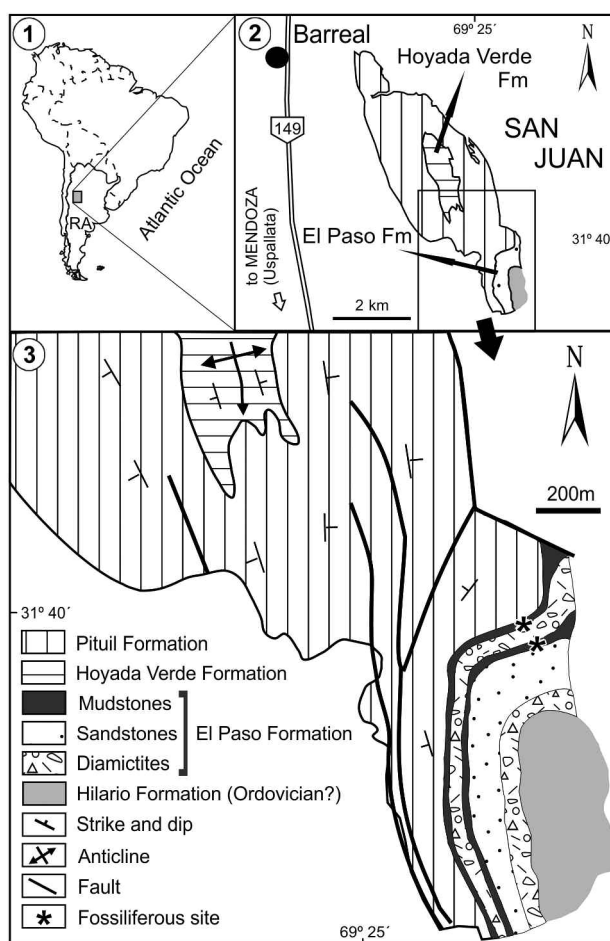
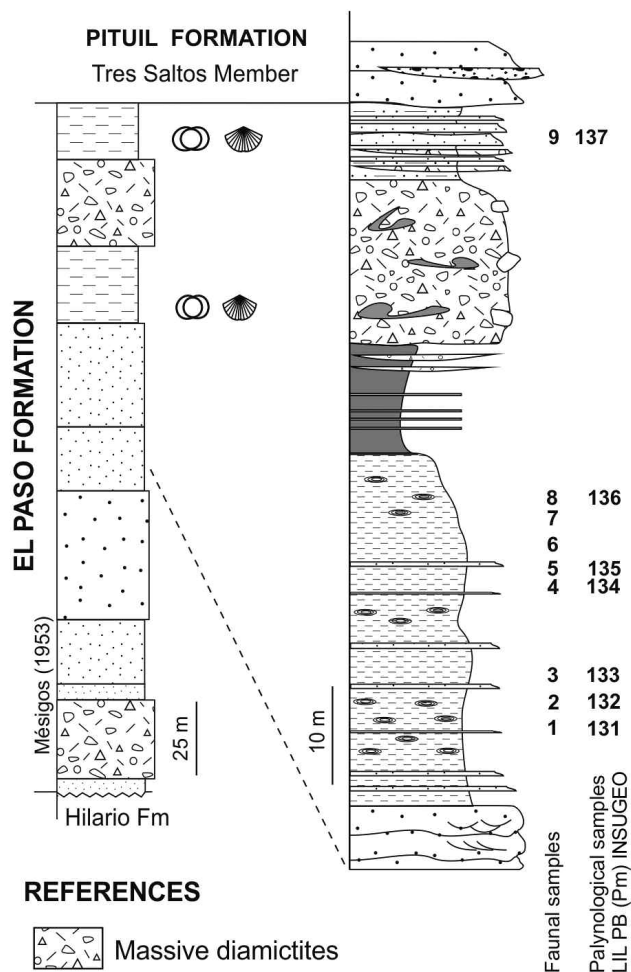


Figure 1. 1, geographic location of the studied area (RA: República Argentina). 2 and 3, geological maps (modified from Mésigos, 1953) showing the distribution of the El Paso Formation outcrops and the fossil localities.

gressive system tract -TST, in López Gamundí and Martínez, 2003: fig. 4) dominated by brachiopods and gastropods accompanied by bivalves and crinoids. Orthoconic nautiloids and conularids appear locally in concretionary horizons. The fauna has a continuous distribution but eight sampling points



REFERENCES

- Massive diamictites
- Pebbly sandstones
- Fine-grained sandstones
- Shales
- Gray shales
- Calcareous concretions
- Invertebrates (AT-RM)
- Pollen

Figure 2. Stratigraphic section of the El Paso Formation and vertical distribution of the fossil-bearing samples. Left, section modified from Mésigos (1953) and right, section modified from Simanuskas and Cisterna (2001).

| Period | Age | Paly-nology | Flora | Invertebrates | PAGANZO BASIN | CALINGASTA-USPALLATA BASIN |
|---------------|---------------|-------------|-----------|---------------|---------------|----------------------------|
| | | | | | ? | ? |
| CARBONIFEROUS | Pennsylvanian | Moscovian | ? | ? | T-S | Tupe Fm |
| | | | | | | |
| | Subzone C | | | | | |
| Miss. | Bashkirian | Serpukh. | Interval | A-T/R/M | Guandacol Fm | Hoyada Verde Fm |
| | | | | | Subzone B | |
| | | | Subzone A | Levipustula | | |

*318.79 Ma (Radiometric data from Gulbranson et al., 2010)

- Levipustula Zone
- DM Subzone A
- Aseptella-Tuberculatella / Rhipidomella-Micraperphelia associations

Figure 3. Correlation of the main Carboniferous biozones in Argentina (Modified from Césari et al., 2011). Dotted lines indicate uncertain boundaries.

were defined considering the more important faunal changes observed (Fig. 2). The upper fossil-bearing interval is a 10-m-thick sandstone interval (Interval E interpreted as a high stand systems tract -HST in López Gamundí and Martínez, 2003: fig. 4; sampling point 9, Fig. 2 herein) dominated by brachiopods accompanied by gastropods, bivalves and corals. Plant remains (stems) were also recorded in this interval.

Glaciomarine sequences of the El Paso and Hoyada Verde formations are characterized by two different marine faunal assemblages. The invertebrate fauna of the El Paso Formation recognized as the *Rugosochonetes gloucesterensis-Bulahdelia cf. myallensis* Biozone by Taboada (1989, 2010) has been indirectly related to the palynological *Reticulatisporites magnidictyus-Verrucosisporites quasigobbetti* (MQ) Biozone (Perez Loinaze, 2007), a biozone assigned to the late Visean (Césari et al., 2011, p. 151, 157; p. 156, fig. 6). Marine invertebrates of the Hoyada Verde Formation, however, are included in the widely studied *Levipustula levis* Biozone (Amos and Rolleri, 1965). This biozone is considered to be late Serpukhovian-early Bashkirian because of its relationship to Palynological Subzone A of the *Raistrickia densa-Convolutispora muriornata* (DM) Biozone (Césari et al., 2011, p. 156, fig. 6; p. 157) (Fig. 3).

MATERIAL AND METHODS

Nine palynological samples were taken from the lower and upper fossil-bearing intervals described above. Standard

palynologic techniques were employed in the extraction and concentration of palynomorphs. Seven levels (Fig. 2) yielded palynomorphs with different degrees of preservation (damaged and very dark brown to complete and orange in colour). Samples 136 and 137 from the top of the section were the most productive. The less productive ones appear at the base, except for sample 132.

Identification of palynomorphs was carried out using Nikon Eclipse 80i (1000x of maximum magnification) binocular transmitted light microscope. The photomicrographs were obtained with a Nikon Coolpix S10 (6 megapixels) and Nikon Coolpix 4500 (4 megapixels) camera. Slides are housed in the Palynological Collection of the Instituto Superior de Correlación Geológica (CONICET-UNT) (LILPB (Pm)-INSUGEO). Illustrations are referenced with the collection acronym followed by the England Finder coordinates.

PALYNOLOGY

Characteristic of the associations

Thirty-three spores and nine pollen grain species, as well as four acritarch genera and two Zygnematalean algae species were identified in the seven productive samples (Tab. 1). The assemblages are dominated by trilete spores (75 to 90%), mainly *Cristatisporites stellatus* (Azcuý) Gutiérrez and Limarino, 2001, and other species of the same genus. *Geosusporites microgranulatus* (Menéndez and Azcuý) Pérez Loinaze and Césari, 2004, *Apiculatisporis variornatus* di Pasquo, Azcuý and Souza, 2003, *Tricidarisorites gutii* Césari and Limarino, 2002, *Raistrickia densa* Menéndez, 1965, *Raistrickia rotunda* Azcuý, 1975a and one species of hilate spore (*Psomospora detecta* Playford and Helby, 1968), are other less frequent components of the assemblages. Radial and bilaterally symmetrical monosaccate pollen grains are subordinated (1.5 to 20%), principally represented by *Plicatipollenites* sp. cf. *P. malabarensis* (Potonié and Sah) Foster, 1975; *Circumplicatipollis plicatus* Ottone and Azcuý, 1988; *Costatascyclus crenatus* Felix and Burbridge emend. Urban, 1971; *Potonieisorites* sp. cf. *P. novicus* Bharadwaj emend. Poort and Veld, 1997; and *Potonieisorites magnus* Lele and Karim, 1971. Zygnematalean algae (*Tetraporina* sp. Naumova ex. Naumova emend. Kar and Bose, 1976; and *Brazilea scisa* (Balme and Hennelly) Foster, 1975; together with acritarchs are present at less than 2.5%. Other species of

spores recognized (*Retusotriletes incohatus* Sullivan, 1964; *Reticulatisporites* sp. (Ibrahim) Potonie and Kremp, 1954; *Vallatisporites* sp. Hacquebard emend. Sullivan, 1964; and *Auroraspora* sp. Hoffmeister, Staplin and Malloy, 1955, among others), mainly in the lower levels of the first fossil-bearing interval (Fig. 2, samples 131 to 135), are interpreted as reworked, basically because of their under-representation and poor preservation. Also, some acritarch taxa such as *Baltisphaeridium* sp. Eisenack, 1958 ex Eisenack, 1959 emend. Eisenack, 1969; *Cymatiogalea* sp. Deunff emend. Rasul, 1974; and *Gorgonisphaeridium* Staplin, Jansonius and Pockock, 1965, could be recycled palynomorphs and likely from the underlying Lower Paleozoic Hilario Formation of probable Ordovician age (Mésigos, 1953; López Gamundí and Martínez, 2003).

The stratigraphical distribution of taxa is displayed in Table 1 and the characteristic species are illustrated in Figures 4 and 5.

Samples 131, 132 and 133 of the lower levels studied (Tab. 1 and Fig. 2) are characterized by the dominance of trilete spores (85 to 90%); however, pollen grains first appear in low numbers in sample 132 (1.5 to 4.5%).

The spores *Cristatisporites stellatus*, *C. menendezii* (Menéndez and Azcuý) Playford, 1978; *Apiculatisporis variornatus*; *Psomospora detecta*; *Spelaeotriletes triangulus* Neves and Owens, 1966; and *Tricidarisorites gutii* are the most frequent components of this assemblage. The pollen grains *Circumplicatipollis plicatus*, *Potonieisorites triangulatus* Tiwari, 1965, *P. sp. cf. P. novicus*, *Potonieisorites* sp., *P. magnus*, and *Plicatipollenites* sp. cf. *P. malabarensis* are also present in these samples, and to a lesser extent the spores *Leiotriletes* sp. Naumova emend. Potonie and Kremp 1954; *Cyclogranisorites rinconadensis* Césari and Limarino, 2002; *Punctatisporites* cf. *P. trivialis* Azcuý, 1975a; *Spinozonotriletes hirsutus* Azcuý, 1975b; *Verrucosisorites* sp. cf. *V. chiqueritensis* Ottone, 1989; *Anapiculatisporis* sp. cf. *A. conccinus* Playford, 1962; *Vallatisporites* sp.; *Cristatisporites* sp. and *Densosporites* sp. (Berry) Butterworth, Jansonius, Smith and Staplin 1964. The acritarchs *Baltisphaeridium* sp., *Cymatiogalea* sp. and several species of the genus *Gorgonisphaeridium*, considered recycled material, have been also recognized in this assemblage.

Samples 134, 135 and 136 (Tab. 1 and Fig. 2) show an increase in pollen content (7 to 12%). Several species are re-

TABLE 1. Stratigraphic distribution of species recorded in the El Paso Formation.

| <i>Species/Samples</i> | 131 | 132 | 133 | 134 | 135 | 136 | 137 |
|--|-----|-----|-----|-----|-----|-----|-----|
| <i>Retusotriletes incohatus</i> | x | | | | | | |
| <i>Cristatisporites scabiosus</i> | x | | | | | | |
| <i>Leiotriletes sp.</i> | | x | | | | | |
| <i>Cyclogranisporites rinconadensis</i> | | x | | | | | |
| <i>Punctatisporites sp. cf. P. trivialis</i> | | x | | | | | |
| <i>Spinozonotriletes hirsutus</i> | | x | | | | | |
| <i>Verrucosisporites sp. cf. V. chiqueritensis</i> | | x | | | | | |
| <i>Anapiculatisporis sp. cf. A. concinus</i> | | x | | | | | |
| <i>Spelaeotriletes triangulus</i> | | x | x | | | | |
| <i>Circumplicatipollis plicatus</i> | | x | | | | | |
| <i>Potonieisporites triangulus</i> | | x | | | | | |
| <i>Potonieisporites sp. cf. P. novicus</i> | | x | | | | | |
| <i>Potonieisporites sp.</i> | | x | | | | | |
| <i>Vallatisporites ciliaris</i> | | | | x | x | | |
| <i>Ahrensiporites sp. cf. A. cristatus</i> | | | | x | x | | |
| <i>Verrucosisporites cortaderensis</i> | | | | x | x | | |
| <i>Raistrickia densa</i> | | | | x | | x | |
| <i>Lophotriletes intermedius</i> | | | | x | x | x | |
| <i>Divarisaccus sp. cf. D. stringoplicatus</i> | | | | x | x | | |
| <i>Potonieisporites barrelis</i> | | | | x | x | | |
| <i>Reticulatisporites sp.</i> | | | | x | x | | |
| <i>Auroraspora sp.</i> | | | | x | x | | |
| <i>Tricidariporites gutii</i> | | x | | x | x | x | |
| <i>Apiculatisporis variornatus</i> | | x | x | x | | | |
| <i>Cristatisporites sp.</i> | x | x | x | | | | |
| <i>Vallatisporites sp.</i> | x | x | | | | | x |
| <i>Cristatisporites menendezii</i> | x | x | | | | | x |
| <i>Densosporites sp.</i> | x | x | | x | | x | x |
| <i>Cristatisporites stellatus</i> | x | x | | x | | x | x |
| <i>Potonieisporites magnus</i> | | x | | | x | | x |
| <i>Plicatipollenites sp. cf. P. malabarensis</i> | | x | | | x | | x |
| <i>Psomospora detecta</i> | | x | | | | | x |
| <i>Raistrickia sp. cf. R. superba</i> | | | | | | x | x |
| <i>Cristatisporites rollerii</i> | | | | | | x | x |
| <i>Calamospora hartungiana</i> | | | | | | x | x |
| <i>Grosusporites microgranulatus</i> | | | | | | x | x |
| <i>Raistrickia rotunda</i> | | | | | | | x |
| <i>Punctatisporites glaber</i> | | | | | | | x |
| <i>Punctatisporites malanzanensis</i> | | | | | | | x |
| <i>Indotriradites volkheimeri</i> | | | | | | | x |
| <i>Cristatisporites spinosus</i> | | | | | | | x |
| <i>Costatascyclus crenatus</i> | | | | | | | x |
| <i>Tetraporina sp.</i> | | | | | | | x |
| <i>Brazilea scisa</i> | | | | | | | x |
| <i>Verhyachium sp.</i> | | | | | | | x |
| <i>Gorgonisphaeridium spp.</i> | x | x | | | | x | x |
| <i>Baltisphaeridium sp.</i> | | x | | | | | |
| <i>Cymatiogalea sp.</i> | | | x | x | | | |

corded from this interval, *i.e.* *Vallatisporites ciliaris* (Luber) Sullivan, 1964; *Grossusporites microgranulatus*, *Ahrensia* *porites* sp. cf. *A. cristatus* Playford and Powis, 1979; *Raistrickia rotunda*; *R. densa*; *R.* sp. cf. *R. superba* (Ibrahim) Schopf, Wilson and Bentall, 1944; *Verrucosisporites cortaderensis* Perez Loinaze, 2005; *Lophotriletes intermedius* Azcuy, 1975a; *Cristatisporites rollerii* Ottone, 1989; *Calamospora hartungiana* Schopf in Schopf, Wilson and Bentall, 1944; *Divarisaccus* sp. cf. *D. stringoplicatus* Ottone, 1991, and *Potonieisporites barrelis* Tiwari, 1965. Pollen grains are also present (*Potonieisporites magnus* and *Plicatipollenites* sp. cf. *P. malabarensis*). Likewise, the spores *Apiculatisporis variornatus*, *Tricidarispores gutii*, *Densosporites* sp. and *Cristatisporites stellatus* were identified in the lower level too.

Sample 137 from the upper fossil-bearing interval (Tab. 1 and Fig. 2) exhibits an increase in the proportion of pollen (20%), as well as microplankton (acritarchs and zygne-matalean algae, ca. 2%). *Punctatisporites glaber* (Naumova) Playford, 1962; *P. malanzanensis* Ottone, 1989; *Indotriletes volkheimeri* (Azcuy) Perez Loinaze, 2008a; *Cristatisporites spinosus* Menéndez, 1965, and *Costatascyclus crenatus* have been also identified from this interval and they represent first occurrences in the section studied. Furthermore, the spores *Calamospora hartungiana*, *Grossusporites microgranulatus*, *Cristatisporites menendezii*, *C. stellatus*, *C. rollerii*, *Densosporites* sp., *Vallatisporites* sp., *Raistrickia rotunda*, *Raistrickia* sp. cf. *R. superba*, and the pollen grains *Potonieisporites magnus* and *Plicatipollenites* sp. cf. *P. malabarensis* occurring in the lower levels, appear in this interval. We also identified the Zygnematalean algae *Tetraporina* sp. and *Brazilea scisa* and the autochthonous acritarchs *Verhyachium* sp. Deunff, 1954 and *Gorgonisphaeridium* sp. Staplin, Jansonius and Pocock, 1965.

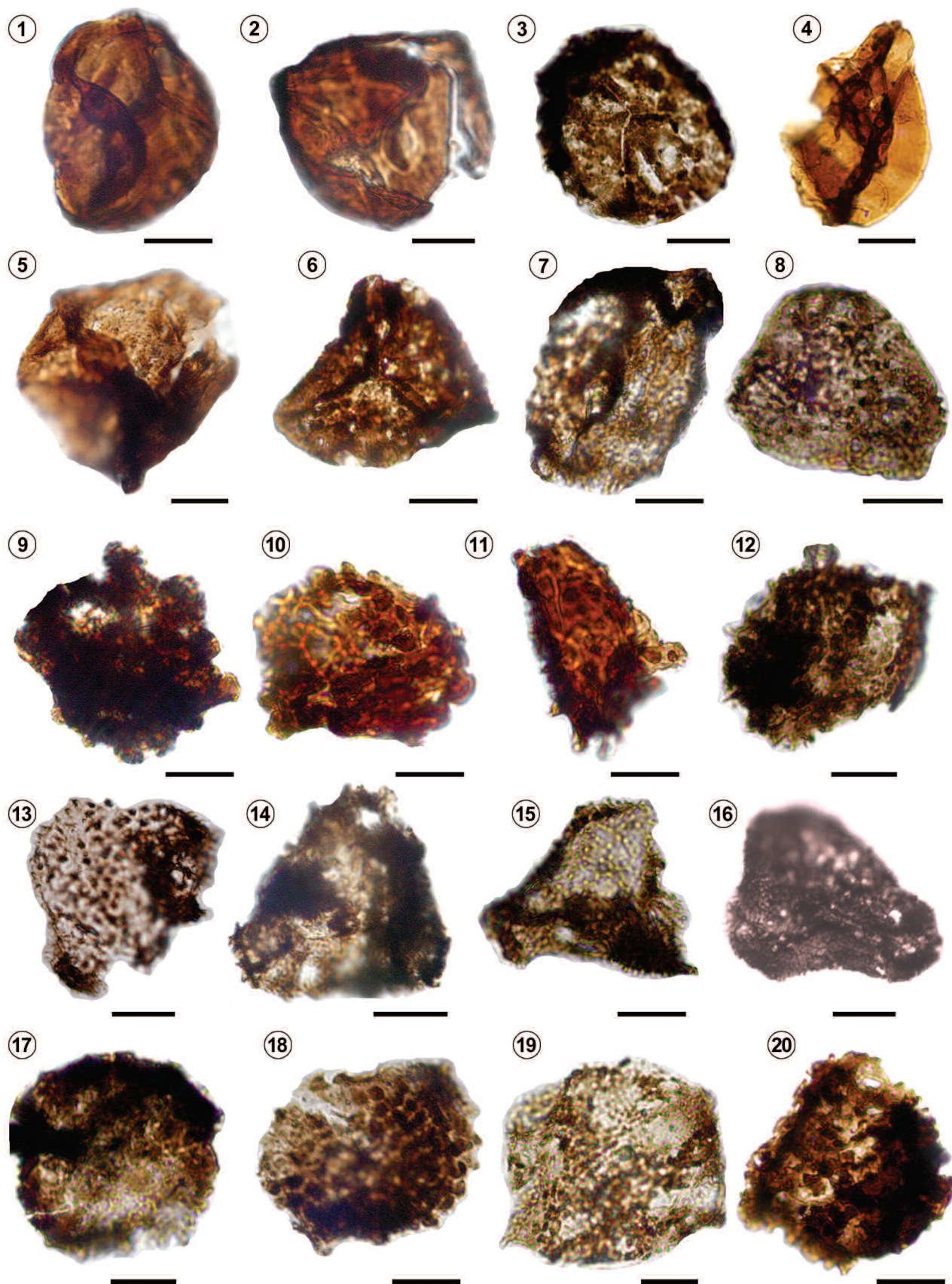
Age

The palynologic assemblages from the El Paso Formation yielded representative miospores from late Mississippian and Pennsylvanian Gondwanic strata such as *Apiculatisporis variornatus*, *Raistrickia densa*, *Spinozonotriletes hirsutus*, *Indotriletes volkheimeri*, *Cristatisporites menendezii*, *Vallatisporites ciliaris* and *Spelaeotriletes triangulus* (Césari and Gutiérrez, 2000; Césari and Limarino, 2002; di Pasquo, 2002; Souza *et al.*, 2003; Azcuy and di Pasquo, 2005, 2006; Perez Loinaze, 2008a,b; Perez Loinaze and Césari, 2012). Also recognized are some long-ranging taxa (Pennsylvanian to Early Permian) not useful for defining age, such as *Calamospora hartungiana*, *Grossusporites microgranulatus*, *Cristatisporites rollerii*, *Psomospora detecta*, *Costatascyclus crenatus*, *Plicatipollenites* sp. cf. *P. malabarensis* and *Potonieisporites magnus*.

The presence of monosaccate pollen grains with a first world record since the Serpukhovian (Stockey, 1981; Bruggman *et al.*, 1985; Loboziak and Clayton, 1988; Clayton *et al.*, 1990; Zhu, 1993; Clayton, 1995; Ouyang, 1996) is relevant from a biostratigraphic viewpoint, indicating an age not older than Serpukhovian for the palynoassemblages herein analyzed.

The appearance of pollen grains in the worldwide fossil record, together with the apparent rise of Cordaitalean or Coniferalean plants, was one of the most significant changes recorded in the late Mississippian or earliest Pennsylvanian. The synchronous global introduction of the monosaccate pollen grains may be reflecting the expansion of those groups of plants. These rapidly advanced towards dry upland niches previously occupied only marginally by pteridophytic and pteridosperm floras (Jones and Truswell, 1992).

Figure 4. 1, *Punctatisporites malanzanensis*, LILPB (Pm) INSUGEO 137 (2) EF: R 18; 2, *Punctatisporites glaber*, LILPB (Pm) INSUGEO 137 (2) EF: Q 58/4; 3, *Punctatisporites* cf. *P. trivialis*, LILPB (Pm) INSUGEO 132 (D) EF: M 37; 4, *Calamospora hartungiana*, LILPB (Pm) INSUGEO 136 (A) EF: Y 29; 5, *Grossusporites microgranulatus*, LILPB (Pm) INSUGEO 137 (1) EF: B 41/B 42; 6, *Leiotriletes* sp., LILPB (Pm) INSUGEO 132 (D) EF: K 25/4; 7, *Psomospora detecta*, LILPB (Pm) INSUGEO 132 (D) EF: V 26/V 27; 8, *Anapiculatisporites* sp. cf. *A. conccinus*, LILPB (Pm) INSUGEO 132 (A) EF: A 23; 9, *Raistrickia densa*, LILPB (Pm) INSUGEO 134 (2) EF: E 65; 10, *Raistrickia rotunda*, LILPB (Pm) INSUGEO 137 (3) EF: F 53; 11, *Raistrickia* sp. cf. *R. superba*, LILPB (Pm) INSUGEO 137 (4) EF: P 62/3; 12, *Apiculatisporis variornatus*, LILPB (Pm) INSUGEO 132 (D) EF: G 22; 13, *Lophotriletes intermedius*, LILPB (Pm) INSUGEO 135 (A) EF: G 43/3; 14, *Ahrensia* *porites* sp. cf. *A. cristatus*, LILPB (Pm) INSUGEO 135 (A) EF: G 43/3; 15, *Tricidarispores gutii*, LILPB (Pm) INSUGEO 135 (A) EF: Q 26/4; 16, *Tricidarispores gutii*, LILPB (Pm) INSUGEO 132 (A) EF: L 52/4; 17, *Cyclogranisporites rinconadensis*, LILPB (Pm) INSUGEO 132 (B) EF: J 23/4; 18, *Verrucosisporites cortaderensis*, LILPB (Pm) INSUGEO 135 (A) EF: H 49/2; 19, *Verrucosisporites chiqueritensis*, LILPB (Pm) INSUGEO 132 (F) EF: C 45/3; 20, *Cristatisporites menendezii*, LILPB (Pm) INSUGEO 131 (C) EF: E 38/1. EF, England Finder. Scale bar = 20 µm.



The first record of pollen grains from Upper Paleozoic sequences in Argentina corresponds to Subzone A of the *Raistrickia densa-Convolutispora muriornata* (DM) Biozone (Césari and Gutiérrez, 2000). The palynological assemblages that have been referred to this subzone came from beds of the Guandacol Formation. This palynoflora was also correlated with palynological assemblages described from the lower sections of the Agua Colorada, Malanzán, Lejenes and Lagares formations in central-western Argentina (Césari *et al.*, 2011; Perez Loinaze and Césari, 2012; Valdéz *et al.*, 2013).

Césari *et al.* (2011) assigned a probable chronostratigraphic range to the DM Biozone based on absolute ages (Gulbranson *et al.*, 2010) obtained from the strata containing fossil associations (flora and fauna) in different sequences of the Upper Paleozoic in western Argentina. Thus, $^{206}\text{Pb}/^{238}\text{U}$ 319.57 ± 0.09 Ma and 318.79 ± 0.10 Ma ages were established for the postglacial transgressive facies in the Guandacol Formation at levels immediately above the basal glacial deposits. These absolute ages confirm the biostratigraphic age of Subzone A and provide a minimum age constraint for this subzone (late Serpukhovian–Bashkirian; Césari *et al.*, 2011, p. 157). Therefore, the assemblages from glacial and postglacial deposits in the lower-middle section of the Guandacol Formation in the Cerro Bola area (La Rioja Province, Césari and Limarino, 2002; Valdéz *et al.*, 2013) and at Quebrada Los Pozuelos in the Huaco area (San Juan Province, Perez Loinaze and Césari, 2012) were constrained to an age not older than late Serpukhovian.

Other stratigraphically significant species herein identi-

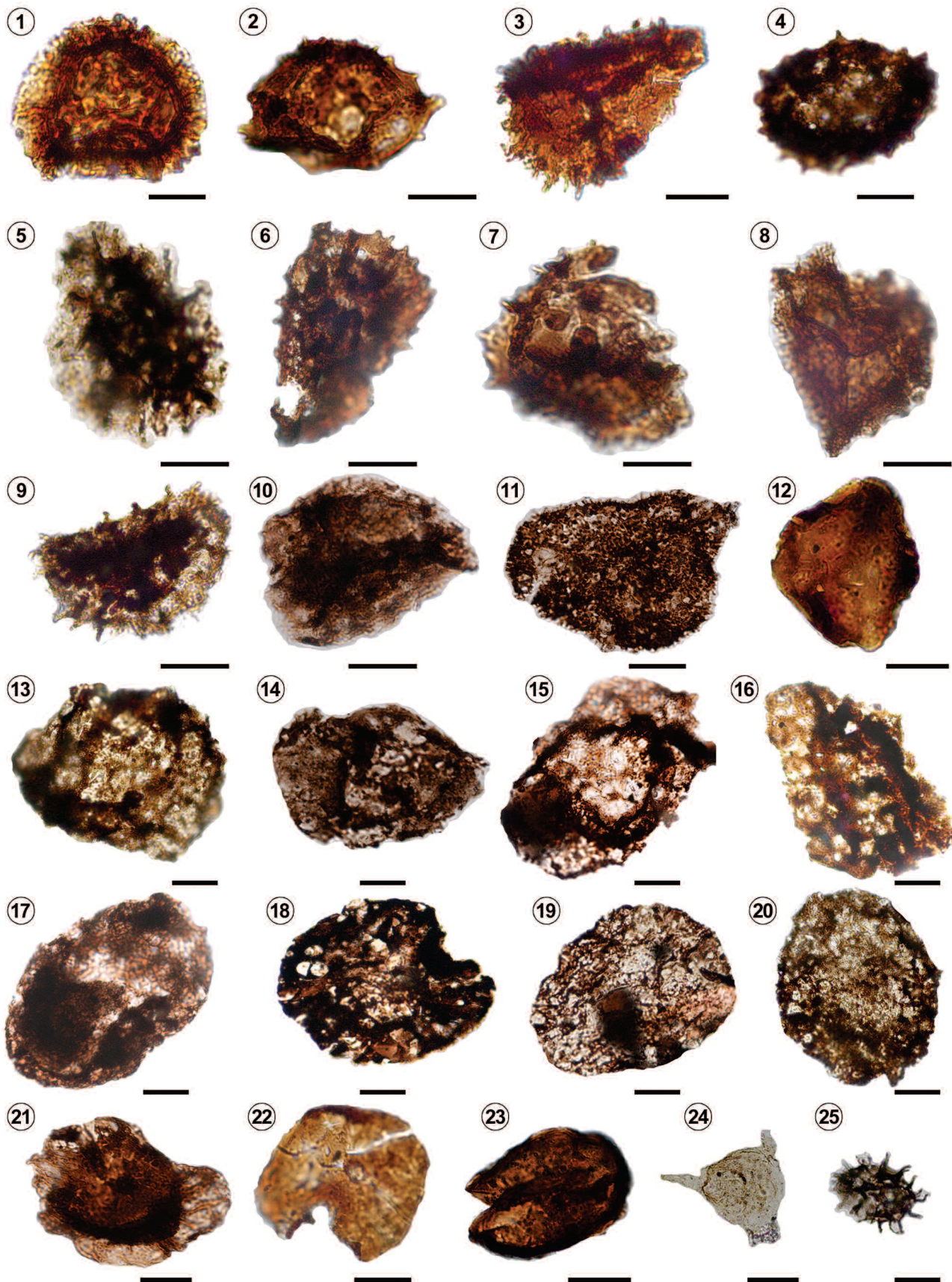
fied in the El Paso Formation are *Ahrensiporites cristatus* and *Psomospora detecta*, with a near-synchronous first appearance in the early Pennsylvanian strata of South America and Australia (Dino and Playford, 2002; di Pasquo, 2003).

The presence of *Tricidariporites gutii*, *Divarisaccus* sp. cf. *D. stringoplicatus* and *Costatascyclus crenatus* indicates a Pennsylvanian age (Gutiérrez, 1993; Playford and Dino, 2000; Félix and Souza, 2008; di Pasquo, 2009).

The *Reticulatisporites magnidictyus-Verrucosiporites quasigobbetti* (MQ) Interval Biozone from the Cortaderas Formation was assigned to the late Visean (Perez Loinaze, 2007). Its upper limit was established from the onset of the monosaccate pollen grains (not recorded yet in this zone) in the DM Zone, as a worldwide event synchronized in the Serpukhovian. It was indirectly related by Taboada (2010) to the *Rugosochonetes gloucesterensis-Bulahdelia* cf. *myallensis* invertebrate Biozone (Taboada, 1989, 2010) of the El Paso Formation. However, the presence of monosaccate pollen grains distinguishes the assemblages of the El Paso Formation from the Cortaderas Formation.

In addition, although the Cortaderas and El Paso formations share some palynological species such as *Apiculatisporis variornatus*, *Cristatisporites menendezii*, *Indotriradites volkheimeri*, *Raistrickia densa*, *Spinozonotriletes hirsutus* and *Vallatisporites ciliaris*, the major difference is the lack of pollen grains in the Cortaderas assemblages. Also, as indicated by Perez Loinaze (2007), the shared species are characteristic of the Upper Carboniferous of Argentina and Brazil (Perez Loinaze 2007, with references herein; Perez Loinaze *et al.*,

Figure 5. 1, *Cristatisporites menendezii*, LILPB (Pm) INSUGEO 137 (5) EF: K 51/1; 2, *Cristatisporites stellatus*, LILPB (Pm) INSUGEO 136 (A) EF: H 32/1; 3, *Cristatisporites spinosus*, LILPB (Pm) INSUGEO 137 (4) EF: X 61/4; 4, *Cristatisporites scabiosus*, LILPB (Pm) INSUGEO 131 (B) EF: V 37; 5, *Cristatisporites* sp., LILPB (Pm) INSUGEO 132 (D) EF: S 26; 6, *Vallatisporites* sp., LILPB (Pm) INSUGEO 137 (2) EF: O 26; 7, *Cristatisporites rollei*, LILPB (Pm) INSUGEO 137 (2) EF: Q 61/4; 8, *Indotriradites volkheimeri*, LILPB (Pm) INSUGEO 137 (2) EF: Q 20; 9, *Spinozonotriletes hirsutus*, LILPB (Pm) INSUGEO 132 (D) EF: M 37; 10, *Vallatisporites ciliaris*, LILPB (Pm) INSUGEO 135 (A) EF: K 24; 11, *Spelaeotriletes triangulus*, LILPB (Pm) INSUGEO 132 (B) EF: B 22/3; 12, *Densosporites* sp., LILPB (Pm) INSUGEO 137 (5) EF: W 44/1; 13, *Potonieisporites magnus*, LILPB (Pm) INSUGEO 132 (C) EF: L 29; 14, *Potonieisporites triangulatus*, LILPB (Pm) INSUGEO 132 (A) EF: A 26; 15, *Potonieisporites novicus*, LILPB (Pm) INSUGEO 132 (D) EF: J 36; 16, *Potonieisporites barrelii*, LILPB (Pm) INSUGEO 135 (A) EF: G 43/3; 17, *Divarisaccus* sp. cf. *D. stringoplicatus*, LILPB (Pm) INSUGEO 135 (1) EF: P 25/3; 18, *Plicatipollenites* sp. cf. *P. malabarensis*, LILPB (Pm) INSUGEO 132 (D) EF: T 69; 19, *Potonieisporites* sp., LILPB (Pm) INSUGEO 132 (D) EF: A 26; 20, *Circumplicatipollis plicatus*, LILPB (Pm) INSUGEO 132 (D) EF: D 22; 21, *Costatascyclus crenatus*, LILPB (Pm) INSUGEO 137 (1) EF: B 45/1; 22, *Tetraporina* sp., LILPB (Pm) INSUGEO 137 (3) EF: B 44; 23, *Brazilea scisa*, LILPB (Pm) INSUGEO 137 (5) EF: Y 41; 24, *Verhyachium* sp., LILPB (Pm) INSUGEO 137 (3) EF: W 60; 25, *Gorgonisphaeridium* sp., LILPB (Pm) INSUGEO 132 (B) EF: J 62. EF, England Finder. Scale bar= 20 µm.



2010) and they were recognized in assemblages of the Guandacol Formation and equivalents, assigned to Subzone A of the *Raistrickia densa-Convolutispora muriornata* Biozone of a younger late Serpukhovian–Bashkirian age (Césari *et al.*, 2011).

CONCLUSIONS

New palynological assemblages are described from the glaciomarine deposits of the El Paso Formation and they contain the first records of diagnostic species for this unit. The assemblages come from the middle-upper part of the section, associated with two fossil-bearing intervals characterized by a conspicuous invertebrate marine fauna.

Thirty-three spore species, and nine pollen-grain species, also four acritarch species and two Zygnematalean algae species are recognized. The spores *Retusotriletes incohatus*, *Reticulatisporites* sp., *Vallatisporites* sp., *Auroraspora* sp. and the acritarchs *Baltisphaeridium* sp., *Cymatiogalea* sp. and some species of the genus *Gorgonisphaeridium* can be considered as recycled palynomorphs. The presence of mono-saccate pollen grains supports a Serpukhovian maximum age and the comparison with other microfloras from the Guandacol, Jejenes, lower sections of the Agua Colorada, Malanzán, and Lagares formations. A late Serpukhovian–Bashkirian age is proposed for the El Paso Formation. The palynological assemblages contained in these units are referred to Subzone A of the *Raistrickia densa-Convolutispora muriornata* (DM) Biozone (Césari and Gutiérrez, 2000), considered to be late Serpukhovian–early Bashkirian (Césari *et al.*, 2011, p. 156, fig. 6; p. 157). The *Levipustula* fauna of the Hoyada Verde Formation is also assigned to the late Serpukhovian–early Bashkirian; consequently, both units would be time-equivalent.

ACKNOWLEDGMENTS

The authors wish to thank CONICET (Consejo Nacional de Investigaciones Científicas y Técnicas) PIP 0091 (GAC); PIP 112–201101–00571 (AFS); CIUNT 26 G–531 (MMV). We also acknowledge Dr. M. Martínez and O. López Gamundí for their help in the field work and valuable discussions on the stratigraphical aspects of the El Paso Formation.

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doi: 10.5710/AMGH.16.07.2015.2860

Submitted: December 1st, 2014

Accepted: July 16th, 2015