Accepted Manuscript

Palynomorphs from the Devonian Talacasto and Punta Negra Formations, Argentinean Precordillera: New biostratigraphic approach

Victoria J. García Muro, Claudia V. Rubinstein, Juan J. Rustán, Philippe Steemans

PII: S0895-9811(18)30151-2

DOI: 10.1016/j.jsames.2018.06.009

Reference: SAMES 1949

To appear in: *Journal of South American Earth Sciences*

Received Date: 6 April 2018

Revised Date: 12 June 2018

Accepted Date: 12 June 2018

Palynomorphs from the Devonian Talacasto and Punta Negra formations, Argentinean Precordillera: new biostratigraphic approach

García Muro, Victoria J. (corresponding author)

Instituto Argentino de Nivología, Glaciología y Ciencias Ambientales (IANIGLA), CCT CONICET Mendoza. Ruiz Leal s/n, Parque General San Martín. CP.: M5502IRA. Mendoza, Argentina. E-mail: vgarcia@mendoza-conicet.gov.ar.

Rubinstein, Claudia V.

Instituto Argentino de Nivología, Glaciología y Ciencias Ambientales (IANIGLA), CCT CONICET Mendoza. Ruiz Leal s/n, Parque General San Martín. CP.: M5502IRA. Mendoza, Argentina. E-mail: crubinstein@mendoza-conicet.gov.ar.

Rustán, Juan J.

Centro de Investigaciones en Ciencias de la Tierra (CICTERRA), Centro de Investigaciones Paleobiológicas (CIPAL), CONICET-Universidad Nacional de Córdoba. Av. Vélez Sarsfield 1611-1° piso of. 11. CP.: X5016GCA. Córdoba, Argentina. E-mail: juanjorustan@gmail.com

Steemans, Philippe

Palaeogeobiology - Palaeobotany - Palaeopalynology, Allée du 6 Août, Bât. B-18, parking 40, University of Liège, B-4000 Liège 1, Belgium. E-mail: p.steemans@ulg.ac.be

Abstract

Marine and terrestrial palynomorphs from the Loma de los Piojos section of the Precordillera Basin, western Argentina, were analyzed. The studied section embraces the upper part of the Lower Devonian Talacasto Formation and the whole Lower-Middle? Devonian Punta Negra Formation, which constitute the Gualilán Group. Terrestrial palynomorphs dominate the Lower Devonian Talacasto Formation whereas marine palynomorphs dominate the Lower-Middle? Devonian Punta Negra Formation. Even though palynomorphs are scarce, poorly preserved, and marked by low diversity, they enable, together with previous palynological data, a new biostratigraphic interpretation for the Devonian units of the Gualilán Group. In addition, an age reassessment of the guide horizon of Keidel (1921), and a correlation of sections from different parts of the basin are provided. Based on palynological data, the age of the Talacasto Formation is constrained to the Lochkovian-late Pragian and the age of the Punta Negra Formation is now considered to be restricted to the late Pragian-Emsian, although a younger age for the uppermost part of Punta Negra is possible.

Keywords

Devonian; Argentinean Precordillera; organic-walled phytoplankton; miospores; biostratigraphy.

1. Introduction

Paleobiogeographic particularities of the Devonian basins from Southwestern Gondwana have greatly hindered regional or wider biostratigraphic accuracy based on faunas. This region, known as the Malvinokaffric Realm (Richter and Richter, 1942), corresponds to a major marine paleobiogeographic unit developed in circum-polar austral cool/cold water settings, mainly recognizable from the Lower-Middle Devonian of southern South America, South Africa and Antarctica. It is characterized by the virtual absence of typical Paleozoic biostratigraphic guide groups such as conodonts, graptolites and goniatites (Boucot and Racheboeuf, 1993) and the endemism of its faunas in South American basins, except in the northernmost ones. Accordingly, palynostratigraphy has proven to be critical in order to reach biostratigraphic proposals for international comparisons and correlations of the Malvinokaffric sedimentary successions (e.g. Grahn, 2002, 2005; Loboziak and Melo, 2002; Melo and Loboziak, 2003; Rubinstein et al., 2005, 2008; Troth, 2011; Grahn et al., 2013). However, in the Precordillera Basin of central-west Argentina, the palynology of the Lower Devonian successions is still poorly known.

The Early-Middle Devonian of the Central Argentine Precordillera is represented by the Gualilán Group (Baldis, 1975), which includes the Talacasto (Padula et al., 1967) and the Punta Negra (Bracaccini, 1949) formations. Despite their extensive exposures, the age of these units has been debated for many decades. Hence, the ages of both formations have been proposed based on alternative macrofaunistic groups, mainly brachiopods and trilobites (e.g. Benedetto et al., 1992; Herrera, 1993, 1995; Herrera and Bustos, 2001; Holloway and Rustán, 2012). Even though the information provided by these benthic groups has been relevant, in many cases, comprehensive revisions are needed, particularly taking into account changes in the stratigraphic range of index taxa, derived either from new worldwide findings or from age revisions of the units from which they were originally reported.

The first palynological reports from these Devonian units were restricted to the basal part of the Talacasto Formation at Cerro del Fuerte locality (Le Hérissé et al., 1997) and two levels of the Punta Negra Formation in the Talacasto Creek (Rubinstein, 1999, 2000). Although these papers represent very relevant biostratigraphic studies in the region, they also include inconsistencies in the species designation that require further revision.

Recently, more extensive palynological studies from the Talacasto and Punta Negra formations were carried out at Cerro La Chilca and Talacasto Creek areas (García Muro et al., 2017). The recorded assemblages, dominated by marine organic walled microphytoplankton, allow constraining the age of the Talacasto Formation to the Lochkovian- probably late Pragian and the lower part of the Punta Negra Formation to the early Emsian. Furthemore, the age of the marker horizon identified by Keidel (1921) and Astini (1991) was restricted to the late Pragian-early Emsian. Paleobiogeographically, the record of typical Gondwanan taxa suggested affinities with this paleocontinent.

In the present contribution, the upper part of the Talacasto Formation and the complete Punta Negra Formation at Loma de los Piojos, where the thickest Devonian successions crop out, were analyzed. In a reliable stratigraphic framework controlled by the Keidel marker horizon, the record of new palynological data contributes to better constrain the ages and the stratigraphic relationships around the boundary of these units and to accurately date the guide stratigraphic horizon involved.

1.1. *Geological setting of the Gualilán Group*

The Devonian outcrops of the Gualilán Group, extend mainly along the Central Precordillera, in the Province of San Juan, extend with a north-south alignment for more than 150 km, from Río Jáchal in the north to Río San Juan in the south (Fig. 1). Some additional outcrops, lateral equivalents to the lower part of the Talacasto Formation, were recognized in the Province of La Rioja, nearly 170 km to the north of the Jáchal área (Rubinstein et al., 2010; Rustán and Vaccari, 2010a).

The Talacasto Formation overlies the mainly Upper Silurian Los Espejos Formation by a paraconformity (Astini and Maretto, 1996). To the south, the hiatus encompasses a Ludlow to lowest Lochkovian interval. However, to the north, near the Jáchal river the Silurian-Devonian boundary has been recognized in the uppermost interval of the Los Espejos Formation (Benedetto et al., 1992; Carrera et al., 2013; García Muro et al., 2014a; García Muro and Rubinstein, 2015).. The lower part of the unit typically displays Lochkovian to Pragian intensely bioturbated dark mudstone levels (Fig. 2), interpreted as an external muddy platform with no influence of wave action and a low sedimentation rate (Astini, 1991). Towards the top, it passes to sand-rich deposits influenced by wave action (Astini, 1991; Carrera and Rustán, 2015; Rustán and Balseiro, 2016). The Talacasto Formation was considered as a muddy-shelf depositional system, developed during a high stand (Astini, 1991).

The upper part of the Talacasto Formation contains a nearly 10 m-thick distinctive ochre, nodule-bearing fossiliferous horizon, interpreted as a marker horizon by Keidel (1921) and Astini (1991). The Punta Negra Formation overlies the Talacasto Formation by a paraconformity that is younger to the north (Salas et al., 2013 and references therein). In the southern sections near the San Juan river, the Punta Negra Formation lies directly above Keidel's horizon through a 40 m-thick interval of alternating purple and green pelites (García Muro et al., 2017). By contrast, in the Loma de los Piojos locality (Fig. 1), the Talacasto Formation extends ca. 300 m above Keidel's horizon (Rustán, 2016), and the overlying Punta Negra Formation includes at the lower part ca. 210 m of light green mudstones. According to the palynological results at the Cerro La Chilca section (García Muro et al., 2017), the layers of the Talacasto Formation located immediately above Keidel´s marker horizon would be Pragian to possibly late Pragian in age, in contrast with the previously proposed early Emsian age based on brachiopods (Herrera, 1993, 1995; Rustán and Vaccari, 2010b; Salas et al., 2013; Sterren et al., 2015; Rustán, 2016; Cichowolski and Rustán, 2017).

Toward the top, the Punta Negra Formation consists of a coarser and thicker succession of intercalated green to blackish-green sandstones and siltstones (Fig. 2). In the Loma de Los Piojos section, the Punta Negra Formation is not arrange in such typical tabular heterolithic rhythmic layers as in the type section in the San Juan river area. The uppermost part of the unit is covered by the Upper Carboniferous glacial diamictite of the Guandacol Formation (Cuerda, 1965). The depositional environment of the Punta Negra Formation has been extensively discussed and interpreted as deposits of submarine fans (e.g. González Bonorino, 1975), a submarine fan with storm events (Herrera and Bustos, 2001), deltaic deposits (Bustos and Astini, 1997) or shallow low-energy marine deposits evolving towards turbiditic sandstone beds (Edwards et al., 2009).

The Loma de los Piojos section is located ca. 8 km southwest of Jáchal city. In this locality, the Talacasto Formation reaches 1145 m, the maximum thickness of the unit. In turn, the Punta Negra Formation is approximately 1000 m thick to the south of the basin whereas in the surveyed transect it is restricted to nearly 350 m due to a strong erosive paleorelief filled with the glacial diamictites representing the base of the Carboniferous Guandacol Formation. On the basis of the trilobite *Acanthopyge* (*Lobopyge*) *balliviani* (Kozłowski, 1923) reported by Rustán and Vaccari (2010a) in the very same transect, the layers located about 250 m above the base of the Punta Negra Formation were considered Middle Devonian in age. Taking into account the lithology, the stratigraphic position and the brachiopod fauna, such as *Salopina* and *Metaplasia* (L. Benedetto, personal communication), these strata were correlated with those reported in a similar stratigraphic position at the southwest Río de las Chacritas section and dated as Emsian by Herrera and Bustos (2001).

2. Materials and Methods

Fifty palynological samples from the Loma de los Piojos locality in an east-west transect situated at 30º 18,504’ S/68º 47,399’ W were analyzed. Fifteen samples were collected from the upper 250 m of the Talacasto Formation and 35 samples from the lower 320 m of the Punta Negra Formation, that is up to the erosive discordance of the base of the Upper Carboniferous Guandacol Formation (Fig. 2).

The samples were processed in the Palaeopalynology Laboratory of IANIGLA, CCT CONICET Mendoza, Argentina, using the standard palynological HCl–HF–HCl acid maceration technique (Traverse, 2007). The organic residue was sieved through a 10 µm mesh and, when necessary, oxidized for 1 or 2 minutes with nitric acid (HNO_3). The palynomorphs were mounted in glycerin jelly as permanent palynological slides and examined using light microscopy and differential interference contrast (DIC) when the palynomorphs were transparent.

A set of samples from the Punta Negra Formation, which yielded scarce palynomorphs, was also processed at the University of Liège, Belgium. The samples were processed by a similar acid maceration technique, although all of them were oxidized in low-grade Schulze solution (HNO_3 and $KClO_3$) and sieved through a 12 µm mesh. The samples corresponding to each level are listed in Table 1 and numbered from 1 to 50, from the bottom to the top of the section.

The slides are housed in the palaeopalynological collection of IANIGLA, CCT CONICET Mendoza, Argentina. Each figured palynomorph is located by slide numbers and England Finder coordinates between brackets.

3. Results

The Talacasto and the Punta Negra formations at the Loma de los Piojos section, yielded poorly preserved marine and terrestrial palynological assemblages of low diversity. Palynomorph identifications at the species or generic level were possible in a total of 26 levels, and they are illustrated in Figures 3-5. In the other levels, the palynomorphs were carbonized, broken and dark brown to black in color, thus hindering their identification even as a marine or terrestrial group.

The studied section of the Talacasto Formation, which ranges from two meters below Keidel's horizon up to the top of the formation, nearly 250 m above such horizon, yielded badly preserved palynomorphs. In most of the levels, only a few palynomorphs, mainly miospores, were identified (Fig. 3). The presence of trilete spores cf. *Verrucosisporites* sp. and ?*Knoxisporites riondae*, in the lowermost studied level is highlighted. The following levels lack biostratigraphically relevant palynomorphs.

The uppermost studied level of the Talacasto Formation (level 15), located approximately 230 m above Keidel's horizon, yielded the most abundant and diversified assemblage, with 10 miospore species, four organic-walled microphytoplankton species, and two fresh water acritarchs. Trilete spores that first appear in the Early Devonian, such as *Dibolisporites echinaceus*, *Dictyotriletes emsiensis* Morphon and ?*Knoxisporites riondae*, were recognized in this level. This is the only level containing some identifiable marine organic-walled microphytoplankton species, such as *Diexallophasis remota* Group and *Veryhachium trispinosum* Group, although they are biostratigraphically widely distributed in Lower Paleozoic rocks and thus not useful to accurately date this part of the section.

The Punta Negra Formation yielded a more diverse and better preserved palynomorph assemblage than the Talacasto Formation. The marine organic-walled microphytoplankton was more abundant and diverse than the terrestrial palynomorphs. A few fresh water acritarch taxa are also present (Figs. 4 and 5). The lower light green mudstone-rich interval of approximately 210 m yielded very scarce species such as *Schizocystia saharica* and *Estiastra rugosa*. Upwards in the sequence, in level 32, close to the coarser succession of intercalated greenish-gray wackes and siltstones, some miospores including *Cymbosporites proteus* occur. Levels 33 to 39 contained some biostratigraphically relevant organic-walled microphytoplankton species such as *Bimerga paulae* and *Navifusa bacilla*, and the miospore *Chelinospora verrucata* Morphon. The upper 80 m of the section, below the Carboniferous diamictite of the Guandacol Formation, yielded poorly preserved palynomorphs with no biostratigraphic value.

The complete list of species recorded in the section is given in the appendix. The corresponding illustrations are depicted in Figures 6-10.

4. Discussion

4.1. *Biostratigraphy*

Le Hérissé et al. (1997) studied the lower part of the Talacasto Formation recording more than 50 species with scarse biotratigraphic value. Nevertheless, according to these authors, the chitinozoan *Urochitina loboi* Volkheimer et al., 1986, the acritarchs *Demorhethium lappaceum* Loeblich and Wicander 1974 and *Schizocystia pilosa*, and the trilete spores *Dibolisporites echinaceus* and *Dictyotiletes emsiensis* Morphon, would suggest a maximum Lochkovian age for this part of the unit. Later, the Silurian/Devonian boundary was recognized within the underlying Los Espejos Formation by García Muro et al. (2014a) based on palynomorphs. These authors dated the uppermost 6.25 m of the Los Espejos Formation and the basal 31.5 m of the

Talacasto Formation at the Río Jáchal locality as Lochkovian. This age is supported by the occurrence of the spores cf. *Streelispora newportensis* (Chaloner and Streel) Richardson and Lister 1969, cf. *Dictyotriletes emsiensis* Morphon, *Cymbosporites paulus*? in Wellman (1993) and the phytoplankton species *Schizocystia pilosa* and *Polyedryxium condensum* in the upper part of the Los Espejos Formation. *Streelispora newportensis* is one of the index species of the early Lochkovian MN Biozone defined by Richardson and McGregor (1986) for the Old Red Sandstone continent, and also of the equivalent *micrornatus-newportensis* Biozone erected by Streel et al. (1987). This species was also recorded in the Peri-Gondwanan terrane of Spain (Richardson et al., 2001) and the Moesian Terrane (Steemans and Lakova, 2004). The miospores *Dibolisporites echinaceus* and *Breconisporites* sp. from the lower part of the Talacasto section, would be consistent with that age.

In a recent contribution of García Muro et al. (2017), a comprehensive revision of previous palynological data was performed, and new palynological assemblages from the Talacasto Formation and the lower part of the Punta Negra Formation, from different localities, were studied. The lower 15 m of the Talacasto Formation at the Cerro La Chilca locality yielded palynomorph taxa suggesting a Lochkovian *s.l.* age, such as *Schizocystia pilosa* and *Winwaloeusia distracta* (Deunff) Deunff 1977, and the trilete spore *Dictyotriletes emsiensis* Morphon. The upper 850 m of the sequence yielded organic-walled microphytoplankton species such as *Palacanthus ledanoisii* and *Polyedryxium* cf. *P. decorum*, and spores such as *Dictyotriletes favosus* McGregor and Camfield 1976 and ?*Knoxisporites riondae*, that would indicate a Pragian to late Pragian age. According to these findings, the Lochkovian/Pragian boundary would occur in the lowest 15 m of the Talacasto Formation at the Cerro La Chilca locality. These results would contradict the age assigned to the stratigraphic unit based on fauna evidence, in which the Lochkovian/Pragian boundary was generally located hundreds of meters above the base of the Talacasto Formation and the uppermost part of the unit was assigned to the Emsian (Herrera, 1993, 1995).

The lowermost level of the Talacasto Formation studied herein, located 2 m below the guide horizon of Keidel at the Loma de los Piojos locality, yielded a few poorly preserved palynomorphs. However, a specimen of ?*Knoxisporites riondae* and a specimen of cf. *Verrucosisporites* sp. were recorded. The oldest record of ?*Knoxisporites riondae* comes from the San Pedro Formation, northern Spain, dated as "post-Ludlow-Pridoli?" or, most probably, as earliest Lochkovian by Cramer and Diéz (1975) and Rodriguez (1978). Nevertheless, no megafossil independent age control was available. It is noteworthy that ?*Knoxisporites riondae* is a common species in the Pragian/Emsian boundary in Gondwanan and peri-Gondwanan regions (e.g. Steemans, 1989; Breuer and Steemans, 2013).

The sample from Keidel's horizon (level 2) did not provide recognizable palynomorphs, although some phytoclasts and possible miospores were recorded. The remaining section, that consists of the upper 248 m, yielded some miospore specimens, such as cf. *Acinosporites* sp., *Dibolisporites* sp., *Dictyotriletes* sp., and cf. *Dibolisporites echinaceus*. Even though these taxa are already present in the Lochkovian and some of them extend higher in the Devonian, their occurrence would not contradict a possible late Pragian age suggested for the lowermost studied levels.

The uppermost studied level (15) from the Talacasto Formation yielded miospores such as *Dictyotriletes emsiensis* Morphon, *Cymbohilates* sp. and *Apiculiretusispora* sp., as well as additional specimens of ?*Knoxisporites riondae* (Fig. 3). This assemblage would be consistent with a late Pragian age proposed for the lower levels that were sampled herein, especially due to the presence of ?*Knoxisporites riondae* and the lack of taxa that first appear in the Emsian. Moreover, it should be considered that equivalent levels of the Talacasto Formation above Keidel's horizon at the Cerro La Chilca locality were also interpreted as late Pragian based on palynomorphs (García Muro et al., 2017). Thus, the Emsian age assigned for the upper part of the Talacasto Formation based on faunal evidence (e.g. Herrera, 1993), would not be supported by the palynomorphs recorded at the Loma de los Piojos locality. Le Hérissé et al. (1997) proposed an Emsian age for strata located 112 m above the boundary with the underlying Los Espejos Formation at the northern Cerro del Fuerte locality. However, this age was based on doubtfully classified chitinozoans that need further revision. Consequently, the Emsian age for the Talacasto Formation is not based on trustworthy biostratigraphic data.

Rubinstein (1999, 2000) dated the Punta Negra Formation exposed in the northern margin of the Talacasto Creek as Eifelian-Givetian based on badly preserved palynomorphs, of which some were misidentified, such as *Arkonites bilixus* Legault 1973, *Emphanisporites annulatus* McGregor 1961 and *Verrucosisporites scurrus*

(Taugourdeau-Lantz) Richardson and McGregor 1986 (Rubinstein, 1999, p. 15; figure 2). According to Rubinstein (2000), the presence of chitinozoans doubtfully assigned as *Fungochitina pilosa* (Collinson and Scott, 1958) and ?*Ancyrochitina langei* (Sommer and van Boekel, 1964) would point to a middle-late Givetian age. Moreover, the acritarch identified as *Bimerga bensonii* Wood 1995 was considered as an element confirming the Middle Devonian age (Rubinstein, 2000); yet, a taxonomic revision reassigned it to *Bimerga paulae* Le Hérissé 2011, restricting its stratigraphic range to the Pragian-Emsian interval (Le Hérissé, 2011; Daners et al., 2017; Rubinstein et al., in press). Thus, a reappraisal of these assemblages suggests an age not younger than Emsian for the bearing levels. According to García Muro et al. (2017), the lowest part of the Punta Negra Formation (40 m), close to the sample location of Rubinstein (1999, 2000), in the Talacasto Creek, would not be older than Early Emsian in age due to the occurrence of marine palynomorphs such as *Navifusa bacilla* (Molyneux et al., 1996; Fatka and Brocke, 2008).

The shales and mudstones from the lower part of the Punta Negra Formation at Loma de los Piojos yielded poorly preserved palynomorphs, some of which could be reworked. Such is the case of the cryptospore *Artemopyra brevicosta*, recorded in level 17, which ranges worldwide from the Wenlock to the Lochkovian (Steemans et al., 2007). The trilete miospore *Emphanisporites protophanus*, recorded in level 27, could also be reworked, as its younger records correspond to the Pridoli (Steemans et al., 2007). Therefore, the basal part of the formation could not be accurately dated based on the palynomorphs hereby recognized.

Cymbosporites proteus, recorded in level 32, first appears in the Lochkovian MN Zone (Richardson and McGregor, 1986; Streel et al., 1987; Steemans, 1989) and ranges up to the Emsian (McGregor and Camfield, 1976; Rodriguez, 1978). However, no Emsian stratigraphic markers were found in this part of the unit and, consequently, an age younger than Pragian cannot be assumed.

In level 33 from the Punta Negra Formation, two specimens of *Bimerga paulae* were recorded. As stated above, this Gondwanan species would have a short biostratigraphic distribution corresponding to the late Pragian-early Emsian, with records in Brazil (e.g. Le Hérissé, 2011; Mendlowicz Mauller et al., 2007), Bolivia -as *B. bensonii* variant A (Pérez-Leyton, 2007; Wood, 1995)-, Argentina -as *B. bensonii*

(Rubinstein, 2000)- and Uruguay (Daners et al., 2017; Rubinstein et al., in press). Le Hérissé (2011) also pointed out that *B. bensonii* would be typically recorded in younger ages, from the late Eifelian to the Givetian strata, and that the specimen of *B. paulae* recognized by Lange (1967) in the Famennian of the Amazonas Basin in Brazil could be considered as reworked. Therefore, the occurrence of *B. paulae* in level 33 would indicate an age restricted to the late Pragian/early Emsian for this part of the unit, approximately 210 m above the base of the Punta Negra Formation in the Loma de los Piojos section (Fig. 2).

A single specimen of *Latosporites* sp. 1 in Breuer and Steemans (2013) was recorded upward in the section of the Punta Negra Formation, in level 34. According to these authors, this species first appears in the Eifelian, wheras *L. ovalis* is constrained to the Pragian-Emsian. However, *Latosporites* sp. 1 in Breuer and Steemans (2013) is only known from Saudi Arabia, thus inhibiting its biostratigraphic use. The other recorded species from the same level, such as *Archaeozonotriletes chulus*, *Cymatiosphaera* sp., *Polyedryxium* sp. and the *Veryhachium trispinosum* Group, are not germane for determining a precise age.

Riculasphaera fissa, a species formerly considered to be restricted to the Lochkovian (e.g. Loeblich and Drugg, 1968; Loeblich and Wicander, 1976; Wicander, 1986; Limachi et al., 1996; Rubinstein et al., 2008; Vavrdová et al., 2011), was recorded in level 35. This species was also recognized in the Pragian of the Talacasto Formation (García Muro et al., 2017); thus, this findings would confirm a younger stratigraphic range for this species. Interestingly, Turnau and Racki (1999) illustrate a *Pterospermella* sp. (Plate IV, 15; p. 260) in the Givetian of Poland that actually seems to correspond to a *Riculasphaera fissa* specimen, similar to those illustrated by Rubinstein et al. (2008; fig. 7, 4; p. 180).

Few biostratigraphically relevant species, such as *Navifusa bacilla* in level 37, ?*Knoxisporites riondae* in level 38 and *Chelinospora verrucata* Morphon in level 39, appear upward in the section. *Navifusa bacilla* is known in Devonian strata since the Emsian (Molyneux et al., 1996; Fatka and Brocke, 2008; Grahn et al., 2013) and *C. verrucata* Morphon last appears in the Emsian (McGregor and Camfield, 1976; García-Muro et al., 2014b and references therein). Thus, the stratigraphic interval from levels 37 to 39 of the Punta Negra Formation at the Loma de los Piojos locality, approximately at 230 m above the base of the Punta Negra Formation, would be restricted to the Emsian.

Level 40 corresponds to the location in which the trilobite *Acanthopyge bolliviani* was collected (Rustán and Vaccari, 2010a; Salas et al., 2013). This taxon is considered Middle Devonian in South America (Salas et al., 2013 and references therein). Even though the few and poorly preserved spores herein recognized, such as cf. *Acinosporites* sp., *Dibolisporites* sp. and *Dictyotriletes* sp., are not useful to accurately date this level, the occurrence of *Schizocystia pilosa* would not support an age younger than Early Devonian (García Muro et al., 2017 and references therein).

The upper part of the section contains palynomorphs that would point to an Early Devonian age. The acritarch species *Veryhachium trispininflatum*, and the miospore *Raistrickia* sp., are the most relevant taxa from level 41. The uppermost levels yielded a few badly preserved palynomorphs with no biostratigraphic value, such as *Lophosphaeridium* sp. and *Veryhachium trispinosum* Group.

4.2. *Keidel´s guide horizon and age correlations of the Devonian stratigraphic units*

The new palynological information provided here has significant implications, particularly regarding the age and the stratigraphic relationships of Keidel´s guide horizon and the boundary between the Talacasto and the Punta Negra formations.

Keidel´s guide horizon was interpreted to be located around the Pragian-Emsian boundary. This horizon, which constitutes the top of the Talacasto Formation at its type locality at the Talacasto Creek, was initially referred to the earliest Emsian by Herrera (1993, 1995). Later, a late Pragian age for this bed, otherwise indicative of the top of assemblage biozone B of Herrera, was favored by Herrera (1995) based on the brachiopod *Australostrophia penoensis* Herrera, 1995. However, an early Emsian age was not excluded when considering the evolutionary stage of development of the median septum in this taxon. The presence of the chitinozoan *Bulbochitina bulbosa* (Paris 1981) in the upper part of the Talacasto Formation, in the Talacasto Creek, was mentioned by Le Hérissé et al. (1997). This finding would support a late Pragian age for this part of the unit because *Bulbochitina bulbosa* is the index species of the homonymous Interval Range Biozone (Paris et al., 2000). The palynological evidences provided in this contribution also excludes a posible Emsian age for Keidel´s horizon, supporting therefore a late Pragian age for such stratigraphic reference, very useful in the field. Additionally, this bed was correlated (Rustán and Vaccari, 2010b) with the seismic ‘‘marker’’ 4 of the SG Vll from the base of the Emsian in Bolivia (Albariño et al., 2002, p. 53), which has been related to a sudden rise of relative sea level after a strong eustatic fall displayed during the Pragian (Albariño et al., 2002; Álvarez et al., 2003).

This age constraining of the Keidel´s bed, enables alternative interpretations of the stratigraphic relationships between units conforming the Gualilán Group. According to the most accepted stratigraphic scheme, as shown in recent faunalistic contributions by Rustán and collaborators, layers immediately overlying the Keidel´s bed are laterally equivalents despite the changes of facies. However, recent palynological evidence suggests different ages for the layers overlying the Keidel´s bed from south to north. An Emsian age was suggested for the purple and green pelites in the southern Talacasto Creek area corresponding to the base of the Punta Negra Formation. Although, at northern sections, a probably late Pragian age is assumed for the uppermost greenish mudstones in the Cerro La Chilca section (García Muro et al, 2017) and for the greenish gray siltstones and very fine sandstones at the Loma de los Piojos section (this contribution), both corresponding to the upper part of the Talacasto Formation. In this last interpretation, a stratigraphic hiatus immediately above the Keidel´s bed should be invoked to explain the diachronism in layers in such a stratigraphic position along the basin.

This alternative hypothesis suggests that the base of the Punta Negra Formation would not be so broadly diachronic, so that the lowest purple and green pelites from the Talacasto Creek would be lateral equivalents to the green pelitic lowest interval of the Punta Negra Formation at the Loma de los Piojos section (levels 16 to 32 in this contribution). Meanwhile, they would not have equivalent stratigraphic records in the Cerro La Chilca section due to the erosion by the basal discordance of the Carboniferous Guandacol Formation. This could explain the absence of late Pragian layers overlying Keidel´s horizon in the Talacasto Creek locality, but its occurrence in the Cerro La Chilca section (García Muro et al., 2017), and to the north at the Loma de los Piojos section (Fig. 11). Further work is necessary in order to confirm this new stratigraphic proposal. Although based on scarse palynological information, it will have important implications for the classic brachiopod biostratigraphic scheme of Herrera

(1993, 1995). The pioneering biostratigraphic proposals by Herrera allowed the recognition of Lochkovian and Pragian ages in the Precordillera strata of the Gualilán Group that was previously considered exclusively Emsian. New palynological observations suggest that, particularly the Pragian, would be extensively represented.

Additional implications of data presented herein involve the Middle Devonian age proposed for the Punta Negra Formation in the Loma de los Piojos section, based on the occurrence of the trilobite *Acanthopyge* (*Lobopyge*) *balliviani* nearly 245 m above the base of the unit (Rustán and Vaccari, 2010a; Salas et al., 2013). Although the few and badly preserved palynomorphs herein recorded would not provide enough evidences to support a Middle Devonian age for this part of the section. In contrast, a possible Emsian age should not be excluded. Such a putative Emsian assignment would imply the first Lower Devonian reference for the trilobite *A.* (*L.*) *balliviani*, otherwise considered a Middle Devonian guide fossil in Bolivia. Besides, it would confirm the Emsian age based on brachiopods by Herrera and Bustos (2001) from equivalent layers in the Río de las Chacritas section, to the southwest of the basin.

5. Conclusions

The palynomorphs from the upper part of the Talacasto Formation, above Keidel' horizon, and the complete Punta Negra Formation, both from the Loma de los Piojos locality, were studied.

The upper part of the Talacasto Formation mainly yielded terrestrial palynomorphs that would suggest an age not younger than late Pragian.

The Punta Negra Formation contained a more diverse palynological assemblage, with more marine than terrestrial taxa. The lower pelitic part of the Punta Negra Formation yielded a few and badly preserved palynomorphs consistent with the late Pragian age proposed for the underling Talacasto Formation. Upwards in the section, in level 33, the late Pragian/early Emsian *Bimerga paulae* appears. The record of *Navifusa bacilla*, ?*Knoxisporites riondae*, and *Chelinospora verrucata* Morphon in the interval between levels 37 and 39 would confirm an Emsian age for this part of the unit. The palynological assemblages of the uppermost part of the stratigraphic section did not provide evidence for the age of this part of the unit.

Accordingly, based on palynological evidence, the age of the Keidel guide horizon is now constrained to the late Pragian. In a newly proposed stratigraphic interpretation, the stratigraphic interval immediately above Keidel´s horizon, would be Emsian in the southern sections, near Talacasto Creek, corresponding to the base of Punta Negra Formation, and to the late Pragian in the northern sections, near Jáchal, corresponding to the upper part of the Talacasto Formation.

Although the new biostratigraphic palynological data presented herein, encourage new stratigraphic interpretations for the units conforming the Gualilán Group, biostratigraphic information is still scarce and preliminary. Further work is still necessary to definitively date and correlate these formations in different parts of the Precordillera basin.

Acknowledgements

We thank B. Waisfeld and E. Vaccari (CICTERRA, Universidad Nacional de Córdoba) for helping with the field work. A. Moschetti and M. Giraldo are acknowledged for the palynological laboratory processing. We are grateful to R. Bottero for the drafting and to F. Carotti for the language revision of the manuscript before submission. We also thank Compañía Minera del Pacífico and Ing. E. Alonso for the permission to work at Loma de Los Piojos area and the city hall of the San José de Jáchal and C. Sarasqueta for building new ways to access to the stratigraphic section. We acknowledge to the reviewers R. Wicander and F. González as well as the regional editor F.J. Vega for their useful comments to improve the manuscript.

Funding: This work was supported by CONICET (PIP 11220120100364); FONCYT (PICT 2013-2206 and PICT 2015-0473) and CONICET-FNRS Project (Scientific Cooperation Program between Argentina and Belgium).

Declarations of interest: none.

References

Albariño, L., Dalenz Farjat, A., Alvarez, L., Hernandez, R., Pérez Leyton, M., 2002. Las secuencias sedimentarias del Devónico en el Subandino Sur y el Chaco. Bolivia y Argentina. 5º Congreso de Exploración y Desarrollo de Hidrocarburos. Trabajos técnicos. Mar del Plata, Buenos Aires.

Álvarez, L.A., Dalenz-Farjat, A., Hernández, R.M., Albariño, L., 2003. Integración de facies y biofacies en un análisis secuencial en plataformas clásticas devónicas del sur de Bolivia y noroeste Argentino. Revista de la Asociación Argentina de Sedimentología, 10, 103-121

Astini, R.A., 1991. Sedimentología de la Formación Talacasto: plataforma fangosa del Devónico precordillerano, Provincia de San Juan. Asociación Geológica Argentina, 66, 277-294.

Astini, R.A., Maretto. H.M., 1996. Análisis estratigráfico del silúrico de la Precordillera Central de San Juan y consideraciones sobre la evolución de la cuenca. XII Congreso Geológico Argentino., II Congreso de Exploración de Hidrocarburos. Actas 1, 351-368.

Baldis, B.A., 1975. El Devónico Inferior de la Precordillera Central. Parte I: Estratigrafía. Revista de la Asociación Geológica Argentina, 30, 53-83.

Balme, B.E., 1988. Miospores from Late Devonian (early Frasnian) strata, Carnarvon Basin, Western Australia. Palaeontographica, Abteilung B, 209, 109-166.

Benedetto, J.L., Racheboeuf, P.R., Herrera,Z., Brussa, E.D., Toro, B.A., 1992. Brachiopodes et biostratigraphie de la Formation de Los Espejos, Siluro-Dévonien de la Précordillère (NW Argentine). Geobios, 25, 599-637.

Boucot A.J., Racheboeuf, P.R., 1993. Biogeographic summary of the Malvinokaffric Realm Silurian and Devonian fossils: Revista Tecnica de Yacimientos Petroliferos Fiscales Bolivianos, 13, 71-75.

Bracaccini, O.I., 1949. El perfil de Tambolar. Revista de la Asociación Geológica Argentina, 4, 165-179.

Breuer, P., 2007. Devonian Miospore palynology in Western Gondwana: An application to oil exploration. Volume III: Taxonomy. Ph.D. thesis, Université de Liège.

Breuer, P., Steemans., P., 2013. Devonian Miospores from Northwestern Gondwana. Palaeontology, 89, 1-163.

Breuer, P., Al-Ghazi, A., Al-Ruwaili, M., Higgs, K.T., Steemans, P., Wellman, C.H. 2007. Early to middle Devonian miospores from northern Saudi Arabia. Revue de micropaléontologie, 50(1), 27-57.

Burgess, N.D., 1991. Silurian cryptospores and miospores from the type Llandovery area, Southwest Wales. Palaeontology, 34, 575-599.

Burgess, N.D., Richardson, J.B., 1991. Silurian cryptospores and miospores from the type Wenlock area, Shropshire, England. Palaeontology, 34, 601-628.

Bustos, U.D., Astini. R.A., 1997. Formación Punta Negra: análisis secuencial y evolución de la Cuenca Devónica Precordillerana. Asociación Geológica Argentina, 4, 97-109.

Carrera, M.G., Rustán, J.J., 2015. The new genus *Talacastospongia*: insights on the first record of a Devonian sponge from South America. Journal of Paleontology, 89, 912-919.

Carrera, M.G., Montoya, E., Rustán, J.J., Halpern, K., 2013. Silurian-Devonian coral associations across a sequence stratigraphic boundary in the Argentine Precordillera. Geological Journal, 48, 256-269.

Cichowolski, M., Rustán, J.J., 2017. First report of Devonian bactritids (Cephalopoda) from South America: paleobiogeographic and biostratigraphic implications. Journal of Paleontology, 91, 417-433.

Collinson, C.W., Scott, A.J., 1958. Chitinozoan faunule of the Devonian Cedar Valley Formation. Illinois State Geological Survey, 247: 34 pp.

Cramer, F.H., 1964. Microplankton from three Palaeozoic formations in the Province of León, NW Spain. Leidse Geologische Mededelingen, 30, 253-361.

Cramer, F.H., 1970. Distribution of selected Silurian acritarchs. An account of the palynostratigraphy and paleogeography of selected Silurian acritarch taxa. Revista española de micropaleontologia, número extraordinario, pp. 1-203.

Cramer, F.H., Diéz, M. del C., 1975. Earliest Devonian miospores from the province of Leon, Spain. Muséum National D'Histoire Naturelle, 17, 331-344.

Cuerda, A.J., 1965. *Monograptus leintwardinensis* var. *incipiens* Wood en el Silúrico de la Precordillera. Ameghiniana, 4, 171-178.

Daners, G., Le Hérissé, A., Breuer, P., Veroslavsky, G., 2017. Pragian–Emsian palynomorphs from the Cordobes Formation, Norte Basin, Uruguay: stratigraphically restricted and regionally correlative palynological events in the cool-water Malvinokaffric Realm. Palynology, 41, 121-137.

Deunff, J., 1955. Un microplancton fossile dévonien à Hystrichosphères du Continent Nord-Américain. Bulletin de microscopie appliquée, 2, 138-149.

Deunff, J., 1959. Microorganismes planctoniques du primaire Armoricain. I.- Ordovicien du Veryhac'h (presqu'ile de Crozon). Bulletin de la Société géologique et mineralogique de Bretagne, Nouvelle Sér., 2, 1-41.

Deunff, J., 1961. Quelques précisions concernant les Hystrichosphaeridées du Dévonien du Canada. Compte rendu sommaire des séances de la Société géologique de France, 8, 216-218.

Deunff, J., 1964. Le genre *Duvernaysphaera* Staplin. Grana Palynologica, 5, 210-215.

Deunff, J., 1971. Le genre *Polyedryxium* Deunff. Révision et observations. In. Jardiné, S. (Ed.), Microfossiles Organiques du Paleozoique, 3. Acritarches. Commission internationale de microflore du Paléozoique, Editions du Centre National de la Recherche Scientifique, Paris, p. 7-48.

Deunff, J., 1977. *Winwaloeusia*, genre nouveau d'acritarche du Dévonien. Géobios, 10(3), 465-469.

Dorning, K.J., 1981. Silurian acritarchs from the type Wenlock and Ludlow of Shropshire, England. Review of Palaeobotany and Palynology, 34, 175-203.

Edwards, D., Poiré, D.G., Morel, E.M., Cingolani, C.A., 2009. Plant assemblages from SW Gondwana: further evidence for high-latitude vegetation in the Devonian of Argentina. Geological Society, London, Special Publications, 325, 233-255.

Eisenack, A., 1955. Chitinozoen, Hystrichosphären und andere Mikrofossilien aus dem Beyrichia-Kalk. Senckenbergiana Lethaea, 36, 157-188.

Eisenack, A., Cramer, F.H., Díez, M. del C.R., 1973. Katalog der fossilen Dinoflagellaten, Hystrichosphären und verwandten Mikröfossilien. Band III Acritarcha 1. Teil. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, 1104 pp.

Eisenack, A., Cramer, F.H., Díez, M. del C.R., 1976. Katalog der fossilen Dinoflagellaten, Hystrichosphären und verwandten Mikrofossilien. Band IV Acritarcha 2. Teil. E. Schweizertbart'sche Verlagsbuchhandlung, Stuttgart, 863 pp.

Fatka, O., Brocke, R., 2008. Morphological variability and method of opening of the Devonian acritarch *Navifusa bacilla* (Deunff, 1955) Playford, 1977. Review of Palaeobotany and Palynology, 148, 108-123.

Fensome, R.A., Williams, G.L., Sedley Barss, M., Freeman, J.M., Hill, J.M., 1990. Acritarchs and fossil prasinophytes: an index to genera, species and infraspecific taxa. AASP Contribution Series, no. 25, AASP Foundation, 678 pp.

Furque, G., Baldis, B.A., 1973. Nuevos enfoques estratigráficos en el Paleozoico del noroeste de la Precordillera. 5º Congreso Geológico Argentino, Actas 3, 241-251. Córdoba.

García Muro, V.J., Rubinstein, C.V., 2015. New biostratigraphic proposal for the lower Palaeozoic Tucunuco Group (San Juan Precordillera, Argentina) based on marine and terrestrial palynomorphs. Ameghiniana, 52, 265-285.

García Muro, V.J., Rubinstein, C.V., Steemans, P., 2014a. Palynological record of the Silurian/Devonian boundary in the Argentine Precordillera, western Gondwana. Neues Jahrbuch für Geologie und Paläontologie Abhandlungen, 274, 25-42.

García Muro, V.J., Rubinstein, C.V., Steemans, P., 2014b. Upper Silurian miospores from the Precordillera Argentina: biostratigraphic, palaeonvironmental and palaeogeographic implications. Geological Magazine, 151, 472-490.

García Muro, V.J., Rubinstein, C.V., Rustán, J.J., 2017. Early Devonian organic-walled phytoplankton and miospores from the Precordillera Basin of San Juan, Argentina: biostratigraphic and paleobiogeographic implications. Palynology, 41, 138-157.

González Bonorino, G., 1975. Sedimentología de la Formación Punta Negra y algunas consideraciones sobre la geología regional de la Precordillera de San Juan y Mendoza. Revista de la Asociación Geológica de Argentina, 30, 223-246.

González, F., Moreno, C., Playford, G., 2005. Upper Devonian biostratigraphy of the Iberian Pyrite Belt, southwest Spain. Part two: organic-walled microphytoplankton. Palaeontographica, Abteilung B, 273, 53-86.

Grahn, Y., 2002. Upper Silurian and Devonian Chitinozoa from central and southern Bolivia, central Andes. Journal of South American Earth Sciences, 15, 315-326.

Grahn, Y., 2005. Devonian chitinozoan biozones of western Gondwana. Acta Geologica Polonica, 55, 211-227.

Grahn, Y., Mauller, P.M., Bergamaschi, S., Bosetti, E.P., 2013. Palynology and sequence stratigraphy of three Devonian rock units in the Apucarana Sub-basin (Paraná Basin, south Brazil): Additional data and correlation. Review of Palaeobotany and Palynology, 198, 27-44.

Herrera, Z.A., 1993. Nuevas precisiones sobre la edad de la Formación Talacasto (Precordillera Argentina) en base a su fauna de braquiópodos. XII Congreso Geológico Argentino y II Congreso de Exploración de Hidrocarburos (Buenos Aires), Actas II, 289-295.

Herrera, Z.A., 1995. The first Notanopliid brachiopod from the south American Devonian sequence. Geobios, 28, 337-342.

Herrera, Z.A., Bustos, U.D., 2001. Braquiópodos devónicos de la Formación Punta Negra, en el perfil de río de Las Casitas, Precordillera argentina. Ameghiniana, 38(4), 367-374.

Holloway, D.J., Rustán, J.J., 2012. The trilobite Reedops (Phacopidae) in the Lower Devonian of Argentina (Malvinokaffric Realm). Journal of Paleontology, 86, 253-257.

Jardiné, S., Combaz, A., Magloire, L., Peniguel, G., Vachey, G., 1972. Acritarches du Silurien terminal et du Dévonien du Sahara Algérien. Comptes rendus 7e Congrès international de stratigraphie et de géologie du Carbonifère, Krefeld, 1, 295-311.

Jardiné, S., Combaz, A., Magloire, L., Peniguel, G., Vachey, G., 1974. Distribution stratigraphique des Acritarches dans le Paléozoïque du Sahara Algérien. Review of Palaeobotany and Palynology, 18, 99-129.

Keidel, J., 1921. Observaciones geológicas en la Precordillera de San Juan y Mendoza. La estratigrafia y la tectónica de los sedimentos paleozoicos en la parte norte entre el Rio Jáchal y el Río San Juan. Anales del Ministerio de Agricultura, Sección Geología, Mineralogía y Minería, 15, 7-102.

Kozłowski, R., 1923. Faune devonienne de Bolivie. Annales de Paléontologie, 12, 1-112.

Lange, F.W., 1967. Subdivisão bioestratigráfica e rivisão da coluna siluro devoniana da Bacia do Baixo Amazonas. Atas do saimpósio sobre a Biota Amazônica (Geociências), Belén, 1: 215-326. In: Le Hérissé, A., 2011. A reappraisal of FW Lange's 1967 algal microfossil studies. Essays in Honour of Frederico Waldemar Lange: Editora Interciéncia Ltda, Rio de Janeiro, 151-179.

Le Hérissé, A., 1989. Acritarches et kystes d'algues Prasinophycées du Silurien de Gotland, Suède. Palaeontographia Italica, 76, 57-302.

Le Hérissé, A., 2011. A reappraisal of FW Lange's 1967 algal microfossil studies. Essays in Honour of Frederico Waldemar Lange. Editora Interciéncia Ltda, Rio de Janeiro, 151-179.

Le Hérissé, A., Rubinstein, C.V., Steemans, P., 1997. Lower Devonian palynomorphs from the Talacasto Formation, Cerro del Fuerte Section, San Juan Precordillera, Argentina. Acta Universitatis Carolinae Geologica, 40, 497-515.

Limachi, R., Goitia, V.H., Sarmiento, D., Arispe, O., Montecinos, R., Díaz-Martínez, E., Dalenz Farjat, A., Liachenco, N., Pérez-Leyton, M., Aguilera, E., 1996. Estratigrafía, geoquímica, correlaciones, ambientes sedimentarios y bioestratigrafía del Silúrico-Devónico de Bolivia. XII Congreso Geológico de Bolivia. Tarija, Bolivia, Tarija, Bolivia, 183-197.

Lister, T.R., 1970. The acritarchs and chitinozoa from the Wenlock and Ludlow Series of the Ludlow and Millchope areas, Shropshire. Palaeontographical Society Monographs, London, 1, 1-100.

Loboziak, S., Melo, J.H.G., 2002. Devonian miospore successions of Western Gondwana: update and correlation with Southern Euramerican miospore zones. Review of Palaeobotany and Palynology, 121, 133-148.

Loeblich, A.R.Jr., 1970. Morphology, ultrastructure and distribution of Paleozoic acritarchs. Proceedings of the North American Paleontological Convention, Chicago, 1969, part G, 2, 705-788.

Loeblich, A.R.Jr., Tappan, H., 1976. Some new and revised organic-walled phytoplankton microfossil genera. Journal of Paleontology, 50, 301-308.

Loeblich, A.R.Jr., Drugg, W.S., 1968. New acritarchs from the Early Devonian (Late Gedinnian) Haragan Formation of Oklahoma, USA. Tulane Studies in Geology, 6, 129-137.

Loeblich, A.R., Wicander, E.R., 1974. New Early Devonian (Late Gedinnian) microphytoplankton: *Demorhetium lappaceum* n.g., n. sp. from the Bois d'Arc Formation of Oklahoma, USA. Neues Jahrbuch für Geologie und Paläontologie, Monatshefte, 12, 707-711.

Loeblich, A.R., Wicander, E.R., 1976. Organic-walled microplankton from the Lower Devonian, late Gedinnian Haragan and Bois d'arc formations of Oklahoma, USA. Part I. Plaentographica, Abteilung B, 159, 1-39.

McGregor, D.C., 1973. Lower and Middle Devonian spores of eastern Gaspé, Canadá. I. Systematics. Plaentographica, Abteilung B, 142, 1-77.

McGregor, D.C., Camfield, M., 1976. Upper Silurian? to Middle Devonian spores of the Moose River Basin, Ontario. Geological Survey of Canadian Bulletin, 263, 63.

Melo, J.H.G., Loboziak, S., 2003. Devonian-Early Carboniferous miospore biostratigraphy of the Amazon Basin, Northern Brazil. Review of Palaeobotany and Palynology, 124(3-4), 131-202.

Mendlowicz Mauller, P., Machado Cardoso, T.R., Pereira, E., Steemans, P., 2007. Palynostratigraphic results on the Devonian of the Alto Garças Sub-basin (Paraná Basin-Brazil). In: I.S. Carvalho, R.C.T. Cassab, C. Schwank, M.A. Carvalh, A.C.S Fernandes, M.A.C Rodrigues, M.S.S. Carvalho, M. Arai, M.E.Q. Oliveira (Eds.), Paleontologia: Cenários de Vida. Editora Interciência Ltda., Rio de Janeiro, Vol. 2., 607-619.

McGregor, D.C., 1961. Spores with proximal radial pattern from the Devonian of Canada. Geological Survey of Canada Bulletin, 76, 1-11.

Molyneux, S.G., Le Hérissé, A., Wicander, R., 1996. Palaeozoic phytoplankton. In: Palynology: principles and applications. J. Jansonius and D.C. McGregor (Eds.). American Association of Stratigraphic Palynologist Fundation edition, 493-529.

Moreau-Benoit, A., 1976. Les spores et débris végétaux. In: Les Schistes et Calcaires éodévoniens de Saint-Cénéré (Massif Armoricain, France). Mémoires de la Société Géologiques et Minéralogique de Bretagne, Rennes, 19, 27-58.

Mullins, G.L., 2001. Acritarchs and prasinophyte algae of the Elton Group, Ludlow Series, of the type area. Monograph of the Palaeontographical Society, London, 155(616), 1-154.

Naumova, S.N., 1953. Spore-pollen assemblages of the Upper Devonian of the Russian Platform and their stratigraphic significance. Akademiya Nauk SSSR, Institut Geologii Nauk 143, Geological Series, 60, 203. (in Russian).

Ottone, E.G., 1996. Devonian palynomorphs from the Los Monos Formation, Tarija Basin, Argentina. Palynology, 20, 105-155.

Ottone, E.G., Rossello, E.A., 1996. Palinomorfos devónicos de la Formación Tequeje, Angosto del Beu, Bolivia. Ameghiniana, 33(4), 443-451.

Padula, E., Rolleri, E.O., Mingramm, A.R., Roque, P.C., Flores, M.A., Baldis, B.A., 1967. Devonian of Argentina. 2º International Symposium on the Devonian System. Revista de la Asociación Geológica Argentina, 30, 53-83.

Paris, F., 1981. Les Chitinozoaires dans le Paléozoïque du sud-ouest de l'Europe (cadre géologique - étude systématique - biostratigraphie). Mémoires de la Société Géologiques et Minéralogique de Bretagne, 26, 1-492.

Paris, F., Bourahrouh, A., Hérissé, A.L., 2000. The effects of the final stages of the Late Ordovician glaciation on marine palynomorphs (chitinozoans, acritarchs, leiospheres) in well Nl-2 (NE Algerian Sahara). Review of Palaeobotany and Palynology, 113(1-3), 87-104.

Pérez-Leyton, M., 2007. Analyse des assemblages de palynomorphes du Silurien superieur et du Devonien de Bolivie: Proposition de mise en place d'une échelle biostratigraphique de référence. Thèse, Université de Brest-Université de Liège, Brest, 319 p. Unpublished.

Playford, G., 1977. Lower to Middle Devonian acritarchs of the Moose River Basin, Ontario. Geological Survey of Canada, Bulletin, 279, 1-87.

Pöthé de Baldis, E.D., 1977. Paleomicroplancton adicional del Devonico inferior de Uruguay. Revista Española de Micropaleontología, 9(2), 235-250.

Pöthé de Baldis, E.D., 1998. Acritarcas de la Formación Los Espejos (Silúrico superior) del perfil Aguadas de los Azulejitos, San Juan, Argentina. Revista Española de Micropaleontología, 30, 1-18.

Potonié, R., Lele, K.M., 1961. Studies in the Talchir Flora of India. I. *Sporae dispersae* from the Talchir Beds of South Rewa Gondwana Basin. The Palaeobotanist, 8, 22-37.

Richards, R.E., Mullins, G.L., 2003. Upper Silurian microplankton of the Leinwardine Group, Ludlow Series, in the type Ludlow area and adjacent regions. Palaeontology, 46(3), 557-611.

Richardson, J.B., 1965. Middle Old Red Sandstone spore assemblages from the Orcadian basin north-east Scotland. Palaeontology, 7, 559-605.

Richardson, J.B., Ioannides, N.S., 1973. Silurian palynomorphs from the Tanezzuft and Acacus formations, Tripolitania, North Africa. Micropaleontology, 19, 257-307.

Richardson, J.B., Lister, T.R., 1969. Upper Silurian and Lower Devonian spore assemblages from the Welsh Borderland and South Wales. Palaeontology, 12, 201-252.

Richardson, J.B., McGregor, D.C., 1986. Silurian and Devonian spores zones of the Old Red Sandstone continent and adjacent regions. Geological Survey of Canada, 364, 1-78.

Richardson, J.B., Rodriguez, R.M., Sutherland, S.J.E., 2001. Palynological zonation of Mid-Palaeozoic sequences from the Cantabrian Mountains, NW Spain: implications for inter-regional and interfacies correlation of the Ludford/Pridolí and Silurian/Devonian boundaries, and plant dispersal patterns. Bulletin of the Natural History Museum. Geology Series, 57(2), 115-162.

Richter, R., Richter, E., 1942. Die Trilobite der Weismes-Schichten am Hohen Venn, mit Bemerkungen über die Malvinocaffrische Provinz. Senckenbergiana, 25, 156-279.

Rodriguez, R.M., 1978. Mioesporas de la Formación San Pedro/Furada (Silúrico superior-Devónico Inferior), Cordillera Cantábrica, NO de España. Palinología, 1, 407-433.

Rubinstein, C.V., 1999. Primer registro paleontológico de la Formación Punta Negra (Devónico Medio-Superior), de la Precordillera de San Juan, Argentina. X Simposio Argentino de Paleobotánica y Palinología. Asociación Paleontológica Argentina, Special Publication, 6, 13-18.

Rubinstein, C.V., 2000. Middle Devonian palynomorphs from the San Juan Precordillera, Argentina: biostratigraphy and paleobiogeography. I Congreso Ibérico de Paleontología, XVI Jornadas de la Sociedad Española de Paleontología and VIII International Meeting of IGCP 421 (Évora), 274-275.

Rubinstein, C.V., Melo, J.H.G., Steemans, P., 2005. Lochkovian (earliest Devonian) miospores from the Solimões Basin, northwestern Brazil. Review of Palaeobotany and Palynology, 133, 91-113.

Rubinstein, C.V., Le Hérissé, A., Steemans, P., 2008. Lochkovian (Early Devonian) acritarchs and prasinophytes from the Solimões Basin, northwestern Brazil. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, 249, 167-184.

Rubinstein, C.V., Monge, A.S., Astini, R.A., 2010. Primeros datos palinológicos del Devónico de la sierra de Las Minitas, Precordillera de La Rioja y posición del registro glacial del Paleozoico medio en Argentina, La Plata, Argentina. X Congreso Argentino de Paleontología y Bioestratigrafía and VII Congreso Latinoamericano de Paleontología.

Rustán, J.J., 2016. Los trilobites devónicos de la Precordillera Argentina: Sistemática, filogenia, bioestratigrafía y paleobiogeografía. Revista Facultad de Ciencias Exáctas, Físicas y Naturales, 3(2), 133-143.

Rustán, J.J., Balseiro, D., 2016. The phacopid trilobite *Echidnops taphomimus* n. sp. from the Lower Devonian of Argentina: insights into infaunal molting, eye architecture and geographic distribution. Journal of Paleontology, 90(6), 1100-1111.

Rustán, J.J., Vaccari, N.E., 2010a. Trilobites de la Formación Punta Negra (Devónico Medio) en la sección de Loma de los Piojos (Precordillera de San Juan, Argentina): nuevos elementos para la datación y correlación de los "estratos postdevónicos" de Keidel. 10º Congreso Argentino de Paleontología y Bioestratigrafía and 7º Congreso Latinoamericano de Paleontología. La Plata. Actas, p. 54.

Rustán, J.J., Vaccari, N.E., 2010b. The aulacopleurid trilobite *Maurotarion* Alberti, 1969, in the Silurian-Devonian of Argentina: systematic, phylogenetic and paleobioogeographic significance. Journal of Paleontology, 84(6),1082-1098.

Salas, M.J., Rustán, J.J., Sterren, A.F., 2013. Lower and Middle Devonian Malvinokaffric ostracods from the Precordillera Basin of San Juan, Argentina. Journal of South American Earth Sciences, 45, 56-68.

Sarjeant, W.A.S., Stancliffe, R.P.W., 1996. The acritarch genus Polygonium, Vavrdová emend Sarjeant and Stancliffe 1994: a reassessment of its constituent species. Annales de la Société géologique de Belgique, 117(2), 355-369.

Servais, T., Vecoli, M., Jun, L., Molyneux, S.G., Raevskaya, E.G., Rubinstein, C.V., 2007. The acritarch genus *Veryhachium* Deunff 1954: Taxonomic evaluation and first appearance. Palynology, 31, 191-203.

Sommer, F.W., Van Boekel, N.M., 1964. Quitinozoarios do Devoniano de Goiás. Anais da Academia Brasileira de Ciências, 36(4), 423-431.

Steemans, P., 1989. Paléogéographie de l'Eodevonien ardennais et des regions limitrophes. Annales de la Société Géologique de Belgique, 112(1), 103-119.

Steemans, P., Lakova, I., 2004. The Moesian Terrane during the Lochkovian—a new palaeogeographic and phytogeographic hypothesis based on miospore assemblages. Palaeogeography, Palaeoclimatology, Palaeoecology, 208(3-4), 225-233.

Steemans, P., Le Hérissé, A., Bozdogan, N., 1996. Ordovician and Silurian cryptospores and miospores from southeastern Turkey. Review of Palaeobotany and Palynology, 93(1-4), 35-76.

Steemans, P., Wellman, C.H., Filatoff, J., 2007. Palaeophytogeographical and palaeoecological implications of a miospore assemblage of earliest Devonian (Lochkovian) age from Saudi Arabia. Palaeogeography, Palaeoclimatology, Palaeoecology, 250(1-4), 237-254.

Sterren, A.F., Rustán, J.J., Salas, M.J., 2015. First Middle Devonian Bivalves from Argentina, new records from the Punta Negra Formation and insights on middle Paleozoic faunas from the Precordillera Basin. Ameghiniana, 52(3), 334-349.

Streel, M., 1967. Associations de spores du Dévonien inférieur belge et leur signification stratigraphique. Annales de la Société Géologique de Belgique, 90, 11-53.

Streel M., Higgs, K.T., Loboziak, S., Riegel, W., Steemans, P., 1987. Spore stratigraphy and correlation with faunas and floras in the type marine Devonian of the Ardenno-Rhenish regions. Review of Palaeobotany and Palynology, 50, 211-229.

Traverse, A. 2007. Paleopalynology. Second Edition. Springer, Dordrecht. 813 pp.

Troth, I., Marshall, J.E., Racey, A., Becker, R.T., 2011. Devonian sea-level change in Bolivia: A high palaeolatitude biostratigraphical calibration of the global sea-level curve. Palaeogeography, Palaeoclimatology, Palaeoecology, 304, 3-20.

Turnau, E., Racki, G., 1999. Givetian palynostratigraphy and palynofacies: new data from the Bodzentyn Syncline (Holy Cross Mountains, central Poland). Review of Palaeobotany and Palynology, 106, 237-271.

Vavrdová, M., Isaacson, P.E., Díaz-Martínez, E., 2011. Early Silurian-Early Devonian acritarchs and prasinophytes from the Ananea and San Gabán Formations, southern Peru and their paleogeographic implications. Revista Española de Micopaleontología, 43(3), 157-172.

Volkheimer, W., Melendi, D.L., Salas, A., 1986. Devonian Chitinozoans from Northwestern Argentina. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, 173, 229-251.

Wellman, C.H., 1993. A Lower Devonian sporomorph assemblage from the Midland Valley of Scotland. Transactions of the Royal Society of Edinburgh: Earth Science, 84, 117-136.

Wicander, E.R., 1974. Upper Devonian-Lower Mississippian acritarchs and prasinophycean algae from Ohio, U.S.A. Palaeontographica, Abt. B, 148(1-3), 9-43.

Wicander, E.R., 1986. Lower Devonian (Gedinnian) acritarchs from the Haragan Formation, Oklahoma, U.S.A. Review of Palaeobotany and Palynology, 47, 327-365.

Wood, G.D., 1995. The gondwanan acritarch *Bimerga bensonii* gen. et sp. nov.: Paleogeographic and biostratigraphic importance in the Devonian Malvinokaffric Realm. Palynology, 19(1), 221-231.

Appendix

Organic-walled microphytoplankton

Ammonidium sp. (Fig. 7.B)

cf. *Baculatireticulatus* sp. (Fig. 7.G)

Bimerga paulae Le Hérissé 2011 (Fig. 7.I and 7.J)

Cordobesia oriental Pöthé de Baldis 1977 (Fig. 7.L)

Cymatiosphaera aff. *C. ledburica* in Mullins (2001) (Fig. 7.M)

Cymatiosphaera mirabilis Deunff 1959 (Fig. 7.N)

Cymatiosphaera multisepta Deunff 1955 (Fig. 7.O)

Cymatiosphaera prismatica (Deunff) Deunff 1961 (Fig. 8.O)

Cymatiosphaera salopensis Mullins 2001 (Fig. 7.P)

Cymatiosphaera spp.

Dictyotidium dictyotum (Eisenack) Eisenack 1955

Dictyotidium cf. *D. variatum* Playford 1977 (Fig. 8.A)

Dictyotidium sp. (Fig. 8.B)

Diexallophasis remota Group Mullins 2001

Divietipellis sp. (Fig. 8.C and 8.D)

Dorsennidium rhomboidium (Downie) Stancliffe and Sarjeant 1996 (Fig. 8.E)

Dorsennidium spp.

Dupliciradiatum tenue González, Moreno and Playford 2005 (Fig. 8.F)

Duvernaysphaera aranaides Cramer 1964 (Fig. 8.G)

cf. *Duvernaysphaera wilsonii* Deunff 1964 (Fig. 8.H)

Estiastra culcita Wicander 1974 (Fig. 8.K)

Estiastra sp. in Ottone (1996) (Fig. 8.L)

Estiastra sp. (Fig. 8.M)

Evittia sanpetrensis (Cramer) Lister 1970 (Fig. 8.N)

Fimbriaglomerella divisa Loeblich and Drugg 1968 (Fig. 8.P)

Gorgonisphaeridium sp. (Fig. 8.Q)

Hoegklintia cf. *H. longispina* Pöthé de Baldis 1998 (Fig. 8.S)

Leiofusa bernesgae Cramer 1964 (Fig. 9.B)

Leiosphaeridia spp.

Lophosphaeridium spp.

Melikeriopalla polygonia (Staplin) Mullins 2001

Micrhystridium spp. (Fig. 6.L)

Multiplicisphaeridium cf. *M. rochesterense* (Cramer and Díez) Eisenack et al. 1973 (Fig. 9.C)

Multiplicisphaeridium sp. (Fig. 6.M)

Navifusa bacilla (Deunff) Playford 1977 (Fig. 9.E)

Neoveryhachium carminae (Cramer) Cramer 1970

Palacanthus ledanoisii (Deunff) Playford 1977 (Fig. 9.F)

Palacanthus stelligerum (Deunff) Stancliffe and Sarjeant 1996 (Fig. 9.G)

?*Polyedryxium asperum* Cramer 1964 (Fig. 9.H)

Polyedryxium embudum Cramer 1964 (Fig. 9.K)

Polyedryxium cf. *P. condensum* Deunff 1971 (Fig. 9.I)

Polyedryxium cf. *P. decorum* Deunff 1955 (Fig. 9.J)

Polyedryxium evolutum Deunff 1955 (Fig. 9.L)

Polyedryxium helenaster Cramer 1964

Polyedryxium robustum Deunff 1971 (Fig. 9.M)

Polyedryxium simplex Deunff 1955 (Fig. 9.N)

Polyedryxium sp. (Fig. 9.O)

Pterospermella hermosita (Cramer) Fensome et al. 1990 (Fig. 9.P)

Pterospermella spp.

Quadraditum fantasticum Cramer 1964 (Fig. 9.Q)

cf. *Riculasphaera fissa* Loeblich and Drugg 1968 (Fig. 10.B)

Schismatosphaeridium longhopense Dorning 1981 (Fig. 10.C)

Schismatosphaeridium sp. B in Le Hérissé (1989) (Fig. 10.D)

Stellinium micropolygonale (Stockmans and Williere) Playford 1977 (Fig. 10.H)

Stellinium rabians (Cramer) Eisenack et al. 1976 (Fig. 10.I)

Veryhachium lairdii Group sensu Servais et al. 2007

Veryhachium trispininflatum Cramer 1964 (Fig. 10.N)

Veryhachium trispinosum Group Servais et al. 2007 (Fig. 6.P)

Villosacapsula setosapellicula (Loeblich 1970) Loeblich and Tappan 1976 (Fig. 10.O)

cf. *Visbysphaera* sp. A in Richards and Mullins (2003) (Fig. 10.P)

Fresh water acritarchs

Quadrisporites horridus (Hennelly) Potonié and Lele 1961 (Fig. 9.R)

Quadrisporites variabilis (Cramer) Ottone and Rossello 1996 (Fig. 9.S)

Quadrisporites sp. (Fig. 10.M)

Schizocystia pilosa Jardiné et al. 1972 (Fig. 10.E)

Schizocystia saharica Jardiné et al. 1974 (Fig. 10.F)

Miospores

Acinosporites sp. (Fig. 7.A)

cf. *Acinosporites* sp. (Fig. 6.A)

Ambitisporites avitus Morphon Steemans et al. (1996) (Fig. 7.C)

Ambitisporites tripapillatus Moreau-Benoit 1976 (Fig. 7.D)

Ambitisporites sp. (Fig. 6.B)

Apiculiretusispora plicata (Allen) Streel 1967 (Fig. 7.E)

Apiculiretusispora sp. (Fig. 6.C)

Archaeozonotriletes chulus (Cramer) Richardson and Lister 1969

cf. *Archaeozonotriletes chulus* (Cramer) Richardson and Lister 1969 (Fig. 6.D)

Archaeozonotriletes spp.

Artemopyra brevicosta Burgess and Richardson 1991 (Fig. 7.F)

Brochotriletes foveolatus Naumova 1953 (Fig. 7.H)

Chelinospora verrucata Morphon García Muro et al. (2014b) (Fig. 7.K)

Chelinospora spp.

Cymbohilates sp. (Fig. 6.E)

Cymbosporites proteus McGregor and Camfield 1976 (Fig. 7.Q)

cf. *Cymbosporites verrucosus* Richardson and Lister 1969 (Fig. 7.R)

Cymbosporites spp. (Fig. 6.F; Fig. 7.S)

Dibolisporites echinaceus (Eisenack) Richardson 1965 (Fig. 6.G)

Dibolisporites spp. (Fig. 6.H)

Dictyotriletes emsiensis Morphon Rubinstein et al. (2005) (Fig. 6.I)

Dictyotriletes sp. (Fig. 6.J)

Emphanisporites protophanus Richardson and Ioannides 1973 (Fig. 8.I)

Emphanisporites rotatus (McGregor) McGregor 1973 (Fig. 8.J)

Gneudnaspora divellomedia (Chibrikova) Balme 1988 var. minor Breuer et al. 2007

Hispanaediscus cf. *H. verrucatus* (Cramer) Burgess and Richardson 1991 (Fig. 8.R)

?*Knoxisporites riondae* Cramer and Díez 1975 (Fig. 6.K and 8.T)

Latosporites sp. 1 in Breuer (2007) (Fig. 9.A)

Raistrickia sp. (Fig. 9.T)

Retusotriletes spp. (Fig. 10.A)

cf. *Retusotriletes* sp. (Fig. 6.N)

cf. *Scylaspora* sp. (Fig. 10.G)

Synorisporites lybicus Richardson and Ioannides 1973 (Fig. 10.J)

Synorisporites verrucatus Richardson and Lister 1969 (Fig. 10.K)

Tetrahedraletes medinensis var. *parvus* (Strother and Traverse) Burgess 1991 (Fig. 10.L) cf. *Verrucosisporites* sp. (Fig. 6.O)

Captions

Table. 1. Samples studied per level. Identification number for the samples prepared in the University of Liège, Belgium and in the Palaeopalynology Laboratory of IANIGLA, CCT CONICET Mendoza, Argentina. Fm.: Formation.

Fig. 1. Location and geological map of the study area of Loma de los Piojos. Map modified from García Muro and Rubinstein (2015) and García Muro et al. (2017).

Fig. 2. Stratigraphic section of the upper part of the Talacasto Formation and the Punta Negra Formation at the Loma de los Piojos locality, with the locations of studied samples**.**

Fig. 3. Stratigraphic distribution of organic-walled microphytoplankton, fresh water acritarchs (f.w.a.) and miospores in the Talacasto Formation at the Loma de los Piojos section. The black rectangles indicate species presence; the grey rectangles are questionable occurrences.

Fig. 4. Stratigraphic distribution of the organic-walled microphytoplankton in the Punta Negra Formation at the Loma de los Piojos section. The black rectangles indicate species presence; the grey rectangles are questionable occurrences. *: in Le Hérissé (1989); -: in Ottone (1996); +: in Richards and Mullins (2003); º: in Mullins (2001).

Fig. 5. Stratigraphic distribution of fresh water acritarchs (f.w.a.) and miospores in the Punta Negra Formation at the Loma de los Piojos section. The black rectangles indicate species presence; the grey rectangle are questionable occurrences. ●: in Breuer (2007).

Fig. 6. Recorded species from the Talacasto Formation.

(**A**) cf. *Acinosporites* sp., sample 3-9932D (W25/3)

(**B**) *Ambitisporites* sp., sample 15-9943E (G46/2)

(**C**) *Apiculiretusispora* sp., sample 15-9943E (M27/3)

(**D**) cf. *Archaeozonotriletes chulus*, sample 12-9941D (Z39)

(**E**) *Cymbohilates* sp., sample 15-9943E (K25/1)

(**F**) *Cymbosporites* sp., sample 15-9943E (G30)

(**G**) *Dibolisporites echinceus*. sample 15-9943E (O43/3)

(**H**) *Dibolisporites* sp., sample 15-9943C (B32)

(**I**) *Dictyotriletes emsiensis* Morphon, sample 15-9943D (G34/2)

(**J**) *Dictyotriletes* sp., sample 15-9943E (L38/4)

(**K**) ?*Knoxisporites riondae*, sample 15-9943E (M27)

(**L**) *Micrhystridium* sp., sample 15-9943E (F28/3)

(**M**) *Multiplicisphaeridium* sp., sample 15-9943E (F28/3)

(**N**) cf. *Retusotriletes* sp., sample 15-9943D (L32/4)

(**O**) cf. *Verrucosisporites* sp., sample 1-9930D (O26/2)

(**P**) *Veryhachium trispinosum* Group, sample 15-9943E (K34/2)

Scale bar = 20 µm.

Fig. 7. Recorded species from Punta Negra Formation

(**A**) *Acinosporites* sp., sample 41-73812 (C33/3)

(**B**) *Ammonidium* sp., sample 37-73824 (Q50)

(**C**) *Ambitisporites avitus* Morphon, sample 36-73823 (K31/4)

(**D**) *Ambitisporites tripapillatus*, sample 37-73824 (S38/4)

(**E**) *Apiculiretusispora plicata*, sample 37-73829 (J32/1)

(**F**) *Artemopyra brevicosta*, sample 17-73782 (X34/2)

(**G**) cf. *Baculatireticulatus* sp., sample 34-73788 (O45/3)

(**H**) *Brochotriletes foveolatus*, sample 41-73819 (E34/1)

(**I, J**) *Bimerga paulae*, sample 33-73893 (E34/4), 33-73822 (Q36/2)

(**K**) *Chelinospora verrucata* Morphon, sample 39-73826 (K29/1)

(**L**) *Cordobesia oriental*, sample 33-10091C (J21/2)

(**M**) *Cymatiosphaera* aff. *C. ledburica*, sample 36-73823 (O48/4)

(**N**) *Cymatiosphaera mirabilis*, sample 36-73823 (J50)

(**O**) *Cymatiosphaera multisepta*, sample 37-73829 (S48/2)

(**P**) *Cymatiosphaera salopensis*, sample 33-73822 (G41/2)

(**Q**) *Cymbosporites proteus*, sample 32-73787 (C35/1)

(**R**) cf. *Cymbosporites verrucosus*, sample 38-73825 (T37)

(**S**) *Cymbosporites* sp., sample 36-73823 (E36/1)

Scale bar = 20 µm.

Fig. 8. Recorded species from Punta Negra Formation

(**A**) *Dictyotidium variatum*, sample 37-73824 (D39/3)

(**B**) *Dictyotidium* sp., sample 32-73787 (S40/4)

(**C**) *Divietipellis* sp., sample 33-73894 (H25/4)

(**D**) *Divietipellis* sp., sample 37-73824 (J34)

(**E**) *Dorsennidium rhomboidium*, sample 32-73787 (U43/1)

(**F**) *Dupliciradiatum tenue*, sample 33-73894 (R26/4)

(**G**) *Duvernaysphaera aranaides*, sample 32-73787 (J33/4)

(**H**) cf. *Duvernaysphaera wilsonii*, sample 37-73824 (C34/2)

(**I**) *Emphanisporites protophanus*, sample 27-73833 (M32/1)

(**J**) *Emphanisporites rotatus*, sample 41-73812 (F35/1)

(**K**) *Estiastra culcita*, sample 33-73894 (U29)

(**L**) *Estiastra* sp. in Ottone (1996), sample 33-10091C (V43/1)

(**M**) *Estiastra* sp., sample 36-73823 (D37/1)

(**N**) *Evittia sanpetrensis*, sample 37-73824 (U49/2)

(**O**) *Cymatiosphaera prismatica*, sample 37-10095E (W22)

(**P**) *Fimbriaglomerella divisa*, sample 32-73786 (U38/1)

(**Q**) *Gorgonisphaeridium* sp., sample 36-73823 (X36/2)

(**R**) *Hispanaediscus* cf. *H. verrucatus*, sample 36-73823 (S47/1)

(**S**) *Hoegklintia* cf. *H. longispina*, sample 33-73894 (W48/3)

(**T**) ?*Knoxisporites riondae*, sample 40-73814 (O31/1)

Scale bar = 20 µm.

Fig. 9. Recorded species from Punta Negra Formation

(**A**) *Latosporites* sp. 1, sample 34-73788 (T40)

(**B**) *Leiofusa bernesgae*, sample 37-73824 (F41/2)

(**C**) *Multiplicisphaeridium* cf. *M. rochesterense*, sample 37-73829 (K30/1)

(**D**) *Multiplicisphaeridium* sp., sample 36-73823 (V33)

(**E**) *Navifusa bacilla*, sample 37-73824 (U43/4)

(**F**) *Palacanthus ledanoisii*, sample 37-73824 (S45/4)

(**G**) *Palacanthus stelligerum*, sample 41-73812 (X46/1)

(**H**) ?*Polyedryxium asperum*, sample 37-73824 (N48/3)

(**I**) *Polyedryxium* cf. *P. condensum*, sample 35-73790 (H29/4)

(**J**) *Polyedryxium* cf. *P. decorum*, sample 37-73824 (P44/3)

(**K**) *Polyedrydium embudum*, sample 36-73823 (F45/4)

(**L**) *Polyedryxium evolutum*, sample 36-73823 (M48)

(**M**) *Polyedryxium robustum*, sample 36-73823 (P36)

(**N**) *Polyedryxium simplex*, sample 36-73823 (S28/2)

(**O**) *Polyedryxium* sp., sample 36-73828 (P39/3)

(**P**) *Pterospermella hermosita*, sample 33-73894 (N36/1)

(**Q**) *Quadraditum fantasticum*, sample 27-73833 (X31/2)

(**R**) *Quadrisporites* cf. *Q. horridus*, sample 35-73790 (R49/1)

(**S**) *Quadrisporites variabilis*, sample 37-73824 (J33/1)

(**T**) *Raistrickia* sp., sample 41-73812 (K41)

Scale bar = 20 µm.

Fig. 10. Recorded species from Punta Negra Formation

(**A**) *Retusotriletes* sp., sample 41-73812 (E48)

(**B**) cf. *Riculasphaera fissa*, sample 35-73790 (Q51/2)

(**C**) *Schismatosphaeridium longhopense*, sample 27-73833 (X31/3)

(**D**) *Schismatosphaeridium* sp. B, sample 33-73827 (U35/1)

(**E**) *Schizocystia pilosa*, sample 40-73814 (R34/1)

(**F**) *Schizocystia saharica*, sample 35-73790 (V38/2)

(**G**) cf. *Scylaspora* sp., sample 33-73894 (M45/4)

(**H**) *Stellinium micropolygonale*, sample 32-73786 (K35)

(**I**) *Stellinium rabians*, sample 37-73824 (M44/3)

(**J**) *Synorisporites lybicus*, sample 27-73833 (O51)

(**K**) *Synorisporites verrucatus*, sample 27-73833 (M37/3)

(**L**) *Tetrahedraletes medinensis* var. *parvus*, sample 27-73833 (O30/3)

(**M**) *Quadrisporites* sp., sample 35-73789 (R38/1)

(**N**) *Veryhachium trispininflatum*, sample 41-73812 (O41/3)

(**O**) *Villosacapsula setosapellicula*, sample 37-73824 (G34)

(**P**) cf. *Visbysphaera* sp. A, sample 33-73827 (G29/2)

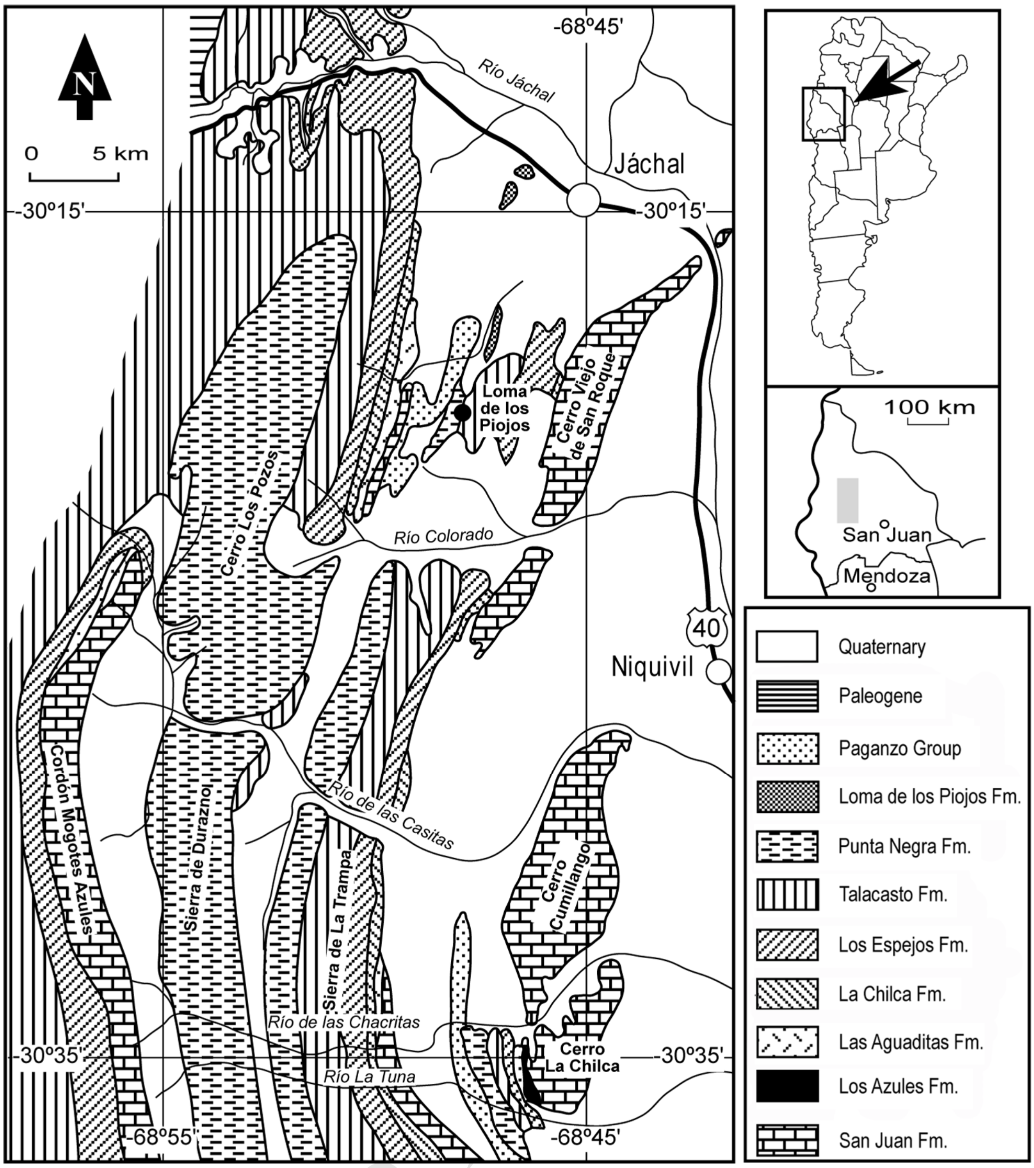
Scale bar = 20 µm.

Fig. 11. Correlation scheme of the studied sections of the Gualilán Group based on phytoplankton and miospores assemblages (García Muro et al., 2017 and this contribution). Loch.: Lochkovian; E: Emsian.

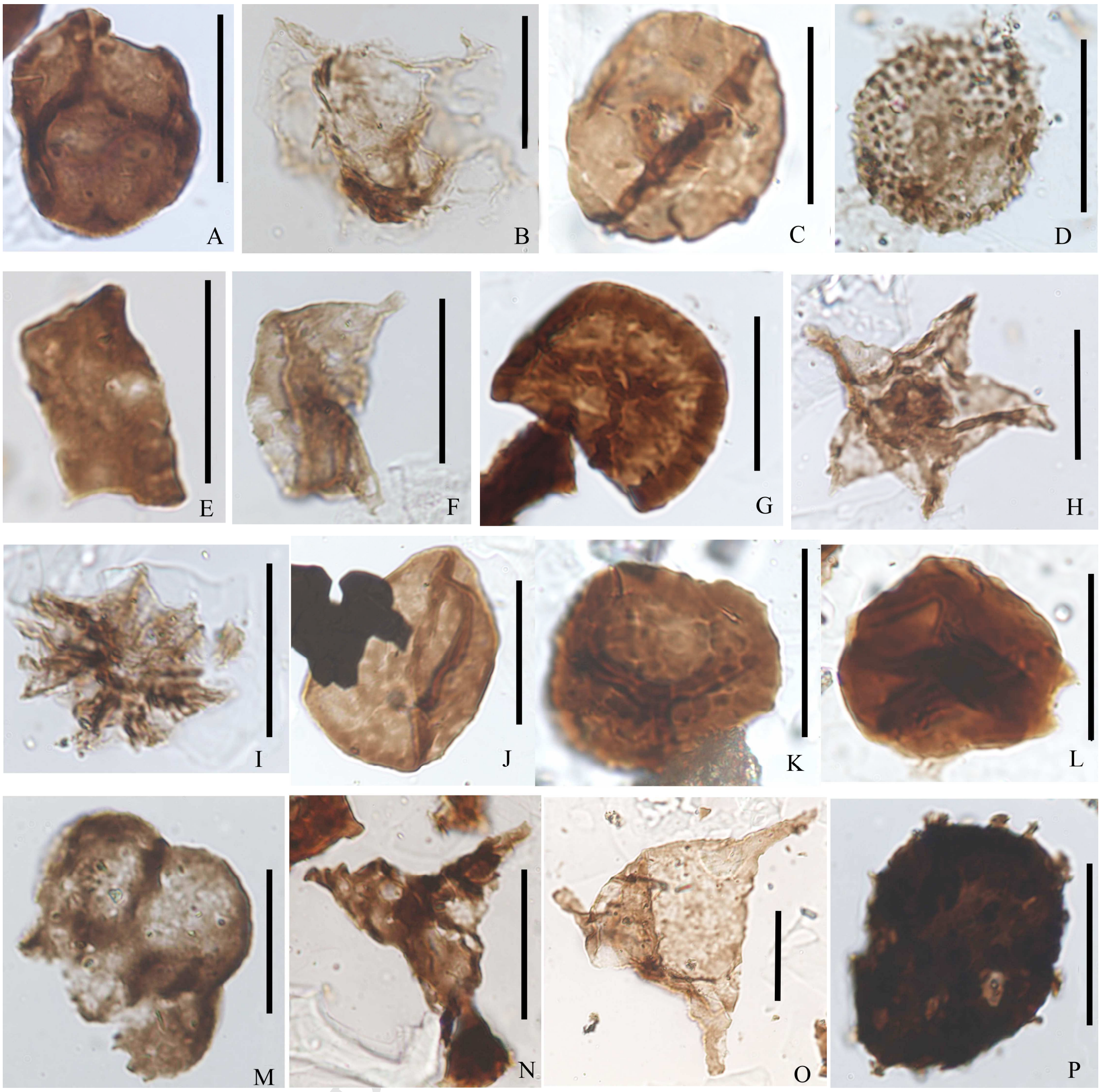
Fm.	Level here simplified	Argentina	Belgium
Talacasto	1	9930	
	2	9931	
	3	9932	
	4	9933	
	5	9934	
	6	9935	
	7	9936	
	8	9937	
	9	9938	
	10	9939	
	11	9940	
	12	9941	
	13	9942	
	14	9960	
	15	9943	
Punta Negra	16	10076	
	17	10074	73782 73783
	18	10075	
	19	10077	
	20	10078	73815
	21	10079	
	22	10080	73816
	23	10081	
	24	10082	73817
	25	10083	73818

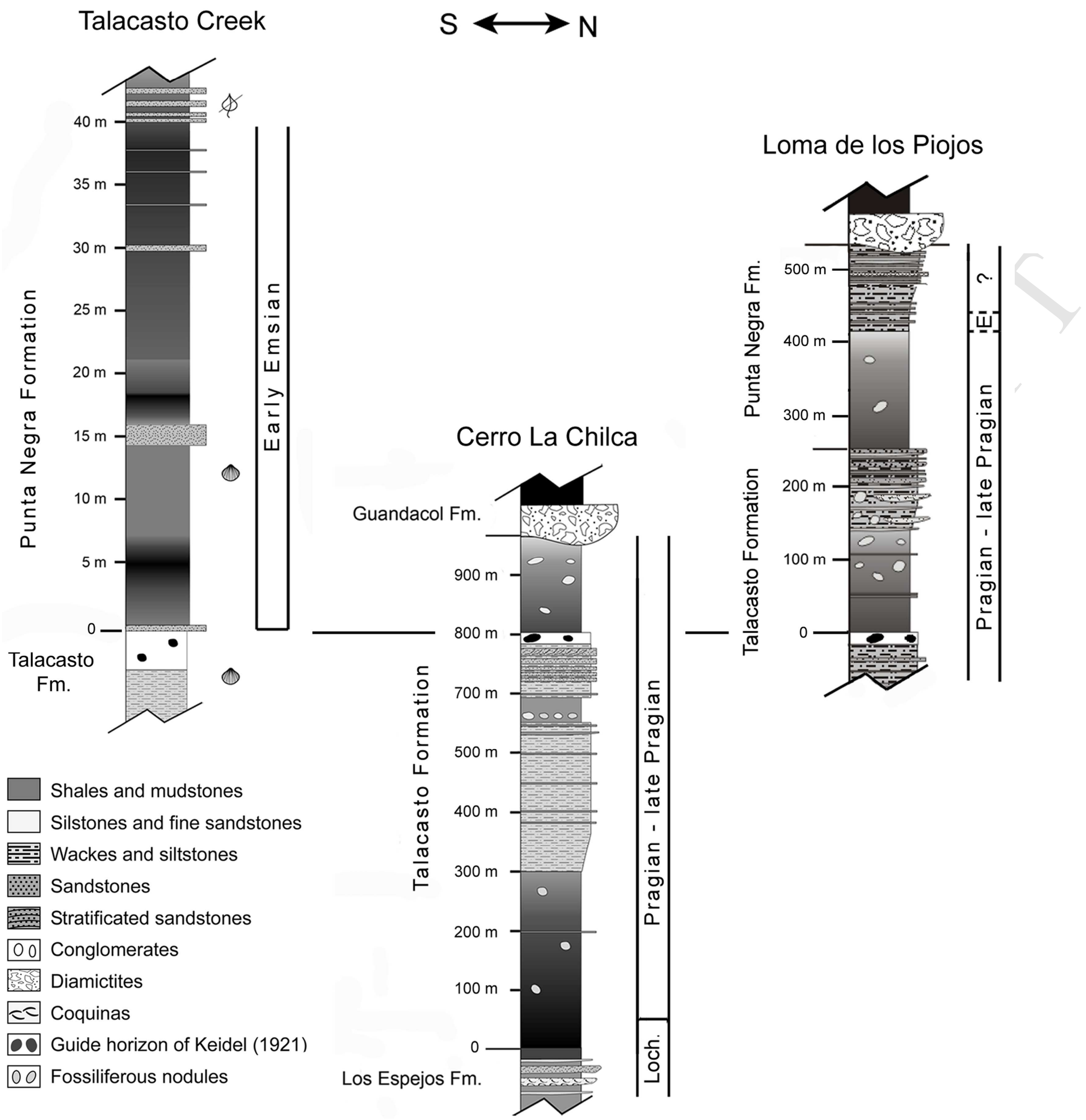
	26	10084	
	27	10085	73833
	28	10086	73784
	29	10087	
	30	10088	73821
	31	10089	73785
	32	10090	73786 73787 73791 73792
	33	10091	73822 73827 73894 73893
	34	10092	73788
	35	10093	73789 73790
	36	10094	73823 73828
	37	10095	73824 73829
	38	10096	73825 73830
	39	10097	73826
	40	10108	73814
	41	10098	73812 73813 73819 73820
	42	10099	73831
	43	10100	73832
	44	10101	
	45	10102	73834
	46	10103	
	47	10104	
	48	10105	73835
	49	10106	

	50	10107	73836

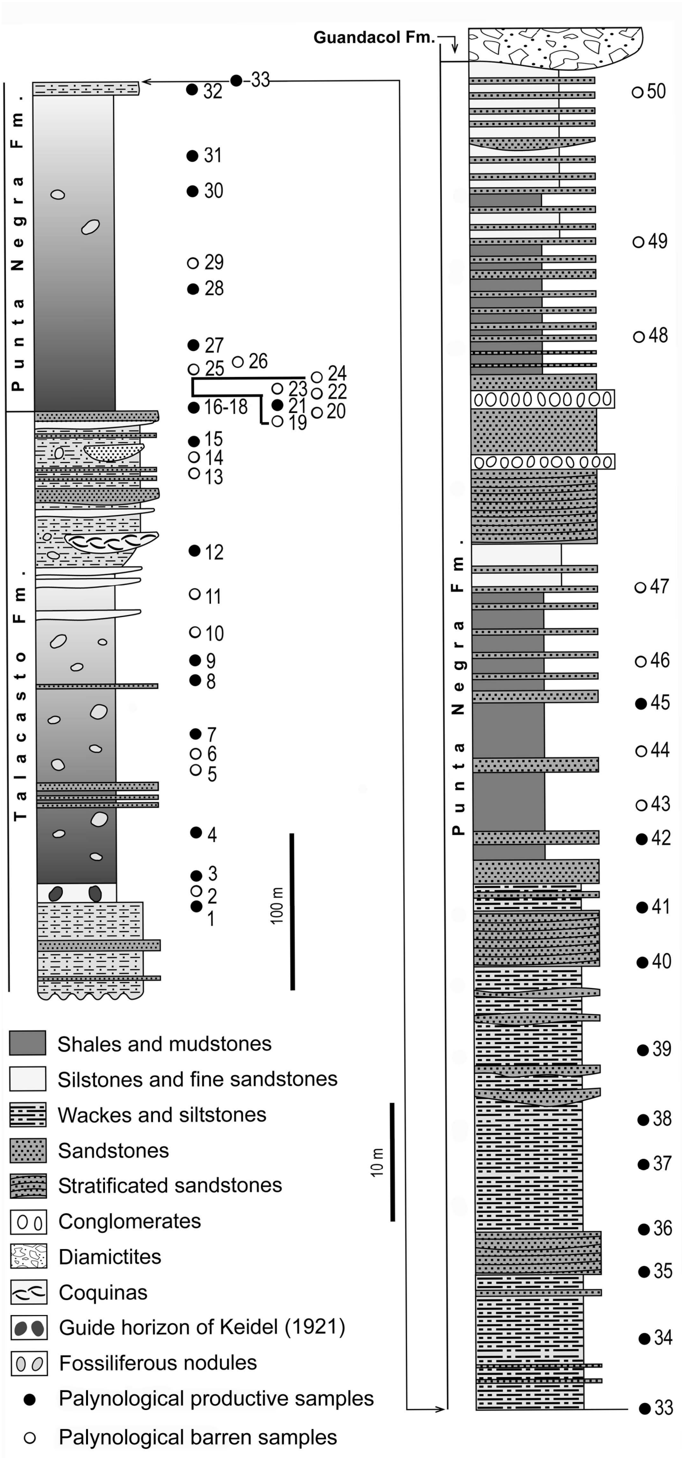


N
0 5 km
-68º45'
Río Jáchal
Jáchal
-30º15'
-30º15'
Loma de los Piojos
Cerro Viejo de San Roque
Cerro Los Pozos
Río Colorado
40
Niquivil
Cordón Mogotes Azules
Sierra de Durazno
Río de las Casitas
Sierra de La Trampa
Cerro Cumillango
Río de las Chacritas
-30º35'
-30º35'
Cerro La Chilca
Río La Tuna
-68º55'
-68º45'
100 km
San Juan
Mendoza
Quaternary
Paleogene
Paganzo Group
Loma de los Piojos Fm.
Punta Negra Fm.
Talacasto Fm.
Los Espejos Fm.
La Chilca Fm.
Las Aguaditas Fm.
Los Azules Fm.
San Juan Fm.

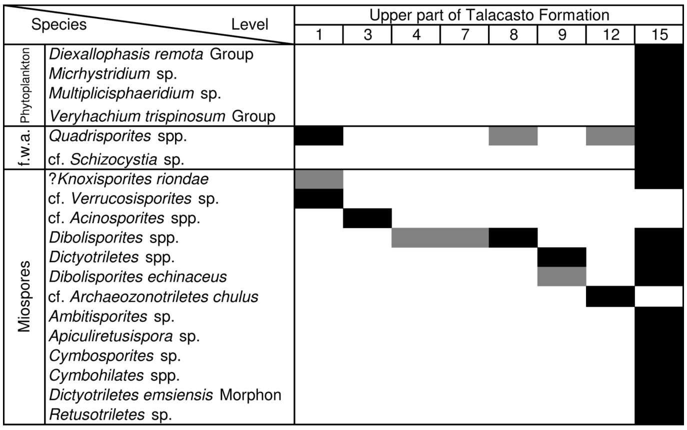

A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P

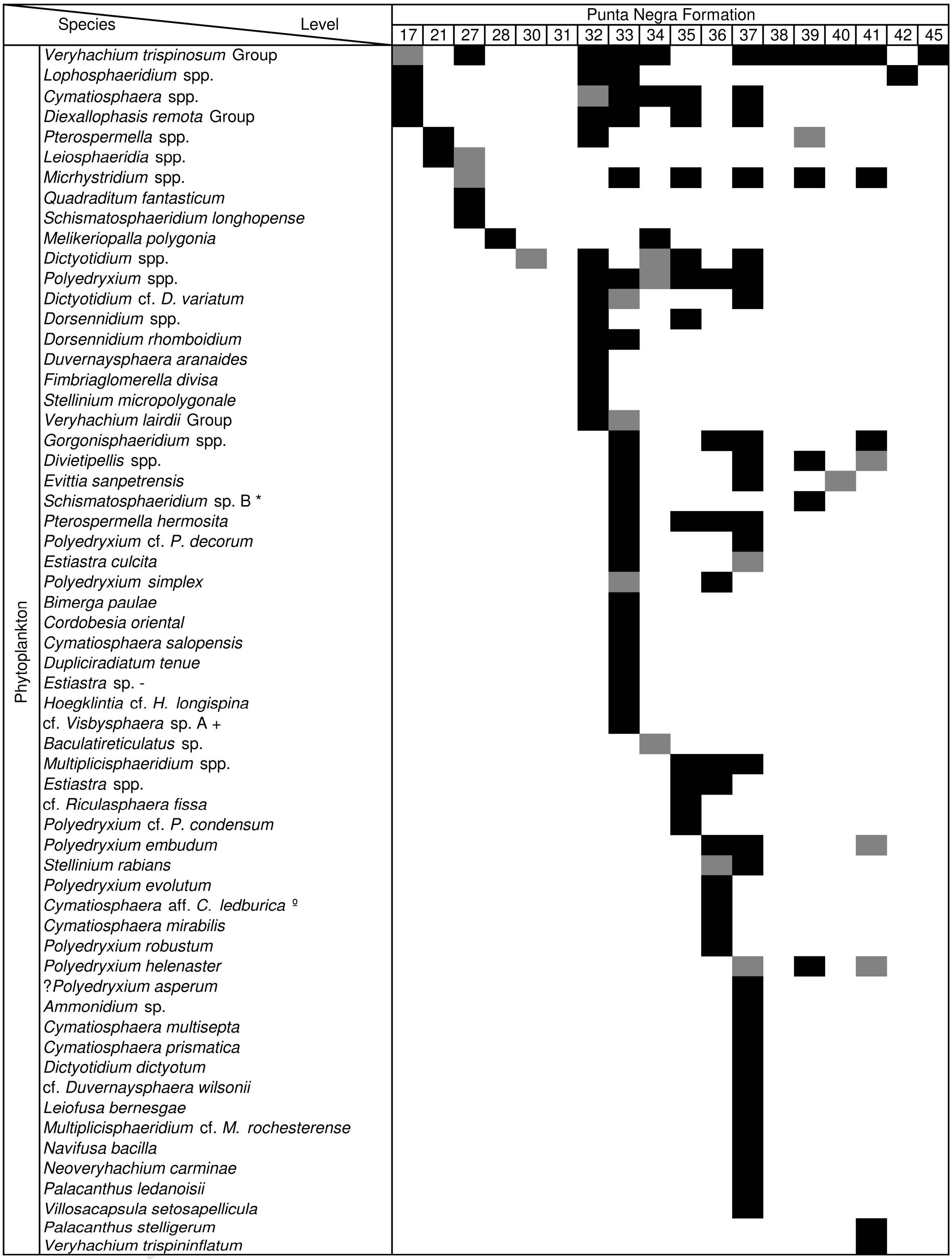


Talacasto Creek
S N
Loma de los Piojos
Cerro La Chilca
40 m
35 m
30 m
25 m
20 m
15 m
10 m
5 m
0
Punta Negra Formation
Early Emsian
Talacasto Fm.
Guandacol Fm.
900 m
800 m
700 m
500 m
400 m
300 m
200 m
100 m
0
Talacasto Formation
Pragian - late Pragian
Loch.
Los Espejos Fm.
Punta Negra Fm.
Talacasto Formation
E ?
Shales and mudstones
Silstones and fine sandstones
Wackes and siltstones
Sandstones
Stratificated sandstones
Conglomerates
Diamictites
Coquinas
Guide horizon of Keidel (1921)
Fossiliferous nodules

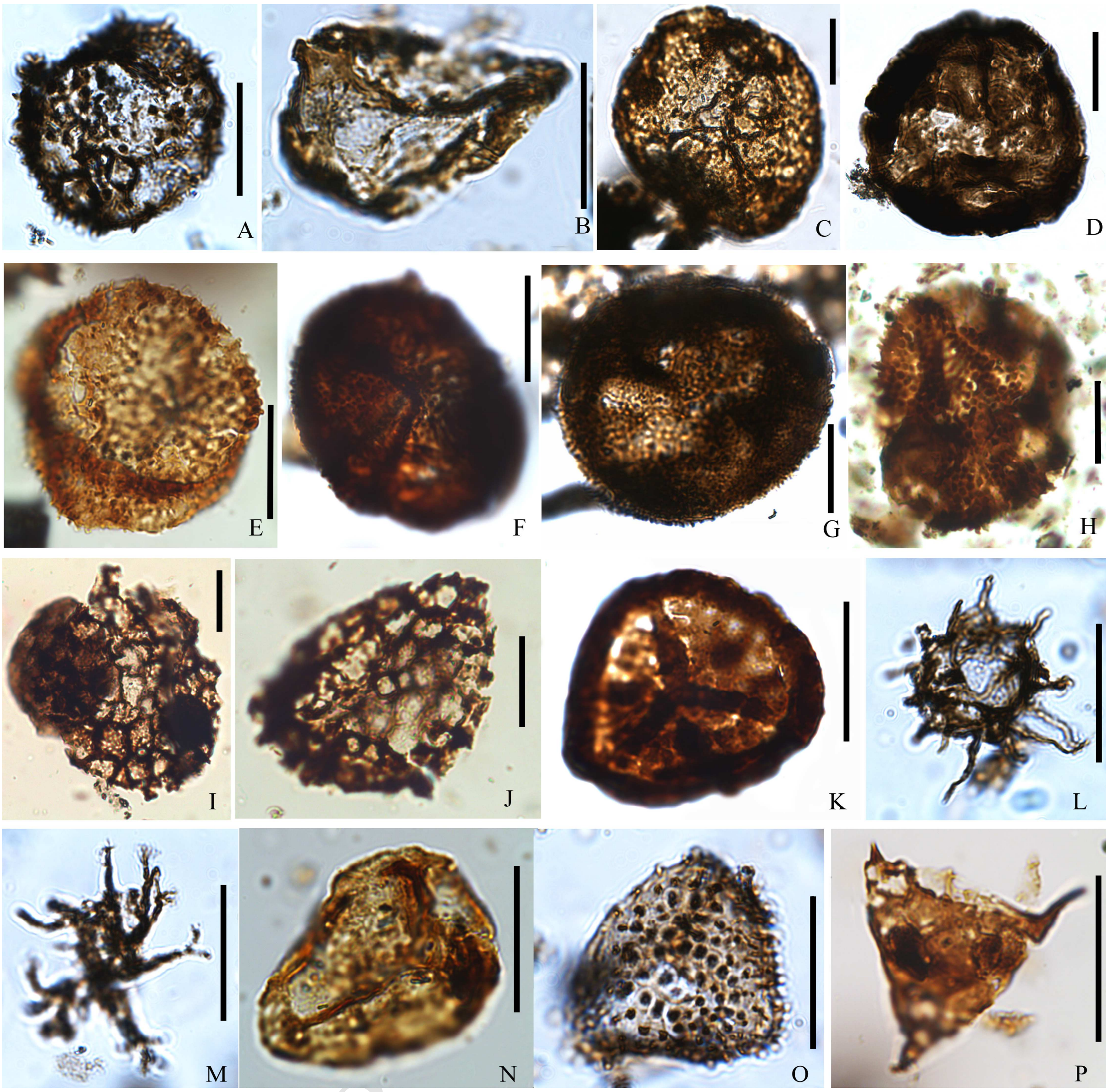


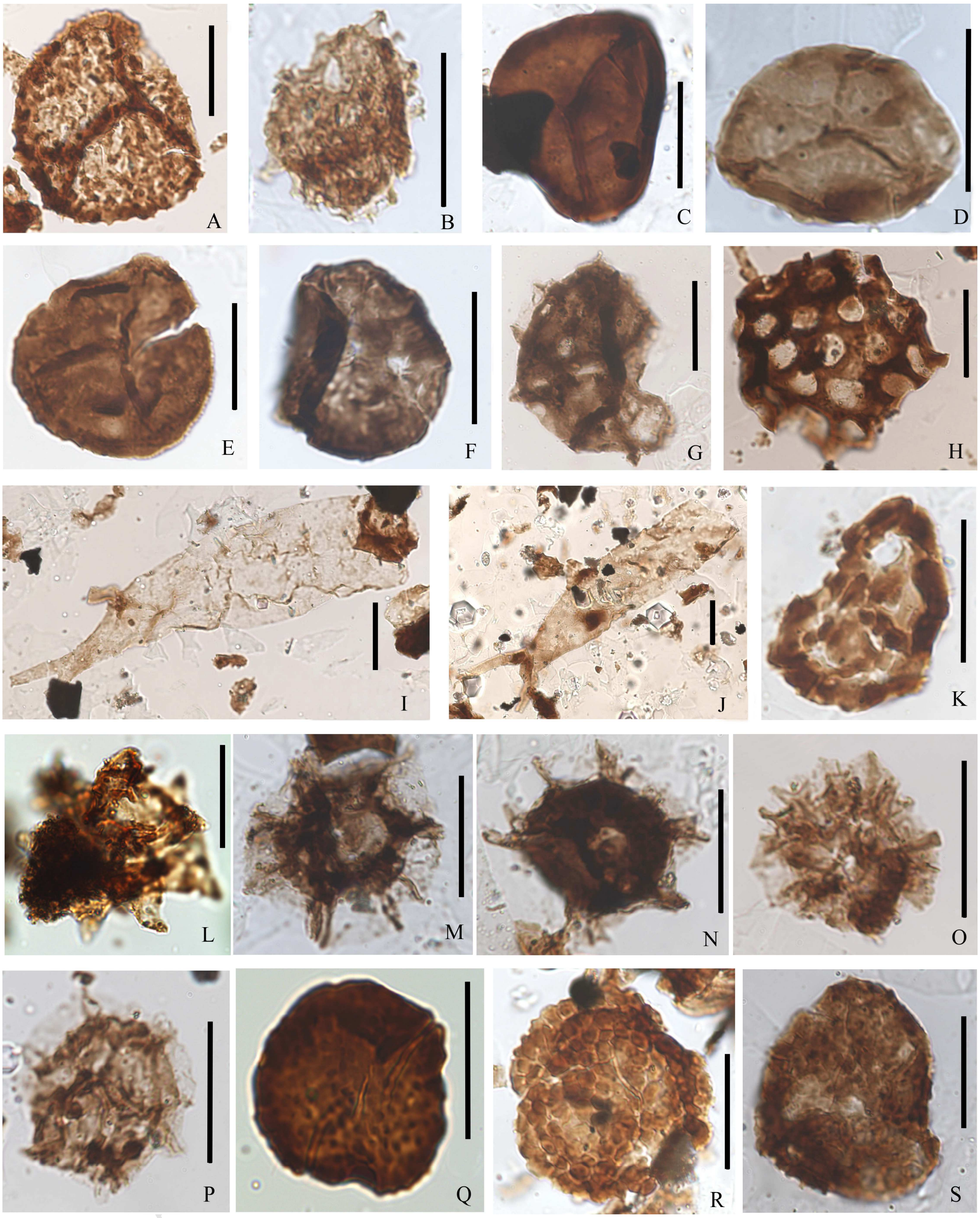
Guandacol Fm.
Punta Negra Fm.
Talacasto Fm.
100 m
10 m
Shales and mudstones
Silstones and fine sandstones
Wackes and siltstones
Sandstones
Stratificated sandstones
Conglomerates
Diamictites
Coquinas
Guide horizon of Keidel (1921)
Fossiliferous nodules
Palynological productive samples
Palynological barren samples

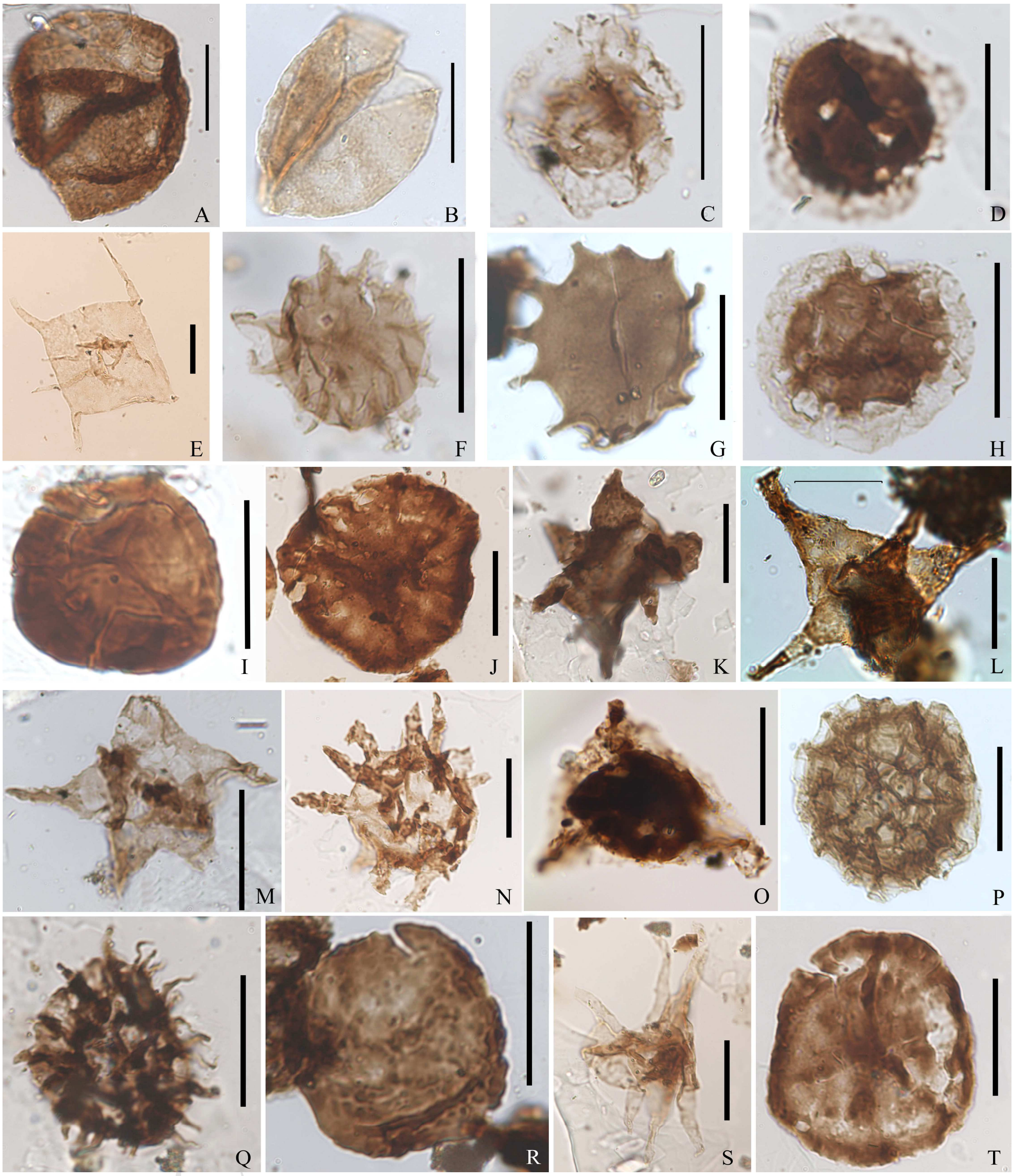

Species
Level
Upper part of Talacasto Formation
1
3
4
7
8
9
12
15
Phytoplankton
Diexallophasis remota Group
Micrhystridium sp.
Multiplicisphaeridium sp.
Veryhachium trispinosum Group
f.w.a.
Quadrisporites spp.
cf. Schizocystia sp.
Miospores
?Knoxisporites riondae
cf. Verrucosisporites sp.
cf. Acinosporites spp.
Dibolisporites spp.
Dictyotriletes spp.
Dibolisporites echinaceus
cf. Archaeozonotriletes chulus
Ambitisporites sp.
Apiculiretusispora sp.
Cymbosporites sp.
Cymbohilates spp.
Dictyotriletes emsiensis Morphon
Retusotriletes sp.

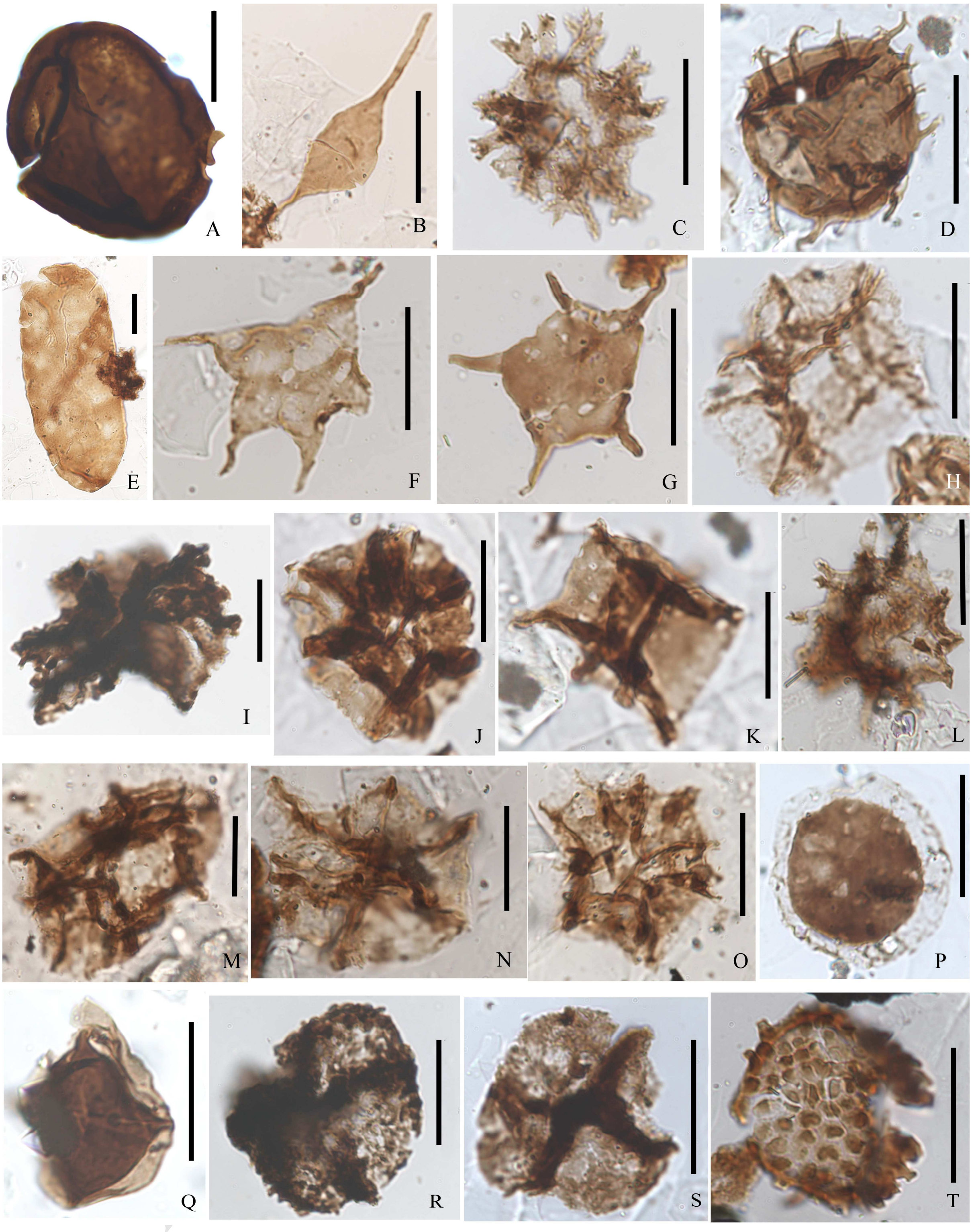

Species
Level
Punta Negra Formation
17 21 27 28 30 31 32 33 34 35 36 37 38 39 40 41 42 45
Phytoplankton
Veryhachium trispinosum Group
Lophosphaeridium spp.
Cymatiosphaera spp.
Diexallophasis remota Group
Pterospermella spp.
Leiosphaeridia spp.
Micrhystridium spp.
Quadraditum fantasticum
Schismatosphaeridium longhopense
Melikeriopalla polygonia
Dictyotidium spp.
Polyedryxium spp.
Dictyotidium cf. D. variatum
Dorsennidium spp.
Dorsennidium rhomboidium
Duvernaysphaera aranaides
Fimbriaglomerella divisa
Stellinium micropolygonale
Veryhachium lairdii Group
Gorgonisphaeridium spp.
Divietipellis spp.
Evittia sanpetrensis
Schismatosphaeridium sp. B *
Pterospermella hermosita
Polyedryxium cf. P. decorum
Estiastra culcita
Polyedryxium simplex
Bimerga paulae
Cordobesia oriental
Cymatiosphaera salopensis
Dupliciradiatum tenue
Estiastra sp. -
Hoegklintia cf. H. longispina
cf. Visbysphaera sp. A +
Baculatireticulatus sp.
Multiplicisphaeridium spp.
Estiastra spp.
cf. Riculasphaera fissa
Polyedryxium cf. P. condensum
Polyedryxium embudum
Stellinium rabians
Polyedryxium evolutum
Cymatiosphaera aff. C. ledburica º
Cymatiosphaera mirabilis
Polyedryxium robustum
Polyedryxium helenaster
?Polyedryxium asperum
Ammonidium sp.
Cymatiosphaera multisepta
Cymatiosphaera prismatica
Dictyotidium dictyotum
cf. Duvernaysphaera wilsonii
Leiofusa bernesgae
Multiplicisphaeridium cf. M. rochesterense
Navifusa bacilla
Neoveryhachium carminae
Palacanthus ledanoisii
Villosacapsula setosapellicula
Palacanthus stelligerum
Veryhachium trispininflatum

	Species \ Level	Punta Negra Formation																	
		17	21	27	28	30	31	32	33	34	35	36	37	38	39	40	41	42	45
f.w.a.	*Schizocystia saharica*			■							■								
	Schizocystia pilosa								■							■			
	Quadrisporites spp.									■	■		■	■		■	■		■
	Quadrisporites cf. *Q. horridus*										■								
	Quadrisporites variabilis												■				■		
Miospores	*Retusotriletes* spp.	▒		■	▒						■		▒				■		
	Gneudnaspora divellomedia				■						■					■			
	Artemopyra brevicosta	■																	
	Ambitisporites spp.		■	■			▒	■	■		■		■		■		■		
	Dictyotriletes sp.			▒									▒			■	■		
	Dibolisporites sp.			▒												■	■		
	Tetrahedraletes medinensis var. *parvus*			■				■									■		
	Synorisporites lybicus			■									■						
	Chelinospora spp.			■									▒						
	Archaeozonotriletes chulus			■	■			▒			▒								
	Emphanisporites protophanus			■				■											
	Synorisporites verrucatus			■															
	Archaeozonotriletes spp.					▒		■		■									
	Cymbosporites proteus							■											
	cf. *Scylaspora* sp.								■										
	Latosporites sp. 1 ●									■									
	Emphanisporites rotatus										■					▒	■		
	Ambitisporites avitus Morphon											■					■		
	Cymbosporites sp.											■							
	Hispanaediscus cf. *H. verrucatus*											■							
	Acinosporites sp.												■			▒	■		
	Dictyotriletes emsiensis Morphon												■	▒					
	Ambitisporites tripapillatus												■						
	Apiculiretusispora plicata												■						
	?*Knoxisporites riondae*													■		■			
	cf. *Cymbosporites verrucosus*													■					
	Chelinospora verrucata Morphon														■				
	Brochotriletes foveolatus																■		
	Raistrickia sp.																■		


A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P


A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S


A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T


A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T

Highlights

- Devonian palynological assemblages from the Argentinian Precordillera are presented
- Marine and terrestrial palynomorphs suggest a late Pragian to Emsian age
- The age of the guide horizon of Keidel is constrained to the late Pragian
- Palynological data enable a new biostratigraphic frame for the Devonian units