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New palynological data from the Devonian Villavicencio Formation, Precordillera of Mendoza, Argentina

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Abstract. New terrestrial and marine palynomorphs of the lower part of the Villavicencio Formation, San Isidro Creek, Precordillera of Mendoza, Argentina, are evaluated. The palynomorph assemblage is dominated by miospores, and also contains acritarchs and scarce chitinozoans. Different processing methods have been tested due to the poor preservation state of the palynomorphs. The new slides provided abundant and diverse palynomorphs and allowed the recognition of 13 miospore species and two acritarch species. This review suggests a late Pragian to early Emsian age, thus confirming and refining previous palynological dating. The miospore assemblage may be correlated with the upper part of the Ems Biozone, in terms of the Devonian miospore zonation of the Brazilian Amazon Basin. Palaeogeographically, acritarchs show perigondwanan affinities. In the light of this refined age determination, the stratigraphic and phytogeographic inferences for the Precordillera land plants should be reconsidered.

Resumen. NUEVOS DATOS PALINOLÓGICOS DE LA FORMACIÓN VILLAVICENCIO, DEVÓNICO DE LA PRECORDILLERA DE MENDOZA, ARGENTINA. Se analizan nuevas asociaciones de palinomorfos continentales y marinos, provenientes de la parte inferior de la Formación Villavicencio, en la Quebrada de San Isidro, Precordillera de Mendoza, Argentina. Las asociaciones contienen predominantemente mioesporas, acompañadas por acritarcos y escasos quitinozoos. Como resultado de nuevos procesamientos paleopalinológicos se obtuvo un gran número de microfósiles, lo que permitió identificar 13 especies de mioesporas y dos de acritarcos. La revisión de las asociaciones sugiere una edad praguiana tardía a emsiana temprana, confirmando y precisando los resultados palinológicos previos. La asociación de mioesporas puede ser correlacionada con la Zona de Intervalo (Ems), correspondiente a la biozonación definida para el Devónico de la cuenca del Amazonas, en Brasil. En lo referente a la paleogeografía, los acritarcos demuestran claras afinidades gondwánicas. Se considera que la asignación estratigráfica, así como la propuesta de una nueva unidad fitogeográfica para las plantas halladas en la parte inferior de la Formación Villavicencio, deben ser revisadas.

Key words. Devonian. Miospores. Acritarchs. Biostratigraphy. Palaeogeography. Precordillera. Mendoza. Argentina.

Palabras clave. Devónico. Mioesporas. Acritarcos. Biestratigrafía. Paleogeografía. Precordillera. Mendoza. Argentina.

Introduction

The Devonian deposits in the Precordillera of Mendoza extend from near the San Juan Province to the valley of the Mendoza River. These deposits were formerly called the "Villavicencio Group" by Harrington (1971). Subsequently, Cuerda *et al.* (1988) divided the group into two units: the Villavicencio Formation, assigned to the Ordovician (Llandeilo-Caradoc), and the Canota Formation, assigned to the early Devonian. Edwards *et al.* (2001) in a contribution on fossil land plants adopted the former name for the Devonian unit. Following these authors, the term Villavicencio Formation is used for the Devonian succession.

The studied palynological assemblages were recovered from San Isidro Creek (figure 1), 20 km west of Mendoza. In this locality, the Villavicencio Formation is separated from the underlying upper Ordovician Empozada Formation by a fault and is overlain by Triassic sedimentary rocks. This unit comprises massive dark grey sandstones alternated with laminated pelite beds, heterolithic facies and laminated sandy heterolithic facies. All of these are interpreted as typical facies of storm-dominated,

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shallow-marine shelf sands (Poiré and Morel, 1996). Due to the scarcity of fossils, the age of the unit was initially interpreted as Early Devonian based on its stratigraphic relationships and the discovery of primitive vascular plant debris related to *Baragwanathia* (Cuerda *et al.*, 1987). Subsequently, a palynological study of the lower part of the unit outcropping in San Isidro Creek suggested a "Siegenian" to Emsian (most probably "Siegenian") age (Rubinstein, 1993a, 1993b, 1994), thus supporting previous age assignment by Cuerda *et al.* (1987).

Later, Edwards *et al.* (2001) described a new land plant assemblage from San Isidro Creek. According to these authors, the assemblage contains some endemic plants and also plants with primitive characters similar to those from basal Devonian assemblages of the northern hemisphere. Edwards *et al.* (2001) assigned a Lochkovian age to the plants. Additionally, they suggested that the Argentine Precordillera assemblage would belong to a distinct phytogeographic unit, due to its composition and isolated position at a mid-latitudinal, possibly cool temperate climate.

Material and methods

Because the palynomorphs recovered from the Villavicencio Formation are poorly preserved and are low in abundance and diversity, different processing methods from three palynological laboratories were tested in an attempt to increase yield.

Three samples (4148 to 4150) were collected from laminated pelites interbedded with fine grained sandstones in the lower part of the formation. Samples 4149 and 4150 yielded poorly preserved palynomorphs, mainly miospores and very rare acritarchs and chitinozoans. Specimens are often flattened, partly opaque and damaged by mineral growth.

The samples were initially processed at the laboratory of the Paleopalynology Unit, IANIGLA, CRICYT, Mendoza, using standard palynological HCl-HF-HCl acid maceration techniques and they were not oxidized. The results were published by Rubinstein (1993a, 1993b, 1994). Later the samples were reprocessed at the palynological laboratories of the University of Saskatchewan (Saskatoon, Canada) and the University of Liège (Belgium). The methods utilized were similar, and the qualitative and quantitative small differences in the assemblages are probably related to the distinct methods and times of oxidation (five minutes using Schulze solution at the University of Saskatchewan and two hours using "low-grade" Schulze solution - with NOH3 at 65% - at the University of Liège) and the efficiency of filtrations after oxidations.

Slides prepared in Canada and Belgium provided more numerous miospore specimens and more taxa, plus some biostratigraphically and palaeogeographically useful acritarchs and a few chitinozoans not recorded in the previous study.

However, abundance and diversity are still low but, despite their relatively poor preservation, 13 miospores species and two acritarch species were identified. All the recognized taxa are listed and figured below.

The palynological slides 4149C are housed in the Paleopalynological Slide Collection of the Paleopalynology Unit, IANIGLA, CRICyT, Mendoza and prefixed MPLP (Mendoza-Paleopalinoteca-Laboratorio de Paleopalinología). Slides 60091 (4149) and 60100 (4150) are housed in the Paleontological Collections of the University of Liège. Specimen locations in the slides are referred to England Finder coordinates.

List of species

Trilete spores

Acinosporites sp. 1 (figures 2.B, C).
Acinosporites cf. *A. lanceolatus* in Le Hérissé 1983 (figure 2.A).
Ambitisporites tripapillatus Moreau-Benoit 1976 (figure 2.D).
Aneurospora cf. *A. goensis* Streel 1964 (figure 2.E).
Apiculiretusispora plicata (Allen 1965) Streel 1967 (figure 2.F).
Perotrilites caperatus (McGregor 1973) Steemans 1989 (figure 2.J).
Cymbosporites cf. *C. echinatus* Richardson and Lister 1969 (figure 2. G).
Cymbosporites proteus McGregor and Camfield 1976 (figure 2.I).
Dibolisporites ehinaceus (Eisenack) Richardson 1965 *emend.* McGregor 1973 (figure 2.H).
Morphon *Dictyotriletes emsiensis* (Allen 1965) McGregor 1973 *sensu* Rubinstein, Melo and Steemans 2005 (figure 2.K).
Dictyotriletes sp. 1 (figure 2.L).
Raistrickia cf. R. sp. A in Le Hérissé, 1983 (figure 2.N).

Cryptospore

Morphon *Dyadospora murusdensa* Strother and Traverse 1979 *sensu* Steemans, Le Hérissé and Bozdogan 1996 (figure 2.M).

Acritarchs

Schizocystia pilosa Jardiné, Combaz, Magloire, Peniguel and Vachey 1972 (figure 2.O).
cf. *Winwaloeusia distracta* (Deunff 1966) Deunff 1977 (figure 2.P).

Biostratigraphic and palaeogeographic results

The palynomorphs provide valuable biostratigraphic information for the lower part of the Villavicencio Formation, despite the low abundance, diversity, and poor preservation of the assemblage.

The species with the oldest stratigraphic range include *Ambitisporites tripapillatus* and *Cymbosporites echinatus*. *A. tripapillatus* appears below the *Syno-*

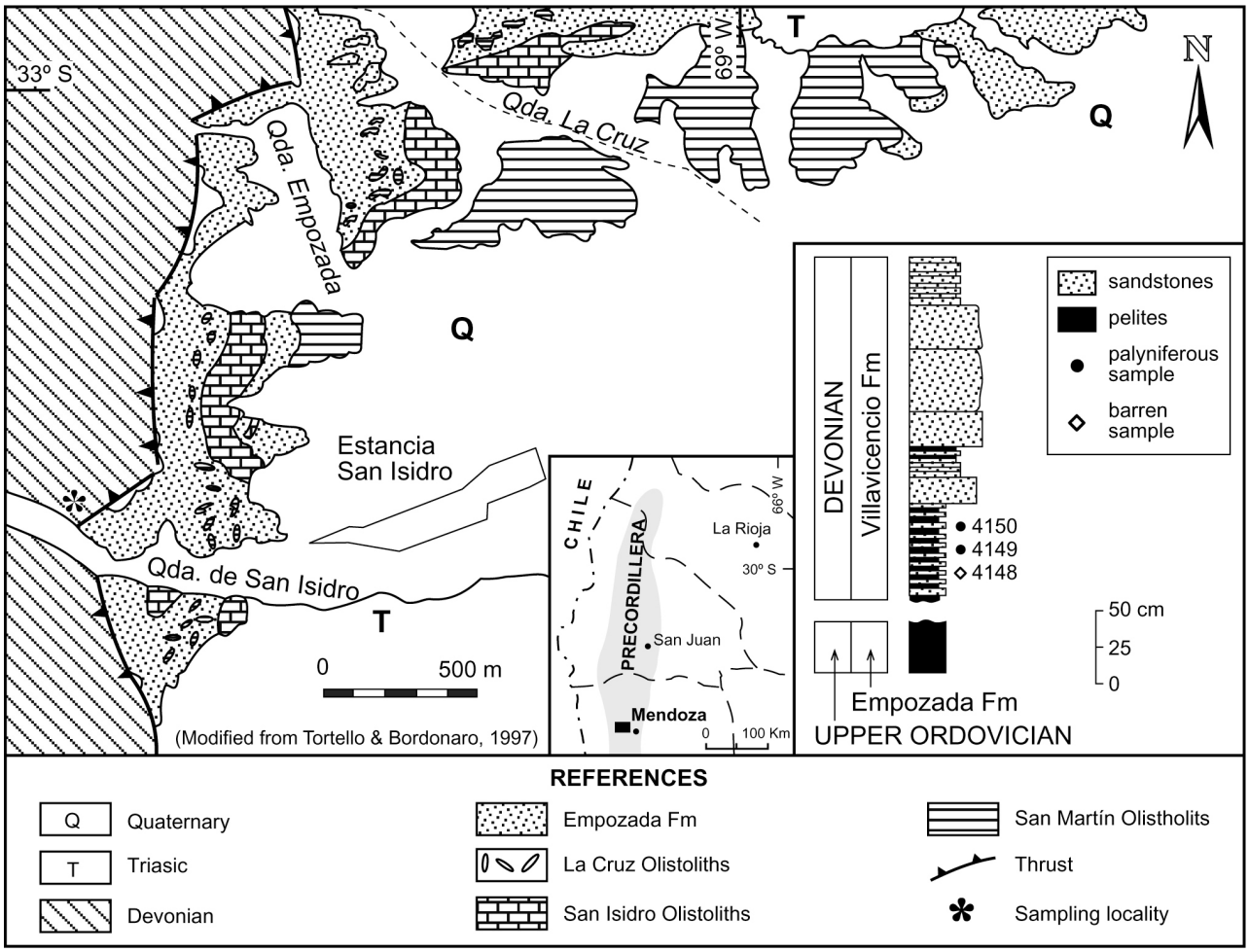


Figure 1. Location and geological map of the study area and stratigraphical section of the Villavicencio Formation at the San Isidro Creek. The location of palynological samples is indicated / *mapa geológico y de ubicación del área de estudio y columna estratigráfica de la Formación Villavicencio en la Quebrada de San Isidro con la ubicación de las muestras palinológicas.*

risporites tripapillatus-Apiculiretusispora spicula biozone of Richardson and McGregor (1986), and *C. echinatus* first occurs in the *S. tripapillatus - A spicula* biozone. This zone was considered as Pridolian and its base was correlated with the Ludlow-Pridoli boundary (Richardson and McGregor, 1986). However, it was demonstrated subsequently that the base of the *S. tripapillatus-A. spicula* biozone is located in the late Ludlow, in Libya (Rubinstein and Steemans, 2002).

Cymbosporites proteus and *Apiculiretusispora plicata* first appear in the MN Oppel Zone in the Lochkovian (Richardson and Lister, 1969; Richardson and McGregor, 1986; Steemans, 1989). Different specimens of *Dictyotriletes* belonging to the *D. emsiensis* Morphon (Rubinstein *et al*., 2005) have also been identified. The biostratigraphic significance of the *D. emsiensis* Morphon from Brazilian and Bolivian basins, where all intermediate forms from "true" *D. emsiensis* to other related species such as *D. granulatus* Steemans 1989 and *D.* cf. *D. subgranifer* McGregor 1973 are present, has been discussed in detail by Rubinstein *et al*. (2005). This morphon ranges from the Lochkovian Nß Zone (Steemans, 1989) to the Emsian AB Zone. Interestingly, it has been noted that *D. granulatus*, *D.* cf. *D. subgranifer* and the intermediate forms of this morphon have only been found in Western Gondwana (South America, Brittany and Saudi Arabia).

Dibolisporites echinaceus is unknown below the Z Phylozone of the *breconensis - zavallatus* (BZ) Oppel Zone (Steemans, 1989) and it is a common species in Lochkovian assemblages of the Solimões Basin (Rubinstein *et al*., 2005). Specimens ornamented by large biform spines do not appear earlier than the late Pragian (Steemans, 1989, and unpublished data).

Perotrilites caperatus (McGregor 1973) Steemans 1989 was first described by McGregor (1973) as *Camptozonotriletes caperatus* from the Emsian of eastern Gaspé, Canada. McGregor (1973) considered this species as being similar to *Zonotriletes* 2 *in* Jardiné and Yapaudjian (1968). Subsequently, it has been found in western Europe, ranging from the mid

Lochkovian Siα Zone (Steemans, 1989) to the basal Eifelian (Richardson and McGregor, 1986).

Even though the genus *Acinosporites* appears in the Lochkovian, it is represented there only by rare small forms (<50 μm). Robust species (>50 μm) first occur in the late Pragian. *Acinosporites* sp. 1, well represented in the Villavicencio Formation, is a large species similar to those from the late Pragian and Emsian. The specimen of *Verrucosisporites* cf. *V. polygonalis* illustrated by Rubinstein (1993b, lám. I, fig. 11) is now reassigned to *Acinosporites* sp. 1. In addition, *Acinosporites* cf. *A. lanceolatus*, also present in the Argentinean assemblage, has been previously recorded in early Emsian rocks of the Armorican Massif (Le Hérissé, 1983).

The single specimen of *Raistrickia* present in the assemblage is similar to *Raistrickia*. sp. A, a species also recorded in the Armorican Massif and dated as Pragian (Le Hérissé, 1983).

Terrestrial palynomorphs predominate in the Villavicencio section, but acritarchs are also present. These are mainly simple forms such as *Veryhachium* and *Micrhystidium* (Rubinstein, 1993a, 1993b) that have no stratigraphical value. However, it is important to highlight the presence of two interesting taxa that are also present.

Schizocystia pilosa, which is a typical Gondwanan taxon, was first recorded in the Lochkovian from the Algerian Sahara (Zone I of Jardiné *et al*., 1974). *Schizocystia*, including *S. pilosa* species, is an abundant taxa in late Lochkovian strata of the Solimões Basin (Rubinstein *et al*., 2000, 2005), in northwestern Brazil. It is also locally common in higher parts of the Jatapu Member of the Maecuru Formation in the Amazon Basin, within the upper (Pragian) section of the Ems Interval Zone (J.H.G. Melo, pers. comm. 2002). In southern Brazil, *Schizocystia* spp. has been reported from the uppermost Furnas Formation, in the Paraná Basin (PISA locality, Dino and Rodrigues, 1995), considered as Lochkovian in age (Gerrienne *et al*., 2001). In addition, it has been reported from Lochkovian - Pragian strata of the northern Bolivian Madre de Dios Basin (Vavrdova *et al*., 1996) and from the southern Subandean Bolivia (McGregor, 1984, as an unidentified acritarch; Melo, 2000, pl. 4, fig. 16). In Argentina, *S. pilosa* has been recorded from the lower part of the Talacasto Formation in the Precordillera Basin of San Juan, dated as late Lochkovian to Emsian in age (Le Hérissé *et al*., 1996).

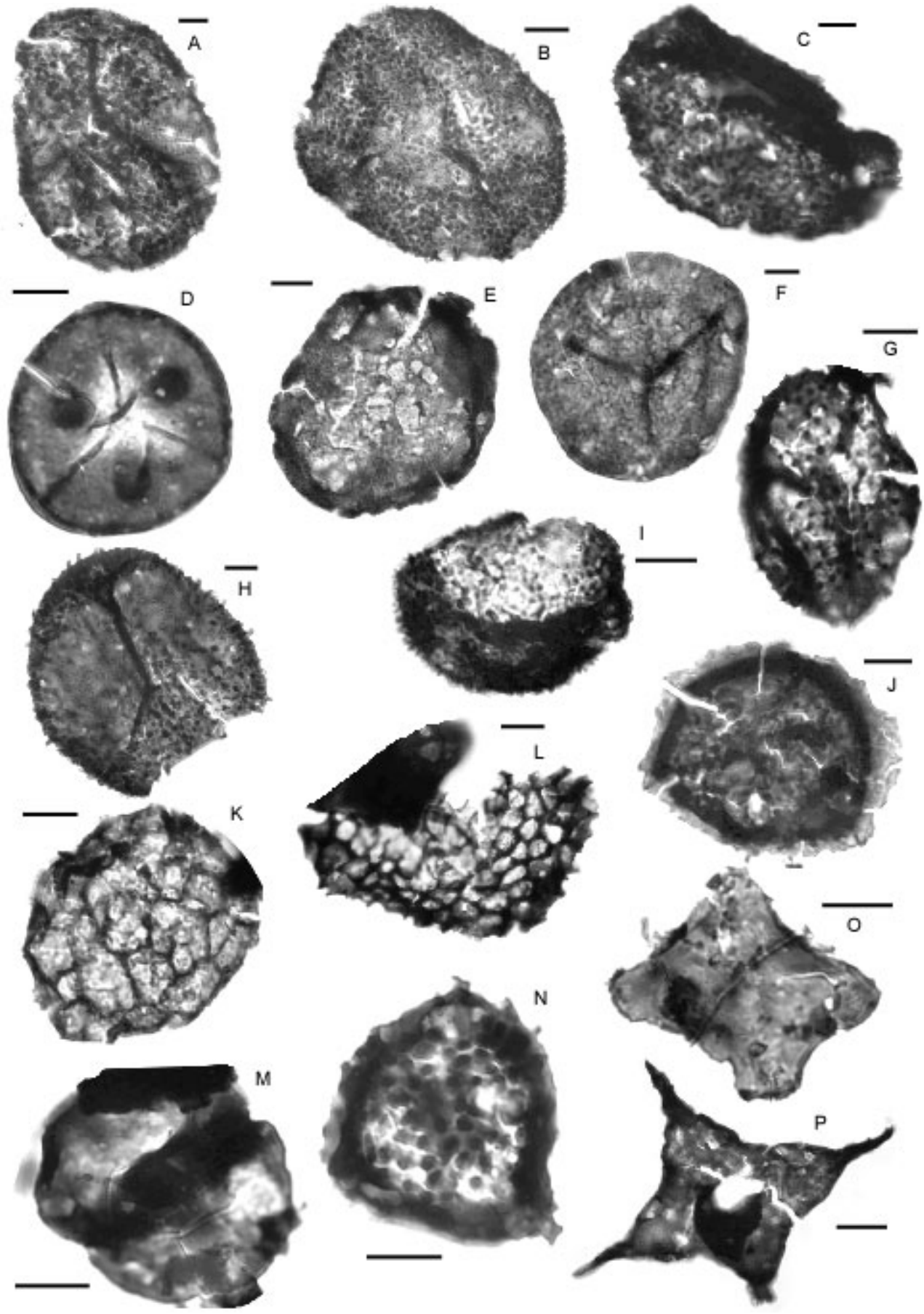
A poorly preserved acritarch specimen has been identified as a probable *Winwaloeusia distracta*. The Gondwanan acritarch *W. distracta* is known from the Lower Devonian of Tunisia and the Algerian Sahara, the Lochkovian of the Armorican Massif and Brittany, in France, and it may reach the Middle and Upper Devonian in North Africa and France (Deunff, 1980). In Brazil, it has also been reported from late Lochkovian rocks of the Solimões Basin (Rubinstein *et al*., 2000, 2005), and from Givetian-Frasnian strata of the Parana Basin (Oliveira, 1977).

The Villavicencio Formation has also yielded a few badly preserved chitinozoans. Grahn (pers. comm., 2005) considers that it is almost impossible to identify these specimens, although they seem to be related to *Ramochitina*, a genus that is well represented in Pragian - early Emsian sections of the Parnaíba Basin, in Brazil.

The studied palynomorphs do not enable a correlation to be made with palynological assemblages of the Devonian units from the Central Precordillera Basin of San Juan. The Villavicencio assemblage only shares *Dibolisporites echinaceus* and *Schizocystia pilosa* with assemblages of the lower part of the Talacasto Formation, which ranges in age from the Lochkovian to the Emsian (Le Hérissé *et al*., 1996). Spores, acritarchs and chitinozoans indicate a Middle Devonian age (probably middle to late Givetian) for the Punta Negra Formation (Rubinstein, 1999, 2000), which thus seems to be younger than levels analysed from the Villavicencio Formation in the Precordillera of Mendoza.

The miospore biozonations originally erected in the Devonian of Western Europe, in the Old Red Sandstone, were initially applied to Brazilian sequences. Recently, however, Melo and Loboziak (2001, 2003) proposed a new Devonian-Early Carboniferous miospore zonation for the Amazon Basin, that is also applicable to other basins in Brazil and Bolivia. According to this scheme the Villavicencio spores may correspond to the upper part of the *Dictyotriletes emsiensis* Interval Zone (Ems) of latest Lochkovian to at least Pragian in age (equivalent to

Figure 2. A, ***Acinosporites*** cf. ***A, lanceolatus*** *in* Le Hérissé, 1983. 4149Cf, U45/3. **B,** ***Acinosporites*** sp. 1. 4149Cf, N33/0. **C,** ***Acinosporites*** sp. 1. 4149Ce, U33/0. **D,** ***Ambitisporites tripapillatus*** Moreau-Benoit 1976. 4149Cf, D40/0. **E,** ***Aneurospora*** cf. ***A. goensis*** Streel 1964. 4149Ce, U31/2. **F,** ***Apiculiretusispora plicata*** (Allen 1965) Streel 1967. 4149Ca, D46/4. **G,** ***Cymbosporites*** cf. **C. echinatus** Richardson and Lister 1969. 4149Ce, Q28/2. **H,** ***Dibolisporites ehinaceus*** (Eisenack) Richardson 1965 *emend*. McGregor 1973. 4149Cg, F28/4. **I,** ***Cymbosporites proteus*** McGregor and Camfield 1976. 4149Ca, X30/0. **J,** ***Perotrilites caperatus*** (McGregor 1973) Steemans 1989. 4149Ce, P37/0. **K,** Morhon ***Dictyotriletes emsiensis*** (Allen 1965) McGregor 1973 *sensu* Rubinstein, Melo and Steemans 2005. 4149Ca, M43/0. **L,** ***Dictyotriletes*** sp. 1. 4149Cg, H44/0. **M,** Morphon ***Dyadospora murusdensa*** Strother and Traverse 1979 *sensu* Steemans, Le Hérissé and Bozdogan 1996. 60091, L38/4. **N,** ***Raistrickia*** cf. ***R***. sp. A *in* Le Hérissé, 1983. 4149Ce, P25/2. **O,** ***Schizocystia pilosa*** Jardiné, Combaz, Magloire, Peniguel and Vachey 1972. 60091, T28/0. **P,** cf. ***Winwaloeusia distracta*** (Deunff 1966) Deunff 1977. 4149Cg, M38/3. The scale bars correspond to 10 μm / *la escala representa 10 μm*.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the E Interval Zone and probably the entire PoW Oppel Zone of the western Europe miospore zonation of Streel *et al*., 1987 and Steemans, 1989). The Ems Interval Zone is characterized by the first occurrence of *Dictyotriletes emsiensis*, *Verrucosisporites* cf. *V. polygonalis* Lanninger 1968, *Dictyotriletes* cf. *D. subgranifer* McGregor 1973 and *Perotrilites* sp. cf. *Zonotriletes* 2 *in* Jardiné and Yapaudjian (1968). Recently the base of the Ems Interval Zone was relocated between the base of Nβ biozone and the E biozone from the ORS Continent based on the range of the *Dictyotriletes emsiensis* Morphon (Rubinstein *et al*., 2005).

In summary, marine and terrestrial palynomorphs suggest an Early Devonian age for the studied levels. However, the presence of the *D. emsiensis* Morphon, *D. echinaceus* with large ornament, large specimens of *Acinosporites* (such as *Acinosporites* sp. 1), together with *Acinosporites* cf. *A. lanceolatus* and *Raistrickia* cf. *R*. sp. A, suggest that the samples belong to the upper part of the Ems Biozone of Melo and Loboziak (2001, 2003), of late Pragian to early Emsian age.

Despite the previous "Siegenian" to Emsian dating of the Villavicencio Formation (Rubinstein 1993a, 1993b, 1994), Edwards *et al*. (2001) considered the plant assemblage from San Isidro Creek as Lochkovian in age. We confirm here the previous age determination by Rubinstein (1993a, 1993b; 1994) and, in addition, we refine this dating by suggesting a more restricted late Pragian to early Emsian age span. Thus, the phytogeographic considerations published in Edwards *et al*. (2001) have to be reinterpreted in the light of the new biostratigraphic interpretations.

Conclusions

Palynological assemblages provide valuable stratigraphic and palaeogeographic information on the poorly known and poorly fossiliferous Villavicencio Formation.

The review of palynological assemblages from the lower part of this unit suggests a late Pragian to early Emsian age. Therefore, the "Siegenian" to Emsian and more probably "Siegenian" age initially proposed by Rubinstein (1993a, 1993b, 1994) is confirmed and refined by the new palynological results.

The miospore assemblage may be correlated with the upper part of the *Dictyotriletes emsiensis* Interval Zone (Ems), in terms of the miospore zonation of the Brazilian Amazon Basin.

From a palaeogeographical viewpoint, acritarchs from the Lower Devonian of the Precordillera of Mendoza clearly exhibit Gondwanan affinities.

Regarding the confirmation of a late Pragian to early Emsian age, instead of the Lochkovian age suggested by Edwards *et al.* (2001), the stratigraphic and phytogeographic implications of the Precordillera San Isidro Creek land plants should be reconsidered.

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