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Plumsteadia pedicellata sp. nov.: A new glossopterid fructification from La Golondrina Formation (Guadalupian–Lopingian), Santa Cruz Province, Argentina

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ABSTRACT

A new specimen of glossopterid fructification – *Plumsteadia pedicellata* – from the Permian of La Golondrina Basin, in Santa Cruz Province, Argentina, is described. The fructification has ?ovule scars, and is attached to a *Glossopteris* leaf. This represents the first Argentinean record of glossopterid fructification in organic connection with its leaf, as well as the first record of *Plumsteadia* for Argentina.

1. Introduction

Glossopterids were the dominant group of plants during the Permian in Gondwana. The record for these gymnosperms in Argentina is represented mainly by vegetative organs (i.e., leaves). However, a few reproductive structures have been described so far. These fructifications include *Ottokaria* sp. cf. *O. bengalensis* Zeiller, 1902 and *Lanceolatus bonariensis* Menéndez (Menéndez, 1962; Borrello, 1966), both from the Lower Permian Bonete Formation (Buenos Aires Province); *Arberia* sp. cf. *A. minasica* White, 1908 (Archangelsky and Arrondo, 1973) and *Ottokaria* sp. (Barreda and Césari, 1995), from the Lower Permian Arroyo Totoral Formation of Sierra de los Llanos (La Rioja Province); and Fructifications sp. A and B (Archangelsky and Bonetti, 1963), from Bajo de la Leona (La Golondrina Formation, Santa Cruz Province). In 1992 *Dictyopteridium* was described for the first time for the Bajo de la Leona area (Archangelsky, 1992). Fragments of *Dictyopteridium* were also described for the Carapacha Basin (Carapacha Formation), La Pampa Province (Melchor and Césari, 1997). Recently, Gallego et al. (2008) described approximately 30 specimens of the morphogenus *Arberia*, from the Lower Permian Tepuel–Genoa Basin (Río Genoa Formation), in Chubut Province, found in close association with *Glossopteris wilsonii* leaves.

Here, we describe a new fertile glossopterid specimen of the genus *Plumsteadia*, from the La Golondrina Formation, La Golondrina Basin. The genus is characterized as a dorsiventrally flattened structure, in which the fertile units completely cover one surface of the sporophyll, and either has an entire marginal wing or not (McLoughlin, 1990).

2. Geological setting

The Golondrina Basin is located at the Deseado Massif, eastern of Santa Cruz Province (Fig. 1). It is bounded by the Deseado River in the NNE and the Río Chico in the SSE; the western limit of the basin is currently unknown (see Jalfin, 1987; Andreis, 2002). Geological and paleontological sites of study in this basin include the Bajo de la Leona, Estancia La Juanita, Cerro Chato, Estancia Dos Hermanos, and the Laguna Dulce localities (Viera and Pezzuchi, 1976; Jalfin, 1987; Bellosi and Jalfin, 1990; Panza, 1994; Archangelsky et al., 1996a). This study is on the Bajo de La Leona locality, situated at a short distance of Estancia La Golondrina and Estancia Leonardo (Fig. 1). The sedimentary sequence is approximately 2600 m thick and composed mostly of late Paleozoic continental sandstones with intercalated gravels and shales (Jalfin, 1990; Andreis, 2002, Archanglesky et al., 1996a), assigned to the Tres Cerros Group, comprising the La Golondrina Formation at the base and La Juanita Formation at the top. The sequence is overlain by upper Triassic sediments from the El Tranquilo Formation, and unconformably overlies deposits of unknown age.

According to Archangelsky et al. (1996a), the La Golondrina Formation is divided into three members, from bottom to top: the Laguna Lillo, Laguna Polina, and Dos Hermanos members (see also Jalfin,

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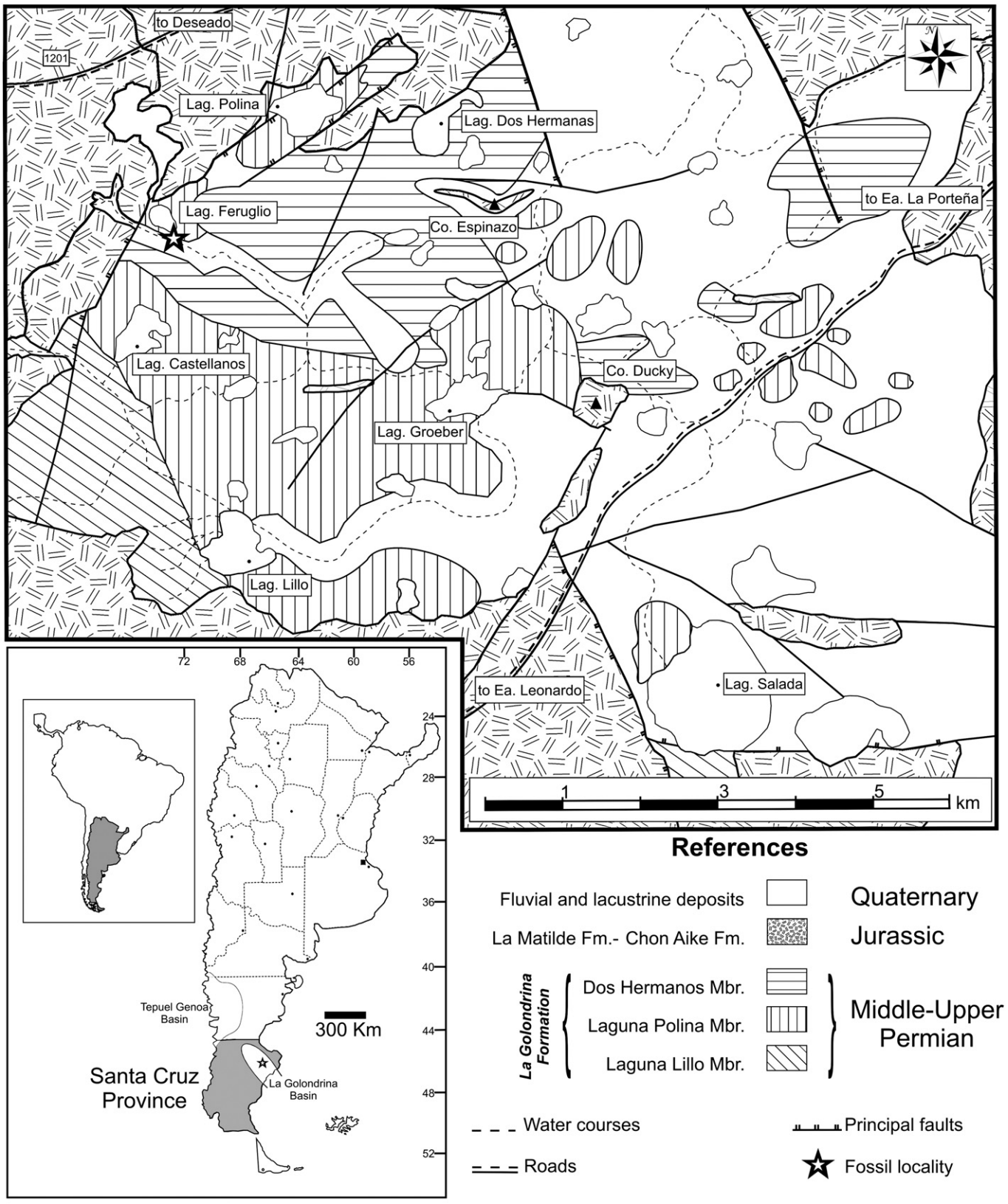

Fig. 1. Geological map of the Bajo de La Leona area, showing the Permian outcrops of La Golondrina Formation (Modified from Panza, 1994).

1987, 1990; Jalfin et al., 1990). Paleoenvironmental reconstructions suggest that the basin fill comprises two different fluvial allocycles that show evolution from a relatively low-energy braided river system with variable sinuosity and sedimentation rates (Laguna Lillo and Laguna Polina members) into a higher energy, less sinuous fluvial system. This change in fluvial facies was caused by tectonic reactivation during the deposition of the Dos Hermanos Member (Jalfin, 1987; Jalfin et al., 1990; Andreis and Archangelsky, 1996; Archangelsky et al., 1996a).

The La Golondrina Formation is the only unit in the Tres Cerros Group that yielded a rich and abundant flora, composed of fertile and

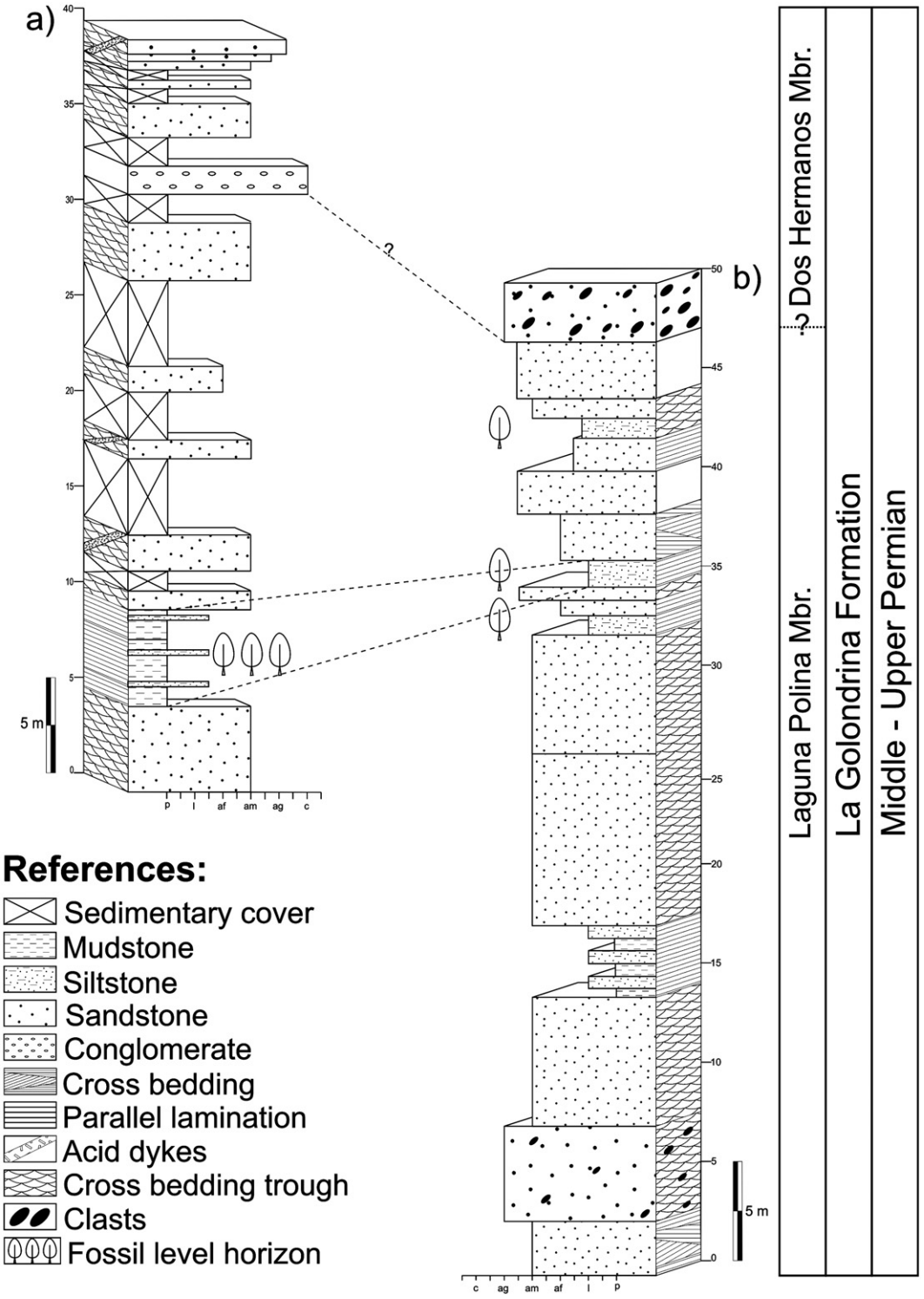

Fig. 2. Sedimentary column for Laguna Feruglio; a) this work, b) modified from Jalfin (1987).

sterile remains of pteridophytes, glossopterids, sphenophytes, and to a lesser degree, lycophytes and cordaitaleans (Archangelsky, 1959a,b; 1960a,b, 1992; Archangelsky and De la Sota, 1960; Archangelsky and Bonetti, 1963; Arrondo, 1972; Herbst, 1978; Archangelsky and Cúneo, 1984; Durango de Cabrera, 1990; Archangelsky et al., 1996a, 1999; Archangelsky, 1999, 2000; Escapa and Cúneo, 2006).

The megaflora of the La Golondrina Formation was assigned to the *Dizeugotheca* Superbiozone (Archangelsky and Cúneo, 1984), and therefore a Middle to Late Permian age was inferred (Archangelsky, 1992; Archangelsky et al., 1996b, 2004; Archangelsky, 2006).

3. Materials and methods

The fossil described here consists of part and counterpart of a compression/impression (MPM-PB 2524 a,b), showing a fructification attached to a *Glossopteris* leaf. The specimen was collected from a new

locality (48°10′31″ S; 67°16′54″ W), on the SE shore of Laguna Feruglio (275 m long N–S direction, and 258 at its maximum width in E–W direction), 7.8 km E of Estancia La Golondrina, and 2.1 km. SSW of Laguna Polina (Fig. 1).

The stratotype for the La Golondrina Formation was described in the Laguna Polina area (Archangelsky, 1957; Jalfin, 1987), where only the middle (Laguna Polina) and the upper (Dos Hermanos) members are represented. In this area, the La Golondrina Formation consists of greenish-grey, fine to medium-grained sandstone beds (in some cases very coarse at the top), dominated by wackestones and arkoses, intercalated with rich fossiliferous beds of silt- and claystone containing a *Glossopteris* flora, and with non-fossiliferous conglomerates in the uppermost part of the sequence (Archangelsky, 1959a; Panza, 1994).

A new section was measured at the recently discovered fossil locality in Laguna Feruglio ("Feruglio lake") (Fig. 2a). The base of the section is about 150 m WSW of the southern shore of the dry lake (48°10′30″ S, 67°16′59″ W; Fig. 1), and the sequence was traced along the lake margin, perpendicular to the N130° strike of the beds. The total thickness of the sequence is 39 m, starting with a medium-grained sandstone with poorly developed, non-parallel, curved internal lamination. Overlying this bed is a greenish-grey mudstone with planar lamination, interbedded with siltstones and fine-grained sandstones, and a single mudstone layer containing the fossil flora. Above the mudstone level are sandstone beds with poorly developed, altered small-scale trough-cross beds. The grain size varies from medium-fine to coarse. Intrusions of subvertical dykes (N80°) of Jurassic age (Andreis, 2002) are present. A clast-supported, polymict conglomerate, reflecting a variety of different source rocks (including granitoid, sand, metamorphite, vulcanite, quartzite, ortoquartzite, quartz-wackestone, quartz-feldespate and phyllite) is exposed approximately 31.5 m above the base of the section. Clasts are smoothly rounded, elongated to flattened, and their imbrications show a N–S paleocurrent, suggesting potential input from the Tepuel-Genoa basin, which is in agreement with Jalfin (1987, p. 129).

Jalfin's (1987) recorded section for Laguna Feruglio (Fig. 2b) has a total thickness of 50 m, and is dominated by medium to coarse grained sandstones with scattered clasts and cross-bedded troughs. Approximately 14 m above the base, there is a level of non-fossiliferous mudstones alternating with planar laminated siltstones. Beds dominated by siltstones are found at ~32, 34, and 42 m above the base (Fig. 2b).

A Nikon SMZ800 stereomicroscope and a digital Nikon DS-Fi1-U2 digital camera were used for detailed analysis and illustration. A Sony DSC-H2 digital camera (6.0 megapixel) was used to photograph the fossil material. The classification scheme used is based on McLoughlin (1990). Fossils are housed at the Museo Regional Provincial "Padre Manuel Jesús Molina" collection, in Río Gallegos, Santa Cruz Province, numbered as MPM-PB 2524 a–b.

3.1. Systematic paleontology

Division PINOPHYTA Meyen, 1984

Class GLOSSOPTERIDOPSIDA Lakhanpal, Maheshwari and Awasthi, 1976

Order DICTYOPTERIDALES Rigby, 1978

Family DICTYOPTERIDACEAE Surange and Chandra *ex* Rigby, 1978 *emend.* Maheshwari, 1990 (nom. corr. McLoughlin, 1995)

Genus *Plumsteadia* Rigby *emend.* Rigby, 1971 *ex* McLoughlin, 1990

Type species: *Plumsteadia microsacca* Rigby, 1963

Plumsteadia pedicellata sp. nov.

Plate I, 1–6; Fig. 3.

Diagnosis: Fructification obovate to spatulate; broadly rounded apex retuse; base acute. Ovule (?) scars ~0.5 mm in diameter, rounded, closely spaced, distributed randomly. Peripheral wing is not present. Pedicel long (10 mm), longitudinally striated, attached to *Glossopteris* sp. cf. *G. pampeana* petiole.

Holotype: MPM-PB 2524 a–b (Plate I, 1–6)

Locus Typus: Laguna Feruglio (48° 10′ 28″ S; 67° 16′ 47″ W), Bajo de la Leona, Santa Cruz Province, Argentina.

Stratotype and age: La Golondrina Formation; Middle–Late Permian.

Etymology: *pedicellata* refers to the long, narrow fructification stalk attached to the petiole of the *Glossopteris* leaf.

Description: Dorsiventral, obovate, ovuliferous fructification, 15 mm long and 7 mm wide (Plate I, 1–2); receptacle apex broadly rounded and retuse (Plate I, 3). The base is markedly acute. The fructification is attached to the petiole of a subtending *Glossopteris* leaf by a striated pedicel, 10 mm long and 1 mm wide (Plate I, 1–4).

Along the upper right margin of the fructification there is a narrow line of contiguous, rounded seed attachment scars, 0.5 mm in diameter (Plate I, 5). Due to the poor preservation, scars cannot be seen along the remainder of the margin. Scars can also be seen on the receptacle surface, although they are too poorly preserved to be characterized. There are faint longitudinal striations on the surface on the lower half of the sterile surface of the receptacle (Plate I, 1–2).

The apical half of the attached *Glossopteris* leaf was detached and laterally displaced during preservation (Plate I, 1). Nevertheless, it is possible to observe the original lanceolate shape. The total blade length (without the petiole) is 45 mm, and the maximum width is 15 mm. The leaf has a well-defined midrib, c. 1.2 mm wide, having the same width from the base to the apex, with a central longitudinal line. Secondary veins arise at a wide angle to the midrib (~80°–90°), and reach the margins at an angle of ~90°. Only few anastomoses can be observed (1 to 2 anastomoses from midrib to margin at medial part), forming long and narrow meshes (3:1) (Plate I, 6). Meshes are narrow and linear, of constant width. The vein density is ~35/cm. The petiole is 20 mm long and 1 mm wide.

4. Discussion and comparisons

The specimen here described can be confidently placed within the Dictyopteridaceae. It is a simple, dorsiventrally flattened fructification, with veins on one receptacle surface, and the other covered with a large number of ovules.

The genus *Plumsteadia* comprises a wide range of ovuliferous fructifications, that can either be attached to the midrib or the petiole of a subtending *Glossopteris* leaf, with receptacles that can be very variable in shape (e.g., elliptical, oblong, lanceolate), and that either lack or possess a wing of variable width (Banerjee, 1984; Anderson and Anderson, 1985; McLoughlin, 1990; Adendorff, 2005). Typically, one side of the receptacle is covered by closely spaced seed scars, and the other side shows veins. In some cases, differentiated scars are seen along the periphery of the receptacle (emend. diag. Adendorff, 2005, p. 268). We assign our fructification to the genus *Plumsteadia* based on the attachment to the petiole to the subtending *Glossopteris* leaf, and the obovate shape of the fructification, with a broadly rounded apex and a

Plate I. 1–6. *Plumsteadia pedicellata* sp. nov.

1. *Plumsteadia pedicellata* sp. nov. attached to a *Glossopteris*, G. cf. *pampeana* leaf.
2. Sterile surface of fructification.
3. Broadly rounded and retuse apex of fructification.
4. Attachment of fructification to petiole of subtending *Glossopteris* leaf.
5. Arrows points rounded seed(?) scars seen along the upper right margin of fructification.
6. Detail of subtending *Glossopteris* leaf venation.


10 mm
1


5 mm
2


5 mm
3


5 mm
4


5 mm
5


2.5 mm
6

markedly acute base. Most importantly, *Plumsteadia* has been diagnosed as fructification with a "receptacle which either lacks a wing or possesses an equidimensional, narrow, grooved, ridged, or smooth wing with an entire margin" (McLoughlin, 1990, p. 285). Along the upper right margin of our specimen (Plate I, 5), contiguous, rounded scars, 0.5 mm in diameter, can be seen. Given the poor preservation of the remaining margin, it is not possible to assert the nature of these scars; however, they could potentially represent a portion of a marginal wing. *Plumsteadia* is the only genus that includes fructifications with or without a wing. Therefore, we assign our fossil to *Plumsteadia*.

Plumsteadia pedicellata sp. nov. shares characters with other known *Plumsteadia* species. However, features such as the long pedicel attached to the leaf petiole and the obovate shape are distinctive enough to justify the creation of a new species.

The spatulate–obovate shape of *P. pedicellata* is very characteristic, and no other member of the Dictyopteridaceae has this shape. However, forms with a more rounded apex and of similar receptacle width have been described, such as the African species *Plumsteadia natalensis* Lacey, van Dijk and Gordon-Grey, 1975 (see Anderson and Anderson, 1985, p. 124, pl. 92, 1–13), and "Fructification sp. B" Archangelsky and Bonetti, 1963 (p. 34, figs. 1–3) from Bajo de la Leona. The latter is an "elongated, oblong shape, slightly expanded on its apical section", that is very similar to that observed in the current specimen. Nevertheless, there are two clear differences that distinguish our specimen from "Fructification sp. B" (Archangelsky and Bonetti, 1963), "Fructification sp. B" has a rounded base (the base in our specimen is markedly acute), and the ovule scars are differently shaped and much larger (ovoid, 2.5 mm long and 1 mm wide vs. round and 0.5 mm in diameter in our fructification). Unfortunately, the poor preservation of our specimen does not allow further comparisons.

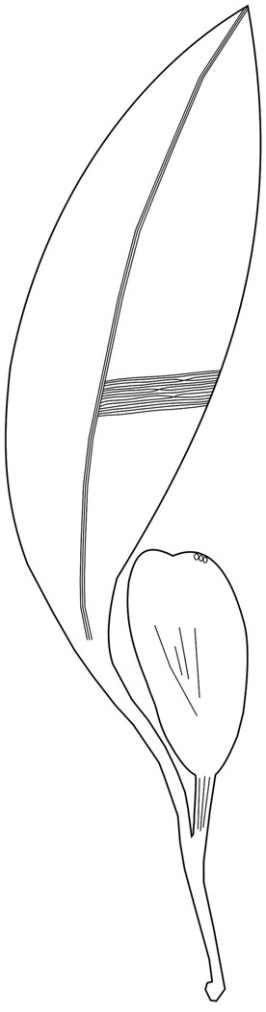

Fig. 3. Reconstruction of *Plumsteadia pedicellata* attached to *Glossopteris* sp. Cf. G. *pampeana* leaf.

The most remarkable character of our specimen is the long pedicel that attaches the fructification to the petiole of the subtending *Glossopteris* leaf (Plate I, 1–4). Quite a few glossopterid fructifications have been described in organic connection with their sterile leaf. In general, it is assumed that fructifications are sessile or attached by an adnate or axillary pedicel to the midrib, or in some cases, at the base of the leaf. Of all other *Plumsteadia* species known, only *P. ovata* Kyle, 1974 (p. 719, Fig. 1) was found attached to the *Glossopteris* leaf's petiole through a pedicel, as in our specimen. However, *P. ovata* differs from *P. pedicellata* in that the stalk of the former is shorter (~6 mm vs 10 mm in our material), and most importantly, in that it is attached where the petiole merges into the midrib (in our specimen it attaches farther from the point where the petiole merges into the midrib). *Plumsteadia bowenensis* (White) Rigby, 1969 (White, 1964, p. 394, pl. XXIV, 11), *P. gibbosa* (Benecke) Anderson and Anderson, 1985 (p. 125, pl. 93, 1–9, pl. 94, 1–14), *P. indica* (Maheshwari) Rigby, 1969 (Maheshwari, 1965, p. 144, pl. 1, 1), *P. microsacca* Rigby, 1963 (pp. 344–345, pl. XI, 5), *P. natalensis* Anderson and Anderson (1985), and *P. stricta* (Plumstead) Rigby, 1969 (Plumstead, 1958, p. 65, pl. XVIII–XX), were all found attached to the midrib of the subtending *Glossopteris* leaf (Table 1). On the other hand, *P. lanceolata* Srivastava 1978 (p. 491, pl. 1, 4–5) and *P. waltonii* (Plumstead) Rigby, 1969 (Plumstead, 1958, p. 61, pl. XXI, 1) have a short, thick pedicel, but both species were found unattached (Table 1).

As mentioned previously, the genus *Plumsteadia* includes a wide range of ovuliferous fructifications that either possess or lack a wing. Our specimen does not clearly show a wing; however, the upper right margin of the fructification seems to be differentiated and could potentially represent a remnant of a wing. Other winged *Plumsteadia* species are: *P. ampla* (White) Rigby, 1969 (White, 1964, pp. 395–396, pl. XXIV, 13), *P. gibbosa* Anderson and Anderson (1985), *P. jensenii* McLoughlin, 1990 (p. 289, pl. 1, 1–2), *P. microsacca* Rigby (1963), *P. natalensis* Anderson and Anderson (1985), *P. ovata* Kyle (1974), *P. semnes* Rigby, 1978 (pp. 11–13, figs. 14–16), and *P. stricta* Rigby (1969). These structures that are commonly called "wings" can either be a sterile marginal flap, or in some cases, clearly differentiated cells (Table 1).

Kyle's (1974) specimen – *P. ovata* – most closely resembles ours in the attachment of the fructifications to the petiole of the subtending leaf, as well as in the presence of a differentiated wing. Nevertheless, they clearly differ from each other in their shape and size (Table 1), and also in the much larger seed scars in *P. ovata*, compared to *P. pedicellata* (Table 1).

Kyle (1974) did not assign a species name to the *Glossopteris* leaf attached to the fructification, because there were not enough visible diagnostic characters due to poor preservation. Moreover, she did not illustrate the leaf, and thus a further comparison to our specimen is not possible.

The *Glossopteris* leaf attached to *P. pedicellata* shares some characters with other Permian *Glossopteris* species from Argentina, such as in the high angle at which the secondary veins arise from the midrib, the near perpendicular angle at which they reach the margin, and in the few anastomoses. Comparable species are *Glossopteris ampla* Dana (Archangelsky, 1957, p. 140, pl. I, 1), *G. stipanicicii* Archangelsky (1957, p. 153, pl. VIII, 1), *G. decipiens* Feistmantel (Menéndez, 1966, pl. III, 1–7), *G.* cf. *euryneura* Maheshwari (Melchor and Césari, 1997, p. 618, Fig. 7) and *G. pampeana* Melchor and Césari (1997, p. 620, Fig. 8).

Glossopteris ampla was originally described from Bajo de La Leona (Archangelsky, 1957), and differs from our specimen because secondary veins are sinuous and the leaf is larger (some specimens>20 cm). *Glossopteris stipanicicii*, also from Bajo de La Leona (Archangelsky, 1957), has a thicker midrib (2 mm) with a fine longitudinal striation. Our *Glossopteris* leaf has a midrib of c. 1.2 mm thick, and shows only a single central longitudinal line.

Table 1
Comparison between *Plumsteadia pedicellata* and other *Plumsteadia* species known.

	Shape and size (L:W, mm)	Ovules (mm)	Marginal flap[a]	Found attached to leaf	Other	Age and locality
Plumsteadia pedicellata Cariglino et al.	Spatulate; 15:7	0.5	No	Yes	Attachment to leaf petiole by long peduncle.	Up. Pm – Argentina
P. ampla (White) Rigby (1969)	?; 35:30	5:4	Yes	No		Up. Pm – Australia
P. bowenensis (White) Rigby (1969)	Lanceolate; 30:8	1:0.6	No	Yes	Attachment to midrib of the leaf, 2 cm from the base.	Up. Pm – Australia
P. gibbosa (Benecke) Anderson and Anderson (1985)	Narrowly ovate; 17–38:5–23	1	Yes	Yes	Attachment to midrib at base of lamina, sessile.	Up. Pm – S. Africa
P. indica (Maheshwari) Rigby (1969)	Broadly elliptical, 21:11	?	Yes?	Yes	Attachment to the midrib of the leaf, sessile.	Up. Pm – India
P. jensenii McLoughlin (1990)	Narrow ovate to narrow obovate; 12–15:5–7	1	Yes	No	Short basal pedicel inferred.	Up. Pm – Australia
P. lanceolata Srivastava (1978)	Elongate to lanceolate; 21:8	1	No	No	Thick pedicel present, swollen attachment zone.	Up. Pm – India
P. microsacca Rigby (1963)	?; 27:9.5	0.8:0.5	Yes	Yes	Attachment to the midrib "by a short, stout pedicel".	Up. Pm – Australia
P. natalensis Anderson and Anderson (1985)	Narrowly ovate; 18–28:7–12	0.5	Yes	Yes	Attachment to midrib near base of lamina, sessile.	Up. Pm – S. Africa
P. ovata Kyle (1974)	Broadly ovate; 40:25	1.5:1	Yes	Yes	Attached to "the top of the leaf petiole at the point where it merges into the midrib".	Pm – Antarctica
P. semnes Rigby (1978)	Circular to polygonal, base strongly cordate; 28–35:12–20	1.2	Yes	No		Low. Pm – Australia
P. stricta (Plumstead) Rigby (1969)	Ovate and auricular; 17–32:11–27	?	Yes	Yes	Attachment to midrib, sessile. Adnate pedicel inferred.	Low. Pm – S. Africa.
P. waltonii (Plumstead) Rigby (1969)	? – 20:13–19	?	No	No	Short, thick pedicel.	Low. Pm – S. Africa

[a]sterile marginal flap, sometimes clearly differentiated cells.

Glossopteris decipiens, described from the Permian of Buenos Aires (Menéndez, 1966), has a dense secondary venation, with long, narrow areoles, like our specimen, but secondary veins arise at an acute angle (<45°) from the midrib, changing abruptly to become almost perpendicular to the margins.

Glossopteris sp. cf. *G. euryneura*, from the Upper Permian of the Carapacha Basin (Melchor and Césari, 1997), is similar in size, in the oblong shape, and also has an acute, cuneate base, but differs in having small veinlets interconnecting the secondaries, which is not to be seen in our specimen.

Glossopteris pampeana (Melchor and Césari, 1997) is most similar to our fossil, in its small size (maximum width 3 cm), its lanceolate shape, its acute apex, in having a well-defined midrib and secondary veins that are nearly perpendicular to the midrib and margin (reaching the latter at an angle of almost 90° in the lower part of the blade, and ~40° in the upper part). Furthermore, the secondary venation shows few dichotomies and anastomoses, forming long and narrow meshes. Nevertheless, the midrib of *G. pampeana* narrows toward the apical region, while our specimen's midrib shows a constant width from the base to the apex. Considering there is only one specimen, and given its poor preservation, it cannot be firmly assigned to *G. pampeana*, and it is better referred as *G.* cf. *pampeana.*

5. Conclusions

Based on the evidence presented here, and considering all other similar glossopterid fructifications, we conclude that specimen MPM-PB 2524 a–b can be assigned to *Plumsteadia*, and given its characteristics, to a new species (*P. pedicellata*). It is attached to a leaf of *Glossopteris*, *G.* cf. *pampeana* Melchor and Césari (1997).

This is the first record of the genus *Plumsteadia* in Argentina, as well as the first Argentinean glossopterid fructification found in organic connection to a *Glossopteris* leaf (*G.* cf. *pampeana* Melchor and Césari). The material is also unique because the fructification is attached to a petiole rather to a midrib, as is typical for other species of the genus. However, further work at the site is needed to try to obtain more material that might help to further elucidate its nature.

Plumsteadia was wide spread during a considerable part of the Permian in Gondwana, and has little biostratigraphic value.

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