

GILBOAPHYTON ARGENTINUM SP. NOV.: A HERBACEOUS LYCOPOD FROM THE EARLY CARBONIFEROUS OF ARGENTINA

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ABSTRACT – A new species of a herbaceous lycophyte with tripartite leaves is attributed to *Gilboaphyton* Arnold on the basis of the leaf morphology and the hexagonal shape of its leaf bases on the stem surface. The new species includes specimens previously classified as *Archaeosigillaria conferta* (Frenguelli) Menéndez, a primitive lycophyte which has been considered of biostratigraphic value in the Lower Carboniferous of Argentina. The excellent preservation of its delicate leaves adpressed to the stem has allowed to recognize its tripartite shape. The fossil remains are from lower strata of the Jaramillo Formation, in the Tepuel - Genoa Basin in NW Patagonia, Argentina. *Gilboaphyton argentinum* Carrizo & Azcuy sp. nov. is compared with the two species of *Gilboaphyton* Arnold, *G. goldringiae* Arnold from New York and *G. griersonii* Berry & Edwards from Venezuela. Its age is discussed and it is concluded that the biocron of the genus *Gilboaphyton* has to be extended into the Early Carboniferous.

Key words: Lycophyte, *Gilboaphyton*, Early Carboniferous, Southwest Argentina.

RESUMO – Uma nova espécie de licófito herbácea é proposta com base na morfologia de suas folhas e no modelo hexagonal de suas bases foliares na superfície do talo. A nova espécie inclui espécimens anteriormente referidos a *Archaeosigillaria conferta* (Frenguelli) Menéndez, uma primitiva licófito, a qual é atribuído um importante valor estratigráfico em formações do Carbonífero Inferior da Argentina. A excelente preservação do material, com delicadas folhas adpresas sobre o talo permitiu reconhecer seu caráter tripartido. Os restos fósseis aqui descritos são provenientes dos estratos basais da Formação Jaramillo, bacia Tepuel-Genoa, na região noroeste da Patagônia. *Gilboaphyton argentinum* sp. nov. é comparada a outras espécies de *Gilboaphyton* Arnold, tais como *G. goldringiae* Arnold de New York e *G. griersonii* Berry & Edwards da Venezuela. Sua idade é discutida e se conclui que o biocron do gênero *Gilboaphyton* deve ser estendido ao início do Carbonífero.

Palavras-chave: Licófito, *Gilboaphyton*, Carbonífero Inferior, Sudoeste da Argentina.

INTRODUCTION

Among the primitive lycophytes of Argentina, one species has been repeatedly cited in scientific literature: *Archaeosigillaria conferta* (Frenguelli) Menéndez (1965). This species has been considered, in the last decades, of important stratigraphic value in the Lower Carboniferous of Argentina. The study of new collections, have allowed the clarification of the status of some specimens of this taxon, mainly on the basis of the leaf morphology.

The identification of tripartite leaves in specimens previously attributed to *Archaeosigillaria conferta*, considered in the light of research carried out by Berry & Edwards (1997) on samples from Venezuela and New York State, makes it necessary to establish *Gilboaphyton argentinum* Carrizo & Azcuy sp. nov., for those specimens in which this type of foliar morphology is recognized.

GEOLOGICAL SETTING

The study area is located in the northern part of Sierra de Tepuel, at the Tepuel-Genoa Basin, Chubut province, Argentina (Figure 1). The specimens, which are here assigned to *Gilboaphyton argentinum* sp. nov., were collected in the basal section of the Jaramillo Formation, 800 m northwest of Puesto Pardo within Estancia La Mimosa (Figure 2). The Tepuel - Genoa Basin is located in southwest Argentina and is one of the Pacific Basins alongside the Andes in southernmost South America. It is a back-arc basin extended between 43° - 45°S latitude and 70° - 71°W longitude. Most of its sedimentary filling has been assigned to the Upper Paleozoic. The geology of the Sierra de Tepuel has been studied by several authors (Suero, 1948; Lesta & Ferello, 1972; Andreis *et al.*, 1985), who have proposed different interpretations of the stratigraphy of the Tepuel - Genoa Basin.

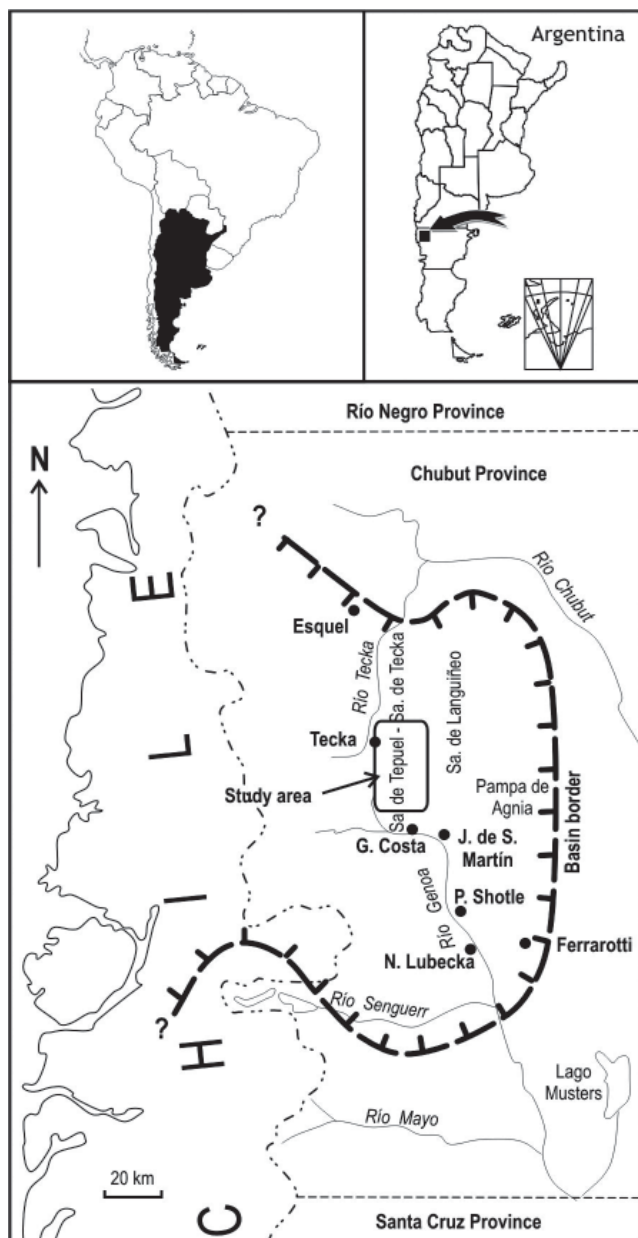


Figure 1. The Tepuel-Genoa Basin of Southwest Argentina, with location of the study area (adapted from González, 1984).

Suero (1948) includes the basin deposits in the “Tepuel System”; while Lesta & Ferello (1972) define Tepuel Group to include the Pampa de Tepuel and Mojón de Hierro formations. Later, Andreis *et al.* (1985) include other units in the Tepuel Group, from oldest to youngest, the Jaramillo, Pampa de Tepuel, Mojón de Hierro and Río Genoa formations. The Tepuel Group is 5000 m thick and the strata are interpreted as marine and terrigenous deposits, with glacial deposits in the Pampa de Tepuel and Mojón de Hierro Formations (González Bonorino & González Bonorino, 1988). The base of Tepuel Group does not crop out in the study area and is only observed in the Catreleo zone, on the western side of Sierra de Agnia (González Bonorino & González Bonorino, 1988). The overlying sediments consist of Jurassic rocks in pseudoconformably relationship (Suero, 1948).

Page *et al.* (1984) provided details of the type section of the Jaramillo Formation (Figure 2A-B). These deposits are located on the western side of Sierra de Tepuel and have also been recognized in the Sierra de Tecka (González Bonorino *et al.*, 1988). The Jaramillo Formation is dominated by sandstones with subordinate shales and conglomerates. These deposits are 1000 m thick and are the oldest of the Tepuel Group. Lacking a visible base, they are underlain paraconformably by Pampa de Tepuel Formation (Figure 3). The sandstones form mostly compact tabular deposits, while dark grey shales are present in banks up to 4 m thick (Figure 2B).

The basal strata of the Jaramillo Formation were deposited in a marine environment along the shore. This is inferred from the presence of undeterminable marine invertebrate (González, pers. comm.). In this section, the sandstones facies is poorly developed. Dark shales of a very fine grain predominate, which favoured the excellent preservation of delicate leaves of lycopphytes, such as those illustrated herein. In the upper section the sedimentation took also place in a marine environment along the shore with the presence of floated stems fragments (Andreis *et al.*, 1987; González Bonorino *et al.*, 1988).

MATERIAL AND METHODS

Studies carried out in different lithostratigraphic units of the Lower Carboniferous of Argentina have recovered abundant fossil lycopphytes, both in variety of species and amount of specimens. The species here analyzed has shown two main types of fossilization in the sense of Schopf (1975). The most common to be found in the greater part of the material, corresponds to imprints and their counterparts, in some cases together with coalified remains, which show details of the surface features.

The other fossilization process includes positive and negative moulds as well as casts. Although there is no information on the anatomical structure of these axes, their external morphology is clearly discernible, including occasionally, slight impressions of epidermal tissue.

However, the preservation of leaf features varies according to the type of lithology and its texture, as well as with the mode of fossilization and location with respect to the stem. When the leaves have been preserved adpressed directly above the stem it is possible to recognize their laminar morphology, whereas in most cases in lateral view the foliar characteristics may become masked by compression and be mistaken for truncated spines of simple morphology.

All the studied material is housed in the Paleobotanical Collection of the Fundación Miguel Lillo, Tucumán Province, Argentina. All numbers are prefixed LIL Pb which identify the paleobotanical collection.

HISTORICAL REVIEW

The first studies and descriptions of Devonian lycopphytes from New York State were carried out by Vanuxem (1842), who considered that his specimen could be closely related to

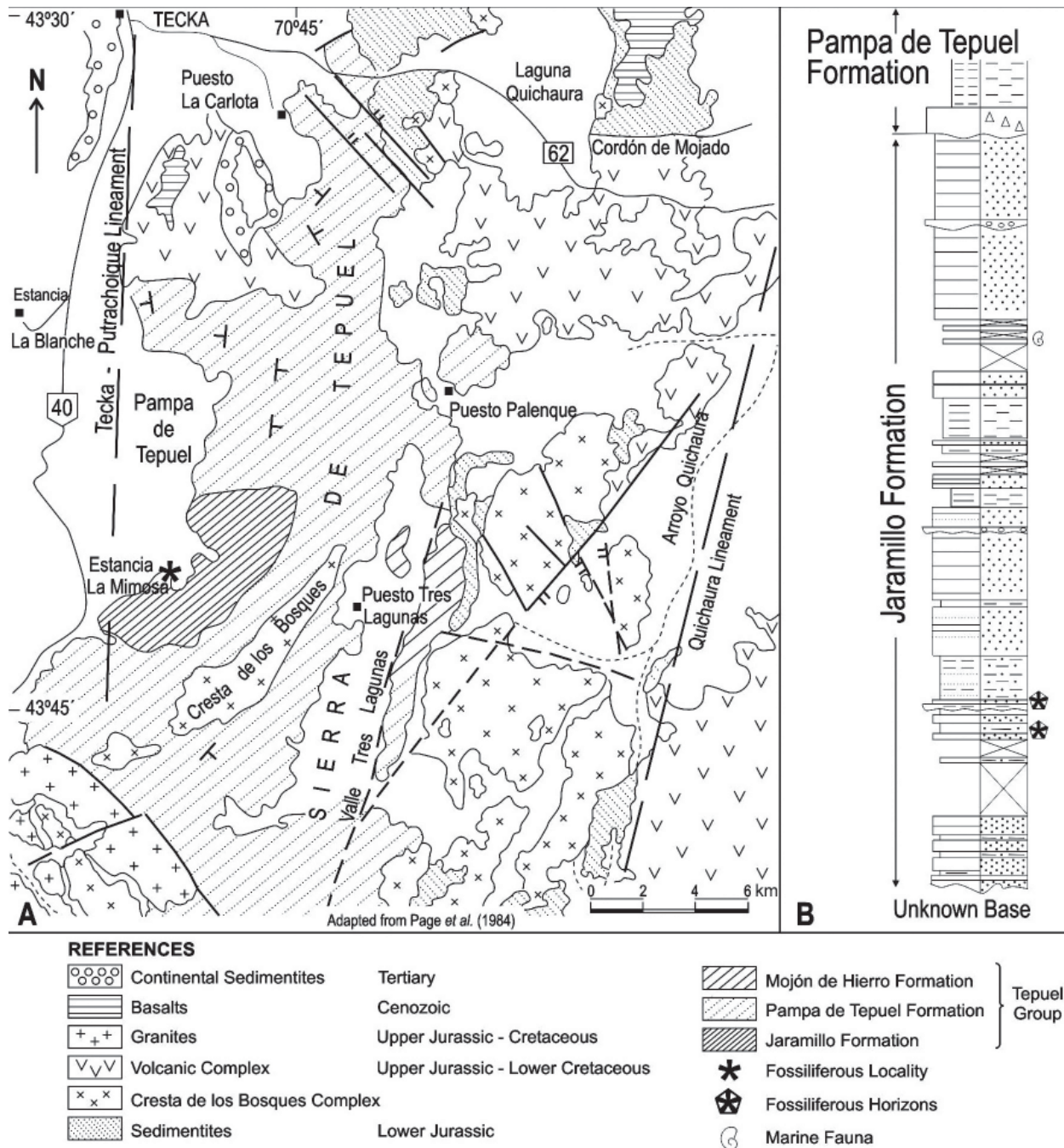


Figure 2. A, geological outline of the Sierra de Tepuel showing the distribution of the Jaramillo Formation (Lower Carboniferous) and the location of the fossiliferous locality; B, schematic columnar section of the Jaramillo Formation, in the northern region of the Sierra de Tepuel, showing fossiliferous horizons with *Gilboaphyton argentinum* sp. nov.

Lepidodendron Sternberg. Later, Göppert (1852) renamed it as *Sigillaria vanuxemi*, while Kidston (1885) referred the North American specimen, as well as some from the Early Carboniferous of England, to *Lycopodites vanuxemi*. Later, Kidston (1901) included the North American specimens together with those from the Early Carboniferous of Great Britain in the genus *Archaeosigillaria*, and designated *A. vanuxemi* as type species. Lacey (1962) and Grierson & Banks (1963) carried out amendments to the generic diagnosis of *Archaeosigillaria*. Lacey incorporated cuticular details, while

Grierson & Banks (1963) included aspects of leaf morphology. Later, while studying specimens from Gilboa in New York State, Arnold (1937) established the genus *Gilboaphyton* with *G. goldringiae* as type species. However, Kräusel & Weyland (1949) considered *Gilboaphyton goldringiae* Arnold (1937) a synonym for *Archaeosigillaria vanuxemi* (Göppert) Kidston (1901), differentiating the material found in the North American Devonian from that having its source in the British Carboniferous. Likewise, they included some specimens of the Early Carboniferous of Great Britain

TEPUEL - GENOA BASIN									
Region		Western Area							
Locality		Patagonian Pre-Range				Patagonian Range			
Age		Sierras Tepuel - Tecka				Sierra Agnia			
M.a.									
Carboniferous	Permian	Late	Early	299	Stephanian	Mojon de Hierro Formation			
	Late	305	Westphalian	316	Namurian	?			
	Early	320	Visean	343	Tournaisian	Pampa de Tepuel Formation			
	Late	354				Jaramillo Formation			
Devonian	Mid					Unknown base			
	Early								

Figure 3. Upper Paleozoic stratigraphic units of the Sierras de Tepuel-Tecka, Agnia and Cordón de Esquel from Western Tepuel - Genoa Basin. Carboniferous time scales after Menning *et al.* (2001).

assigned to *Archaeosigillaria vanuxemi* in the species *Archaeosigillaria kidstonii* Kräusel & Weyland (1949). Fairon-Demaret & Banks (1978) demonstrated the tripartite character of the leaf lamina in the Gilboa specimens, under the name *A. vanuxemi*.

The study of Berry & Edwards (1997) using specimens from New York State, including the *Archaeosigillaria* type specimen, and others originated in the Venezuelan Devonian, allowed these authors to carry out a detailed revision of the genus *Archaeosigillaria* Kidston and to recognize its close relationship to the genus *Gilboaphyton* Arnold. Berry & Edwards (1997) separate these genera because of the non-preservation of leaves in the type specimen of *Archaeosigillaria* (*A. vanuxemii*) and the identification of tripartite leaves in the type species of *Gilboaphyton* (*G. goldringiae*) as reported by Fairon-Demaret & Banks (1978) under the name *A. vanuxemii*. They established a new species *G. griersonii* Berry & Edwards (1997) to recognize the long,

slender leaves of the Venezuelan species.

According to the concepts developed by Berry & Edwards (1997), the uniting factor of *Archaeosigillaria* and *Gilboaphyton* is based on two facts: firstly the tripartite leaf lamina and secondly the hexagonal pattern of depressions surrounding the leaf bases on the surface of the stem.

In Argentina, an important number of specimens of herbaceous lycophytes have been recognized in different formations of the Lower Carboniferous, which have been identified as *Archaeosigillaria conferta* (Frenguelli) Menéndez (Menéndez, 1965; Petriella & Arrondo, 1978; Gutiérrez & Arrondo, 1994; Azcuy & Carrizo, 1995). This collection of pieces attributed to *A. conferta* presents different types of preservation, which according to their frequency of occurrence are: cast, positive and negative moulds and impressions. In casts and positive moulds, protuberances corresponding to leaf bases are observed. Among other details, the negative moulds show the depressions caused by the leaves that have penetrated the sediment. In none of the reported records was possible to recognize leaves upon stems or to identify the morphology of the leaf lamina.

However, the very good preservation of the impressions collected in the Jaramillo Formation, Chubut province (Carrizo, 1998), has allowed for the first time the identification of the leaf lamina. By means of the interpretation of the total of recognized characteristics, it has been possible to identify the complete morphology of the leaves (Figures 4-5) and in that way to reconstruct the axes carrying tripartite vegetative leaves, in a helical pattern typical of this primitive lycophyte.

Based on the above stated, we agree with the criteria proposed by Berry & Edwards (1997) and refer the lycophytes collected at the base of the Jaramillo Formation to *Gilboaphyton argentinum* sp. nov. On other hand, the examination the specimens referred to *A. conferta* (Frenguelli) Menéndez, in the light of the new generic amendment of *Archaeosigillaria* proposed by Berry & Edwards (1997), will allow to name them accordingly.

SYSTEMATIC RESULTS

Class LYCOPHYTA

Order INCERTAE SEDIS

Family ARCHAEOSIGILLARIACEAE

Genus *Gilboaphyton* Arnold *emend.* Berry & Edwards 1997

Gilboaphyton argentinum Carrizo & Azcuy sp. nov.
(Figures 4, 5)

Holotype. LIL-Pb 7175 (1)

Paratype. LIL-Pb 7175 (2)

Etymology. Regarding its occurrence in Argentina.

Repository. Paleobotanical Collection of the Fundación Miguel Lillo (LIL-Pb)

Type locality. Puesto Estancia La Mimosa, Tepuel Sierra, Chubut Province, Argentina.

Stratigraphic horizon. Jaramillo Formation, Lower section, Early Carboniferous.

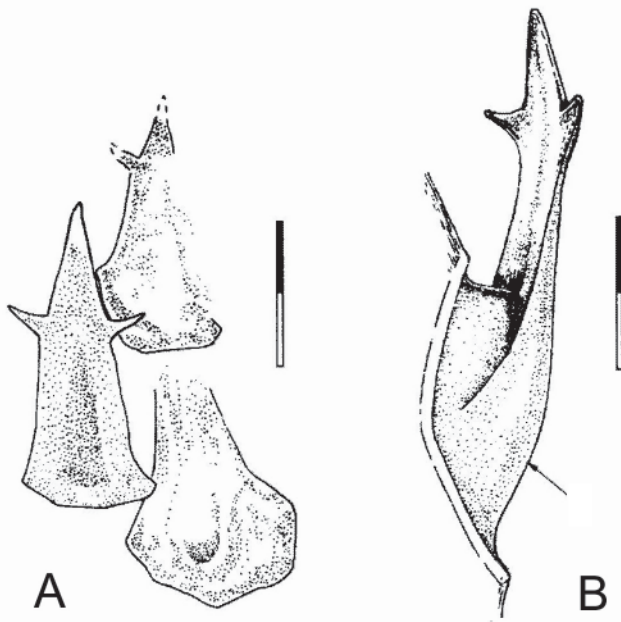


Figure 4. *Gilboaphyton argentinum* Carrizo & Azcuy new species, LIL Pb 7175(2). **A**, drawing in camera lucida showing morphology of the leaf with the central and lateral segment in its distal portion; **B**, profile view showing the strong abaxial decurrence (arrow), the thickness of the base and the characteristic tripartite division in the distal portion. Scale bars= 2 mm for A and 1.5 mm for B.

Additional specimens. LIL-Pb 7176, LIL-Pb7177, LIL-Pb7178, 7LIL-Pb179, LIL-Pb7182, LIL-Pb7183, LIL-Pb7187.

Diagnosis. Impressions of simple and ?ramified axes, herbaceous, covered by persistent laminar leaves, tripartite, attached to the stem at an acute angle and disposed in alternate verticils. Phyllotaxis sigillarioid. Conspicuous hexagonal leaf cushions, equidimensional (ca. 2 mm), contiguous or slightly separated by narrow furrows, forming vertical lines. Leaves with asymmetric leaf bases of basal hexagonal-circular contour. Triangular lamina leaf is 4.5 mm long, with a characteristic tripartite division in its middle distal portion. Triangular middle segment is 1.5 mm long, distally curved upwards. Shorter acuminate lateral segments (0.7 mm) in an almost horizontal position. Leaf lamina and divisions with entire margins. From a lateral view the leaves resemble convex spines with respect to the axis, with a thick decurrent base. At the base of the leaves, carbonized approximately circular traces are interpreted as evidence of a leaf trace. Fructification unknown.

Type-specimen descriptions. The types LIL-Pb 7175(1/2) (Figures 4-5) correspond to an impression and a counter-impression, with traces of carbonization of a ?simple stem fragment preserving leaves above the stem and laterally. The scarce leaves seen in a lateral view (Figure 5B) resemble curved spines. However, the leaves above the stem are of a laminar appearance, tripartite and persistent, disposed in a spiral (Figure 5A). The basal portion of each leaf appears flattened, while the leaf lamina begins to emerge from both margins of the proximal parts of the leaf base. The lower part of the leaf lamina issues from the opposing lateral corners of

the leaf base, where it presents its greater width (ca. 2 mm) (Figure 5C-D). Then it curves upwards, where the adaxial side of the lamina forms a concave arch with respect to the stem. The lamina is 4.5 mm long, with a triangular shape and entire margins; 2.5 mm from the base two lateral, opposite acuminate segments 0.7 mm long are directed outwards. The 2 mm long acute medial segment curves upwards (Figure 5A, D). At the base of the leaves, carbonized approximately circular traces are frequently observed, which are interpreted as evidence of a leaf trace (Figure 5B-C).

Comparison and discussion. Abundant and well-preserved lycophytes of the Early Carboniferous of Argentina have been collected in formations belonging to the Tepuel - Genoa and Uspallata-Iglesia Basins of Patagonia and the Precordillera respectively (Menéndez, 1965; Menéndez, 1967; Azcuy & Carrizo, 1995; Carrizo, 1998; Carrizo & Azcuy, 2000). Some of the identified lycophytes in the Patagonian region have preserved their leaves on stems, one of the main diagnostic features which allow to assign them with systematic precision. The observation of these features has enabled us to state that the material coming from the Jaramillo Formation can be placed in a new species of *Gilboaphyton* Arnold *emend.* Berry & Edwards. *Gilboaphyton argentinum* Carrizo & Azcuy sp. nov. has been defined principally by its tripartite leaf lamina, with a large medial segment and two smaller and shorter opposite lateral segments and by their hexagonal leaf cushions. In axes of *Gilboaphyton argentinum* sp. nov. where only some complete leaves have been preserved, the morphology of their stems and leaf cushions is identical to that one observed in axes without leaves on stems previously assigned to "*Archaeosigillaria*" *conferta* (Frenguelli) Menéndez. These observations show that the axes here referred to *Gilboaphyton argentinum* sp. nov. as well as those identified as "*Archaeosigillaria*" *conferta* probably represent a single natural taxon corresponding to a lycophyte widely recognized in strata of the Early Carboniferous of Argentina (Menéndez, 1965; Azcuy & Carrizo, 1995; Carrizo, 1998; Carrizo & Azcuy, 2000).

Then, the use of the generic name *Archaeosigillaria* is restricted to designate provisionally those samples which in Argentina were assigned to the species "*Archaeosigillaria*" *conferta*. Such denomination shall be applied to those axes which clearly show the morphological characteristics of the leaf cushions and stem in which it is not possible to observe the morphology of the foliar lamina.

The two species of *Gilboaphyton* Arnold presently recognized, *Gilboaphyton goldringiae* Arnold (1937) and *Gilboaphyton griersonii* Berry & Edwards (1997) are separated from *Gilboaphyton argentinum* Carrizo & Azcuy sp. nov. by the characteristics that follow: *Gilboaphyton argentinum* sp. nov. differs from *G. goldringiae* in that the lateral segments occur in the middle-distal part of the lamina and the base of the leaf occupies all the width of the leaf base, while in *G. goldringiae* the lateral teeth occur at the widest part of the lamina, which has a narrow base. On the other hand, *G. argentinum* sp. nov. is separated from *G. griersonii* by the morphological characteristics of its stem in

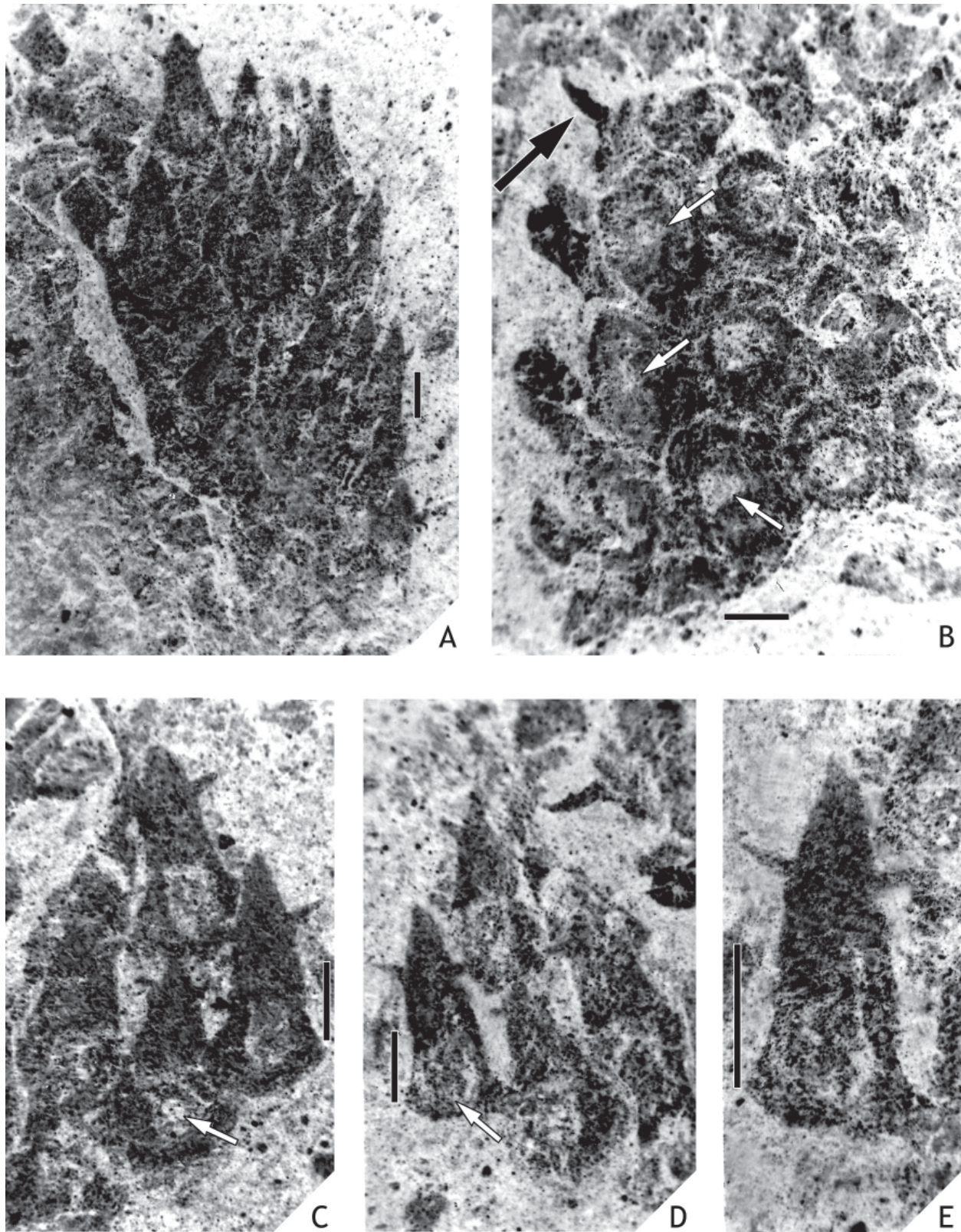


Figure 5. *Gilboaphyton argentinum* Carrizo & Azcuy new species. **A**, LIL Pb 7175(1), impression of a simple axis with vegetative tripartite leaves upon stem, showing the morphology of the leaf lamina in an abaxial view; **B**, LIL Pb 7175(2), compressed leaf bases of hexagonal outline and leaf traces marks partially carbonized in the middle part of each leaf base (white arrow), in a lateral view, spine-shaped leaves (black arrow); **C**, LIL Pb 7175(1), abaxial view of complete tripartite leaves upon stem, emerging from hexagonal leaf bases, the basal portion appears flattened and the leaf lamina begins to emerge from the left and right margins of its base, at the base of the leaves leaf traces marks partially carbonized (white arrow); **D**, LIL Pb 7175(2), tripartite leaves upon stem, hexagonal leaf bases, leaf traces (white arrow), central segment of a greater size curved toward the stem and sharpened lateral segments; **E**, LIL Pb 7175(2), detail of tripartite leaf indicated by a white arrow in D. Photographs taken under water. Scale bars = 2 mm.

which hexagonal-circular, leaf bases of equal dimensions are observed, and by features of the leaf lamina whose central segment is shorter, wider and distally curved toward the stem with its lateral teeth almost horizontal, while in the Venezuelan species the leaf bases are widened forming broadly fusiform to hexagonal patterns, and there is a very slender central segment of the leaf lamina, slightly curved outwards and its opposite lateral teeth are twisted upwards.

DISCUSSION OF AGE

The age of *Gilboaphyton argentinum* sp. nov. is based on three groups of fossils: paleofloras, faunas and miospores. Paleofloras with "*Archaeosigillaria*" *conferta* (Frenguelli) Menéndez and/or *Gilboaphyton argentinum* are known in Argentina in four lithostratigraphic units: Jaramillo, Valle Chico, Malimán and Agua de Lucho (Menéndez, 1965; Azcuy & Carrizo, 1995; Carrizo, 1998; Carrizo & Azcuy, 2000). The first two correspond to Patagonia and the others to the Precordillera. The paleofloras recognized in these units are: *Gilboaphyton argentinum* sp. nov. and "*Archaeosigillaria*" *conferta*, in Jaramillo Formation; *A. conferta* and *Eusphenopteris devonica* (Frenguelli) Sessarego & Césari in Valle Chico Formation; *A. conferta*, *E. devonica*, *Frenguella eximia* Arrondo, Césari & Gutiérrez and *Diplothmema bodenbenderi* (Kurtz) Césari in Malimán Formation; *A. conferta*, *E. devonica* and *Pietzschia schulleri* Gothan in Agua de Lucho Formation. These paleofloras are attributed in literature to the Early Carboniferous (Scalabrini Ortiz, 1972; Petriella & Arrondo, 1978; Arrondo *et al.*, 1991; Azcuy & Carrizo, 1995; Carrizo, 1998; Carrizo & Azcuy, 1998). On the other hand, in the Malimán and Agua de Lucho Formations they are associated with marine fauna corresponding to the *Protocanites scalabrini*-*Paurorhyncha chavelensis* Zone of Early Carboniferous age (González & Bossi, 1987; González, 1993a; Sabattini *et al.*, 2001) whereas in the Malimán Formation the levels with such megaflores overlay immediately or are associated with strata bearing a palynoflora composed of *Verrucosporites nitidus* Playford, *V. congestus* Playford, *Cordylosporites marciae* Playford & Satterthwait, *Apiculiretusispora multiseta* (Luber) Butterworth & Spinner, *A. semiseta* (Playford) Massa, Coquel, Loboziak & Taugourdeau-Lantz, *Convolutispora insulosa* Playford, *Grandispora debilis* Playford, *Dibolisporites microspicatus* Playford, *Densosporites anulatus* (Loose) Schopf, Wilson & Bentall among other species of indubitable Early Carboniferous age (Césari & Limarino, 1995; Rodríguez Amenábar *et al.*, 2003). This data serves as a reference for correlations with other basins in the Argentinean west. Likewise, one must bear in mind that in Argentina, the Upper Paleozoic beds overlie the Devonian strata or ancient basement rocks in an angular unconformity. In the Precordillera, the strata of the Lower Carboniferous, which bear flora with *A. conferta* and marine fauna attributed to the *Protocanites scalabrini*-*Paurorhyncha chavelensis* Zone (Sabattini *et al.*, 2001) are separated from the Devonian strata by an unconformity which is attributed to the Chánica Phase (Turner & Méndez, 1975). The Chánica Phase, that

occurred during the end of the Devonian and beginning of Carboniferous times, was the most important tectonic episode which produced remarkable changes in the paleogeography of the Devonian and modelled the Neopaleozoic basins recognized in that region (Ramos, 1988; Azcuy & Caminos, 1988; González, 1993b; Fernández Seveso & Tankard, 1995; Azcuy *et al.*, 1999). In Extraandean Patagonia, Upper Paleozoic sediments began to be deposited over basement of rock during the Early Carboniferous after tectonic event similar to the one that occurred in the Precordillera (González, 1984).

FINAL CONSIDERATIONS

The genus *Gilboaphyton* is recorded in strata of the Lower Carboniferous in Argentina for the first time.

Observation of leaves preserved upon the stem, allow verify that the axes of *Gilboaphyton argentinum* sp. nov. present a morphology of stems and leaf cushions identical to those axes without leaves upon stem previously assigned to "*Archaeosigillaria*" *conferta* (Frenguelli) Menéndez. The axes referred to *Gilboaphyton argentinum* sp. nov. and those identified as "*A. conferta*" probably represent a natural taxon.

Gilboaphyton argentinum sp. nov., associated with "*Archaeosigillaria*" *conferta*, has been recognized in the Early Carboniferous of Argentina. Based on this, the biocron of the genus *Gilboaphyton* is extended to the Early Carboniferous.

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