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Revaluation of the *Glossopterids* from the Lower Permian of Cambaí Grande Outcrop, Paraná Basin, RS

Reavaliação das Glossopterídeas do Permiano Inferior do Afloramento Cambaí Grande, Bacia do Paraná, RS

Graciela Pereira Tybusch[1], Roberto Iannuzzi[1], Mary Elizabeth Cerruti Bernardes-de-Oliveira[2] and Ricardo da Cunha Lopes[3]

[1]Universidade Federal do Rio Grande do Sul - UFRGS, Instituto de Geociências, Departamento de Paleontologia e Estratigrafia, Avenida Bento Gonçalves, 9500, CEP 91509-900, Porto Alegre, RS, Brazil (gracielatybusch@yahoo.com.br; roberto.iannuzzi@ufrgs.br)

[2]Universidade de São Paulo - USP, Instituto de Geociências, Departamento de Geologia Sedimentar e Ambiental - GSA, Laboratório de Paleobotânica e Palinologia, Programa de Pós-graduação em Geoquímica e Geotectônica, São Paulo, SP, Brasil (maryeliz@usp.br)

[3]Universidade do Vale dos Sinos - UNISINOS, São Leopoldo, RS, Brasil (ricardol.voy@terra.com.br)

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Abstract

The Cambaí Grande Outcrop, located in the municipality of São Gabriel of the State of Rio Grande do Sul, southernmost Brazil, is characterized by the occurrence of an exclusive fossil assemblage composed of marine invertebrate shells associated with some plant remains of elements from the "*Glossopteris* Flora". The main goal of this work is to reevaluate the "Cambaí Grande Flora" as well as section reanalysis. Therefore, the authors reviewed the existing paleobotanical material deposited at Universidade Federal do Rio Grande do Sul (UFRGS) and Universidade do Vale do Rio dos Sinos (UNISINOS) and redescribed the outcrop section. The outcrop sequence is 60 m thick and is divided into two well defined sections (both upper and lower). The studied plants were found in the basal part of the upper section. Besides the paleobotanical contents like *Gangamopteris*, *Samaropsis*, *Cordaicarpus, Cordaites*, unidentified remains of algal filaments and a cone of gymnosperm previously recorded by several authors and not properly understood thus far have been analyzed. This study confirmed for the first time the presence of *Glossopteris*-type leaves and the Indian species *Gangamopteris cyclopteroides* Feistmantel in the Cambaí Grande flora which increases the possibility of a correlation of this plant assemblage with that of the Rio Bonito Formation, Brazil, and those of the younger horizons of India.

Keywords: *Glossopteris*; *Gangamopteris*; Cambaí Grande; Rio Bonito Formation; Lower Permian; State of Rio Grande do Sul.

Resumo

O Afloramento Cambaí Grande está localizado no Município de São Gabriel, no Estado do Rio Grande do Sul, Brasil, sendo conhecido pela ocorrência de uma associação ímpar, composta de conchas de pelecípodes marinhos associados a restos vegetais de alguns elementos da "Flora *Glossopteris*". O presente trabalho teve como principal objetivo a reavaliação da paleoflora de Cambaí Grande, bem como a reanálise do posicionamento estratigráfico do afloramento. Para tanto, foi realizada a revisão do material paleobotânico existente em coleções e uma redescrição da seção aflorante. A seqüência aflorante está dividida em duas seções bem definidas (uma inferior e outra superior), sendo que os megafósseis vegetais estudados encontram-se na parte basal da seção superior. Diferentemente do que se encontra estabelecido na literatura, as correlações com sondagens indicaram que o Afloramento Cambaí Grande posiciona-se estratigraficamente no intervalo correspondente à porção médio-superior da Formação Rio Bonito e não na porção superior do Grupo Itararé. Além disso, o conteúdo paleobotânico levantado por diversos autores compreendia, até o presente trabalho, a presença dos gêneros *Gangamopteris*, *Samaropsis*, *Cordaicarpus* e *Cordaites*, afora restos não identificados atribuídos a algas e a um cone de gimnosperma. Este estudo, no entanto, confirmou a presença do primeiro registro de folhas do tipo *Glossopteris* na paleoflora de Cambaí Grande, além da ocorrência, pela primeira vez, da espécie indiana *Gangamopteris cyclopteroides* Feistmantel, o que aumenta a possibilidade de correlação desta associação com as das paleofloras mais jovens, pertencentes à Formação Rio Bonito, e com aquelas dos estágios florísticos indianos.

Palavras-chave: *Glossopteris*; *Gangamopteris*; Cambaí Grande; Formação Rio Bonito; Permiano Inferior; Rio Grande do Sul.

INTRODUCTION

The Cambaí Grande Outcrop is located in the municipality of São Gabriel, State of Rio Grande do Sul, southernmost Brazil. It is characterized by the occurrence of an exclusive fossil assemblage composed of marine invertebrate shells associated with the plant remains of some elements belonging to the *Glossopteris* Flora (Figure 1).

In the Cambaí Grande Outcrop, Martins and Sena Sobrinho (1950) registered the existence of *Orbiculoidea maricaensis*, *Lingula budoensis* and pelecypod shells, attributed to the genus *Aviculopecten* McCoy. Later, the pelecypod fossils found in this outcrop were studied by Martins (1951) who nominated them as *Aviculopecten cambahyensis*, based on the similarities with those described from Taió, Santa Catarina (Cowper Reed, 1930).

Regarding the plant remains, Zingano and Cauduro (1959), Loczy (1964), Barcellos (1973), Pinto and Purper (1974), Dohms (1977) and Corrêa da Silva (1978) cited (without identifying, describing or illustrating) the occurrence of *Phyllotheca*, *Gangamopteris* and *Glossopteris* remains, adding to the previous paleofloristic records from this outcrop (Pinto,1955).

Cazzulo-Klepzig et al. (1980a) discussed the contents of several paleofloristic outcrops of the Itararé Group, in Rio Grande do Sul, and modified the palaeobotanical contents, earlier recorded by Corrêa da Silva (1978). These include the elements of the Cambaí Grande palaeobotanical outcrop like indeterminate algae, *Gangamopteris* sp., *G. obovata*, *G. angustifolia*, *G. buriadica*, *Cordaites* sp., *Cordaicarpus* sp. and a cone of an unidentified gymnosperm. Cazzulo-Klepzig et al. (1980b) critically reviewed the Cambaí Grande paleofloristic contents and recorded *Gangamopteris* (55%), *Samaropsis* (18%), *Cordaites* (16%), unidentified algae (10%) and fructifications (1%). Besides, *Gangamopteris angustifolia*, *G. buriadica* and *G. obovata*, *Cordaites* sp. were also described. Cazzulo-Klepzig et al. (1980b), Guerra-Sommer and Cazzulo-Klepzig (1981), Cazzulo-Klepzig and Guerra-Sommer (1985) reproduced the same plate published earlier by Cazzulo-Klepzig et al. (1980a) with no changes.

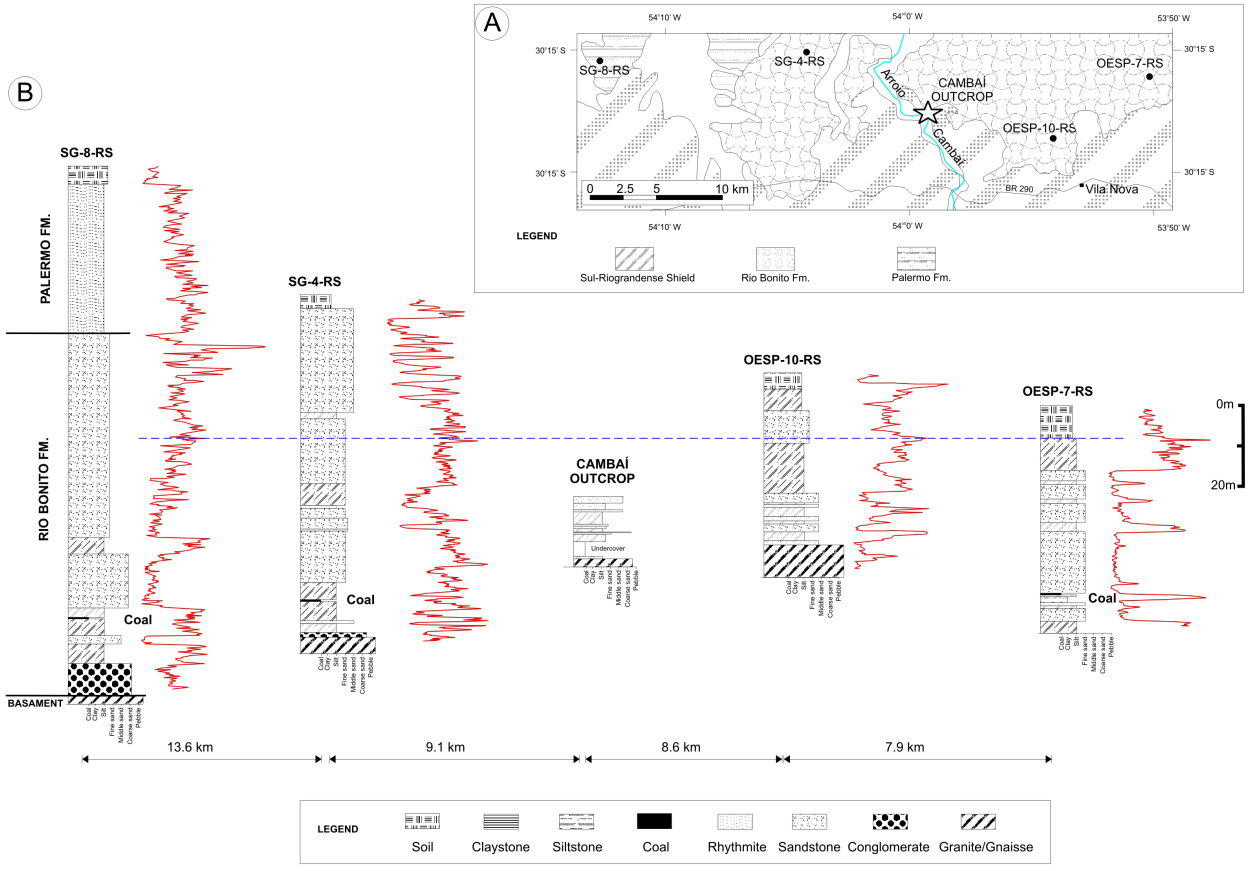

Figure 1. Map of the Cambaí Grande outcrop locality in São Gabriel, Rio Grande do Sul, and its correlation with wells from surrounding areas confirming the stratigraphic position within the unit Rio Bonito Formation.

Finally, Tybusch and Iannuzzi (2008) revised the forms included in the genera *Gangamopteris* and *Rubidgea*, from the outcrops of Itararé Group and Rio Bonito Formation in Rio Grande do Sul. These authors considered *Gangamopteris angustifolia sensu* Cazzulo-Klepzig et al. (1980b, est.1, fig.8), described from the Cambaí Grande outcrop as a new species, *Gangamopteris revoluta.* This was the last contribution that addressed elements belonging to the Cambaí Grande paleoflora. It should be noted that the *Glossopteris* leaves are usually among the fossil plants that have their classification and nomenclature less elucidated within an association. This is mainly due to its venation pattern, which complicates a comparison among the morphotypes and the absence of cuticles and attached fructifications, in most cases. However, since they are composed of several species of wide geographic and stratigraphic distribution, the glossopterids have been commonly used in biostratigraphy in various sections of the Permian Gondwanan basins (Archaryya et al., 1977; Chandra and Surange, 1979; Maheshwari, 1991; Guerra-Sommer and Cazzulo-Klepzig, 1993; Tewari et al., 2015) and thus, deserve special attention. Previously placed in the Itararé Group (Corrêa da Silva, 1978; Cazzulo-Klepzig et al., 1980a, 1980b; Guerra-Sommer and Cazzulo-Klepzig, 1993), the Cambaí Grande Outcrop has recently been related to the Rio Bonito Formation by Elias et al. (2000) owing to lithological similarities based on the researches carried out for coal exploration in the nearby areas ranging from 7.5 and 12 km east of this outcrop (Figure 1). Therefore, the main objective of this study is the revaluation of the glossopterids from Cambaí Grande and a review of the stratigraphic position of this outcrop section as well. Consequently, the paleobotanical collection deposited in the repository of Universidade Federal do Rio Grande do Sul (UFRGS) and Universidade do Vale do Rio dos Sinos (UNISINOS) was reviewed and the outcrop profile was redescribed.

GEOLOGY

The outcrop is approximately 52 m thick along the road cutting, considering the basement of the basin at an elevation of 128 m, down from the hill toward the bridge over the Arroyo Grande Cambaí, and the top of the hill, north at elevation 170 m. In the path from the arroyo to the top, the first 12 meters are concealed, followed by 17.35 m thick sedimentary rocks beginning with a layer of very coarse-grained arkosic sandstone with low spherical angular grains, and conglomerate containing quartz granules and pebbles (Figure 2). Overlying this is a is 0.70 m thick light grey pelitic and 3.60 m thick covered section, followed by 1,85 m heterolithic facies comprising siltstone and lenses and very fine quartzose sandstone lenses. Following this is

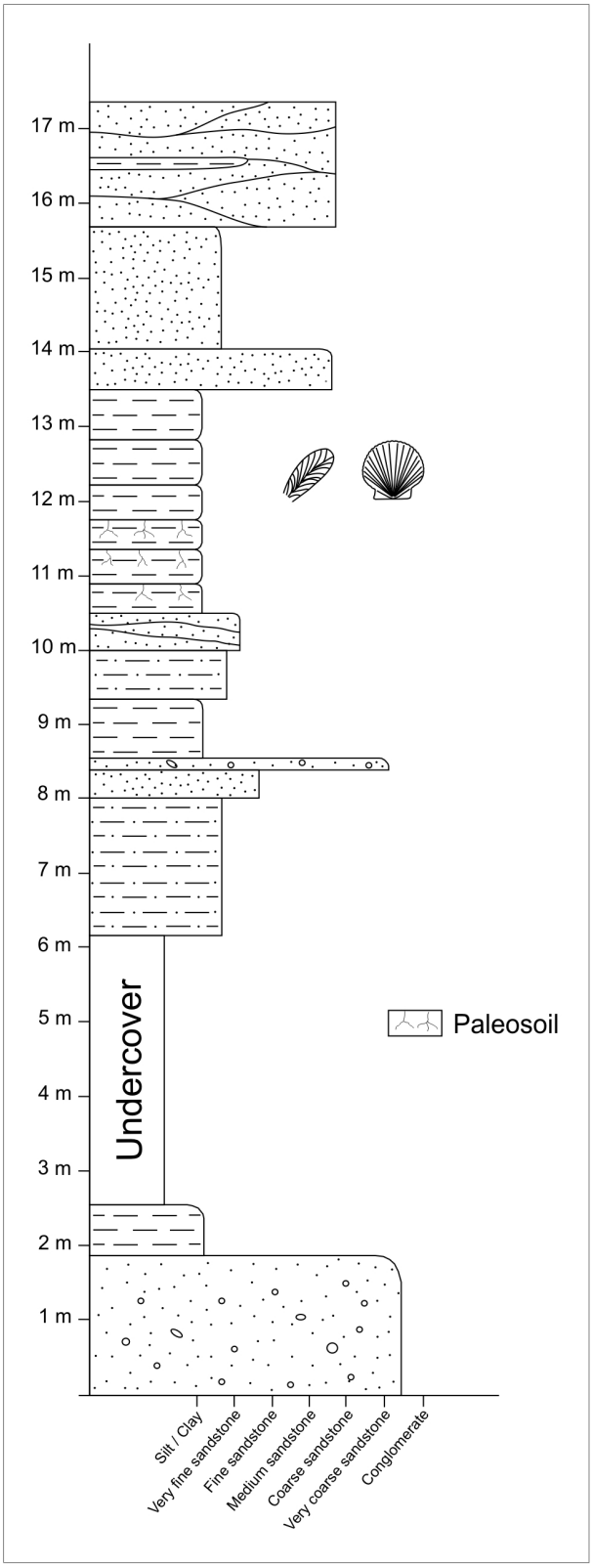

Figure 2. Stratigraphic section of the Cambaí Grande Outcrop, showing the horizon containing the plant and invertebrate fossils.

a 0.40 m thick fine to very fine quartzose sandstone with siltstone drapes and a lens of 0.15 m thick coarse to medium quartzose sandstone, above which is a 0.80 m of sandy siltstone, succeeded by a layer of 0.65 m thick heterolithic bedding with very thin sandstone layers alternating with layers of dark gray siltstone. The samples containing impressions of unidentified algae and seeds were collected from the base of this layer.

Above the siltstone is a set of amalgamated layers, consisting of elongate lenticular, very fine sandstone with a thickness of 0.48 m. Succeeding these layers are those of light gray siltstone of total 1.27 m thickness, containing overlapping incipient paleosol levels. The samples for palynological analysis were collected from the lower portion of the topmost layer.

Above this, is a gray siltstone layer containing algae and bivalve shell mold impressions consisting of tabular amalgamated layers of 2 to 7 cm thick and massive or laminated plain parallel layers of 0.45 m thickness. Overlying this, are two more layers of siltstones, the first layer is 0.60 m thick and plain, from which the pollen test sample was collected and the second layer is 0.50 m thick with parallel lamination and oxidation color from ocher to burgundy red, similar to the previous siltstone but devoid of fossils.

This pelitic package shows an abrupt contact with an upper layer of 0.55 m thick medium to coarse grained quartzose sandstone, partially lateritic which is overlain by a very fine sandstone to massive silty, red color layer of 1.65 m thickness. The analyzed profile completes with a 1.65 m thick quartzose sandstone layer composed of amalgamated lenticular layers of 8 cm thickness with elongate, solid and wavy top, alternating with gray siltstone drapes with a thickness of about 3 cm (Figure 2).

This same facies analysis has been used by several authors who have studied this outcrop as one of the arguments to place this section at the top of Itararé Group. However, the stratigraphic analyses made in this study as well as the correlation made by the surveys to the east (Elias et al., 2000), indicated that the Cambaí Grande strata stratigraphically position themselves in the range corresponding to the upper middle portion of the Rio Bonito Formation.

These facies are interpreted as having been generated in shallow marine environment located near the coast as indicated by the presence of the plant remains, representatives of the terrestrial flora, associated with conchiferous organisms, representatives of the marine fauna. This deposit would have been formed during a transgressive event, possibly corresponding to that noted in the Paraguaçú Member, Rio Bonito unit. In this case, the taxonomic affinity between pelecypods from Cambaí Grande and those found in the "Taió Fauna", proposed by Martins (1951), corroborates the repositioning of this outcrop along the Rio Bonito Formation and strongly suggests a correlation with the transgressive event that generated the deposits of the Taió region, in Santa Catarina, which are positioned in the Paraguaçú Member.

MATERIAL AND METHODS

Thirty one specimens were reviewed, some previously described and figured by Cazzulo-Klepzig et al. (1980a, 1980b), Guerra-Sommer and Cazzulo-Klepzig (1981) and Cazzulo-Klepzig and Guerra-Sommer (1985), and other new ones belonging to the Cambaí Grande Outcrop. The reviewed specimens are preserved only as impressions some as parts and counterparts. The material was studied as per standard methodology used in Paleobotany for analysis of impressions/compressions (observation through binocular stereo microscope, measurements from pachymeter, ruler and illustrations with the help of photographic equipment and camera lucida drawings). To accomplish the description and comparison of the specimens, characteristics such as shape and type of lamina and kinds of leaf base and apex were defined according to the classification adopted by Chandra and Surange (1979).

To obtain the characteristics regarding density of venation, emergence and secondary venation divergence angles and the maximum width of the median venation, the parameters and techniques described by Rohn et al. (1984) were used. Finally, in order to clarify the description of the types of anastomoses present in the venation of the studied leaf specimens three stipulated categories were defined as follows: a) oblique connections: originated as from the bifurcation, at acute angles, of secondary veins surrounding running parallel toward the border, b) cross-connections: originating from transverse veins (subparallel to the median veins or central midrib, or in almost straight angles) that connect neighboring secondary veins running parallel toward the leaf margin, c) "X"-type connections: originating from the meeting or intersection of neighboring secondary veins, running parallel toward the leaf margin (Figure 3).

The analyzed paleobotanical material is deposited in the Museum of Paleontology (MP), Paleontology and Stratigraphy Department (DPE) of the Geosciences Institute (IGeo) in the Federal University of Rio Grande do Sul (UFRGS), and is cataloged as MP-Pb, and the Museum of Paleontology, History of Life and Earth Laboratory (LaViGea), in the Vale do Rio dos Sinos University (UNISINOS), where it is cataloged as UMVT.

The systematics used in this study follows the one established by Stewart and Rothwell (1993). For the purpose of systematic analysis or even to estimate the approximate size of leaf samples, even those relatively incomplete, the classification for the dimensions of megaphylls proposed by Ash et al. (1999) was used.

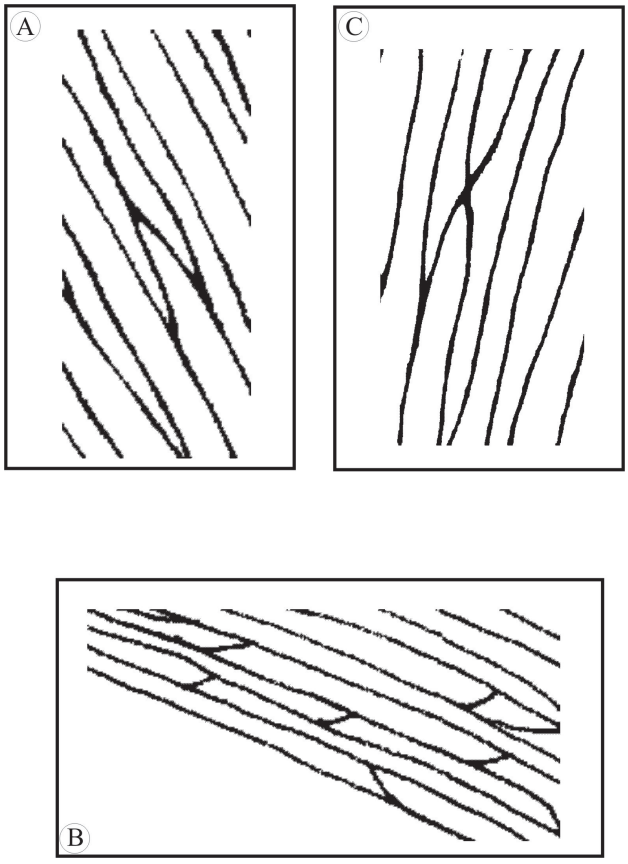

Figure 3. Anastomoses types in glossopterid leaves: (A) oblique connection; (B) transverse connection; (C) "X"-type connections.

PALEONTOLOGIC SYSTEMATIC

Division: TRACHEOPHYTA
Class: GYMNOSPERMOPSIDA
Order: GLOSSOPTERIDALES
Genus: *Gangamopteris* McCoy 1847
Specie-Type: *G. angustifolia* McCoy 1875
Gangamopteris cyclopteroides Feistmantel 1879
Figure 4C-E.

Gangamopteris buriadica (*auct. non*) Feistmantel, 1879. Cazzulo-Klepzig et al.,1980b, Est. I, figs.2, 5.
Gangamopteris obovata (*auct. non*) Maithy, 1965. Cazzulo-Klepzig et al.,1980b, Est. I, fig. 6.
Gangamopteris obovata (*auct. non*) Maithy, 1965. Tybusch and Iannuzzi, 2008, figs. 6, 7C, 7F.

Described Material: MP-Pb 1042, 1043, 2721, 2723 and 3196.

Description: The studied material consists of simple leaves with entire margins, microphylls to notophylls, apical to medium portions preserved; apex and base absent, the blade form seems to vary from oblanceolate to oblong; the length of the leaves varies from more than 3.7 cm (MP-Pb 1042) to more than 7.3 cm (MP-Pb 3196); the leaf width is more than 2.1 cm (MP-Pb 1042, 2723) to higher than 3.0 cm (MP-Pb 3196). The middle region is occupied by subparallel veins forming elongate to rectilinear meshes; central veins are sharp except near the apical region (top third), which has more diffused veins. The lateral veins arise at angles of about 18 ° to 20 °, arch backwards and reach the leaf margins with sharper curves, at about 45 ° to 54 °. The lateral veins form elongate, rectangular meshes, with a greater density near the leaf margin (29 veins per centimeter), which bifurcate and anastomose themselves several times through oblique connections, transverse and in "X", thereby forming shorter and narrow meshes.

Discussion: The analyzed specimens are compared to *Gangamopteris obovata* (Carr.) White (Carruthers, 1869, White, 1908), *Gangamopteris cyclopteroides* Feistmantel (Feistmantel, 1879) and *Gangamopteris clarkeana* Feistmantel (*in* Maithy, 1965), for venation formed by secondary upright veins that anastomose to form elongate and rectangular meshes. However, they differ from *G. clarkeana* in oblanceolate to oblong laminar shape and in the middle region occupied by clear subparallel veins that persist till the apical portion of the leaf, which are more diffuse. The studied specimens still resemble *G. obovata* in shape of the lamina; however, they differ in the median region clearly occupied by straight subparallel veins except at the final quarter of the leaf, where they vanish. Finally, the specimens studied herein, show close resemblance with *G. cyclopteroides* in (i) similar size, (ii) the shape of the lamina, (iii) the median region and (iv) lateral veins that curve almost upright toward the borders from the middle region [angle (emergence) of 18° to 20°], and while approaching the leaf border bifurcate and anastomose several times, thereby forming shorter and narrower meshes, reaching the edges with a more pronounced curvature [angle of (divergence) ranging from 45° to 54 °].

Thus, the studied specimens correspond to those classified by Feistmantel (1879) as *G. cyclopteroides*, especially with the smaller leaves with which they effectively maintain a specific level identity. The occurrence of *G. cyclopteroides* species in deposits of the Paraná Basin was initially suggested by Seward (1903), based on synonymy with the material described by Carruthers as *Noeggerathia obovata* (Carruthers, 1869). However, White (1908) transferred Carruthers' species to the genus *Gangamopteris*, erecting *G. obovata*, considered it as a valid species, and placed all the specimens previously classified as *G. cyclopteroides* to the Brazilian species.

According to White (1908), since the Brazilian form had been published before (Carruthers, 1869), the *obovata* specific epithet should have priority over *cyclopteroides* epithet of the Indian form (Feistmantel, 1879) on the basis of priority of publication. Thus, he admitted the similarity

between the shapes of leaves of both the continents, but challenged their synonymy, as previously proposed by Seward. Later, Dolianiti (1946, 1953) and Barbosa (1958) recorded *G. cyclopteroides* in the basin, but without describing or illustrating the specimens that could be attributed to this species. Subsequently, Dolianiti (1954a, 1954b), identified the new forms of *Gangamopteris* (i.e. *G. angustifolia*, *G. buriadica*, *G. buriadica* var. *acrodeltoidis* and *G. obovata* var. *major*),

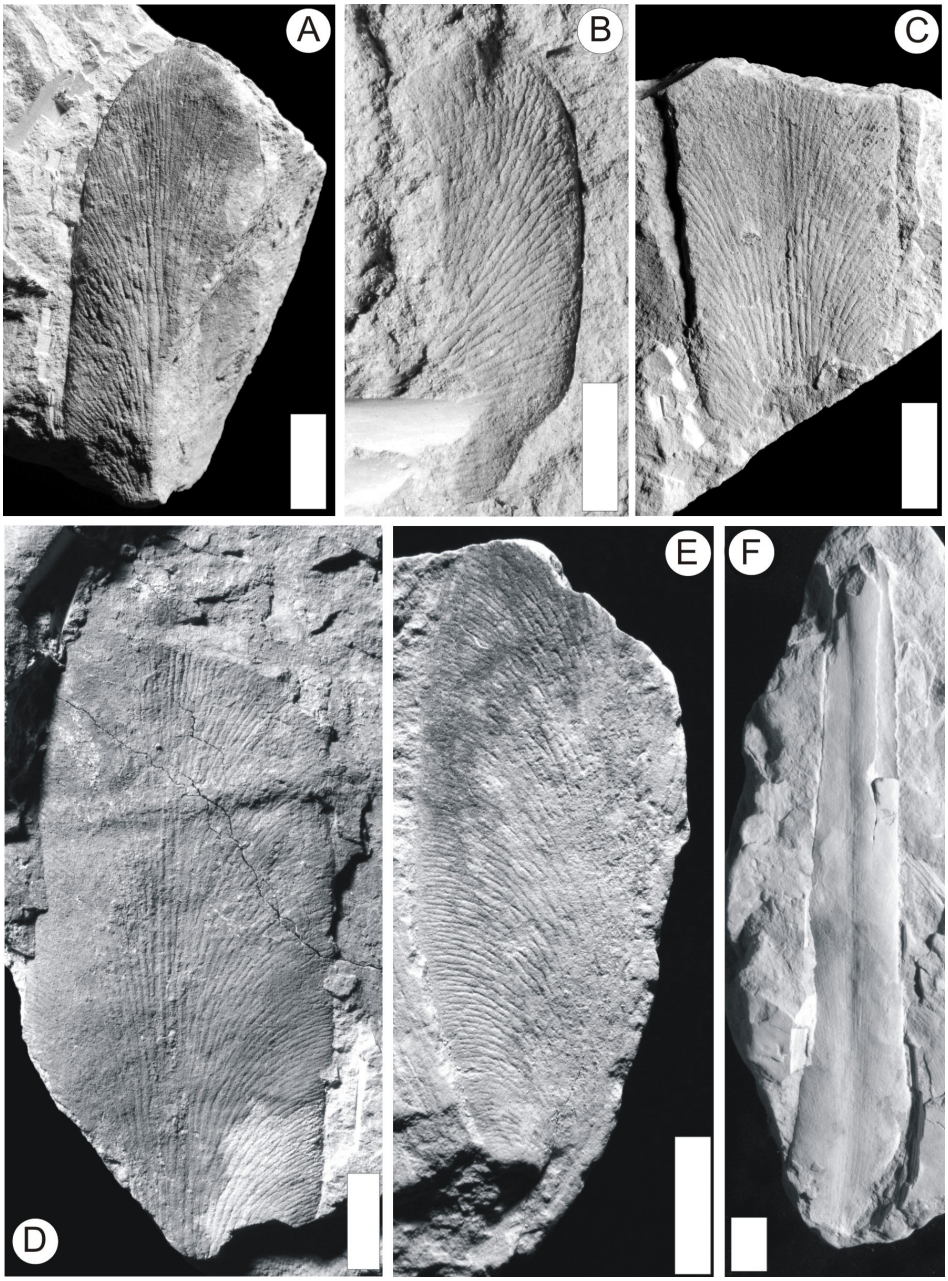

Figure 4. *Gangamopteris cf. G. mosesi* Dolianiti: (A) MP-Pb 1083, leaf showing acute apex and median region occupied by subparallel veins that are evanescent in the apical portion and form wider meshes. (B) MP-Pb 1080, leaf with preserved apical region showing upright veins forming virtually long, rectangular to oblong meshes with a higher density near the leaf borders. *G. cyclopteroides* Feistmantel: (C) MP-Pb 1042. (D) MP-Pb 3196. (E) MP-Pb 2721, leaves showing: i) the median region occupied by subparallel veins forming elongated and rectangular meshes, the central veins are sharp but evanescent in the apical region; ii) lateral veins nearly straight bowing from the middle region at angles of 18° to 20°, reaching the leaf margins with a steepening angles (the divergent) ranging from 45° to 54°, the secondary veins form elongate, rectangular meshes with a higher density near the leaves, margin. *G. revoluta* Tybusch and Iannuzzi: (F) MP-Pb 3099, figured specimen properly described in Tybusch and Iannuzzi (2008, Figure 3D, E). Scale bars = 1 cm.

and included in *G. obovata* all the forms previously considered by him as belonging to the Indian species *G. cyclopteroides*, by accepting the synonymy suggested by White (1908). Therefore, *G. cyclopteroides* disappeared from the list of valid species of lower Permian which was subsequently published by various authors (Rigby, 1970; Rösler, 1978; Bernardes-de-Oliveira, 1980). However, according to the comparisons made in this study (see above), the present authors consider both *G. obovata*, and *G. cyclopteroides*, as distinct species and therefore, valid. They are distinguished mainly by the absence (in Brazilian species) or presence (in the Indian species) of straight sharp subparallel veins in the middle region of the lamina from the base to the apical region of the leaf, just below the apex. As a result, this is the first study which confirms in a more convincing way, the presence of *G. cyclopteroides* in the Paraná Basin as is evident by the detailed description and illustration of the analyzed specimens.

Gangamopteris aff. *G. mosesi* Dolianiti 1954b
Figure 4 A, B

Described Material: MP-Pb 1080 and 1083.

Description: The studied material comprises two simple leaves with entire margin, leaves small, only the median and apical portions preserved, apex acute; the length of the leaves vary from more than 3.2 cm (MP-Pb 1080) to more than 5.4 cm (MP-Pb 1083), the leaves have a width of more than 1.0 cm (MP-Pb 1080) to more than 2.0 cm (MP-Pb 1083). The middle region is occupied by slightly sinuous subparallel veins that are not distinct in the apical region, apparently forming a larger reticulum. The lateral veins are practically upright and arch from the middle region of the leaves at an angle of about 10 °, reach the leaf margins with a curve at slightly steeper angles ranging from 26 ° (MP-Pb 1083) to 28 ° (MP-Pb 1080). The veins are virtually upright, form oblong to rectangular long meshes, with a greater density close to the leaf border, where there are approximately 18 veins / cm.

Discussion: The studied specimens are compared to the *Gangamopteris mosesi* Dolianiti (Dolianiti, 1954b) and *G. mucronata* Maithy (Maithy, 1965) due the median region occupied by winding subparallel veins and almost upright lateral veins which form rectangular to oblong long meshes. However, they differ from *G. mucronata* in presence of acute apex, and venation of the median region that vanishes in the apical portion of the lamina forming larger reticulum and by the less narrow lateral venation. The studied specimens yet compare with *G. mosesi* by acute apex, median venation and by the acute angles of emergence of lateral veins. However, they differ from the same by having less divergent angle and less dense venation. Although the specimens are rather incomplete, these morphological differences are characteristic enough to classify them as *Gangamopteris* aff. *G. mosesi*.

Gangamopteris revoluta Tybusch and Iannuzzi 2008
Figure 4 F

Previous citations: Tybusch and Iannuzzi, 2008, figs. 3D, 3E.

Analyzed Material: MP-Pb 3099.

Comments: The specimen MP-Pb 3099 was described and figured in Tybusch and Iannuzzi (2008), who classified it as *Gangamopteris revoluta.* This specimen had previously been described by Cazzulo-Klepzig et al. (1980b, Plate I, Figure 8) as *Gangamopteris angustifolia* (see synonymy in Tybusch and Iannuzzi, 2008).

Genus: *Glossopteris* Brongniart 1828

Specie-type: *Glossopteris browniana* Brongniart 1828

Glossopteris aff. *G. zeilleri* Pant and Gupta 1968
Figure 5 A, B

Described Material: UMVT 4184A, B.

Description: The studied specimens represent small leaves (notophylls), part and counterpart with, simple, entire margins, the basal and middle portions of the leaves are preserved. As from the more complete analysis of the leaf (specimen A U-4184) it was observed that the shape of the blade is apparently oblanceolate, base is acute cuneate (U-4184 specimens A, B); the length of the leaf is more than 7.2 cm, while the leaf width exceeds 2.0 cm. The midrib in the apical region, evanescent (specimen U-4184A); whereas, it is distinct in the basal portion with a width of 0.4 cm (specimen U-4184A). The secondary veins are derived from the midrib, in the leaf midbasal portion at acute angles, around 10 ° to 19 °, curve gently and reach margin at angles of about 42 ° to 45 °. The venation density along the middle portion of the leaf varies from 18 to 20 veins / cm in the central part, and 29-30 veins / cm, near the leaf border. The secondary venation is quite evident in all the specimens, where it was possible to observe the presence of narrow, elongate and polygonal meshes, near the median venation and the central part of the lamina and shorter and narrower, meshes near the leaf margin, where veins often bifurcate, thereby increasing the density of venation. Throughout the lamina oblique and X type cross connections are present, but there are also some transverse (= cross connections) which run parallel toward the leaf margin.

Discussion: The venation pattern of the studied specimens resembles *Glossopteris zeilleri* Pant and Gupta (in Chandra and Surange, 1979), *G. decipiens* Feistmantel (Feistmantel, 1879) and *G. formosa* Feistmantel (in Dolianiti, 1953), in the nature of midrib. However, the studied form here is distinguished from *G. formosa* and *G. decipiens* by the presence of (i) narrow, elongate and polygonal meshes near the midrib and the central part of the lamina and shorter and narrower meshes near the leaf margin where density of veins is high and (ii) in the shape of the leaf which is

oblanceolate. Further, it is distinguished from *G. decipiens* by a not very dense secondary venation.

On the other hand, the described specimens resemble *G. zeilleri* in the venation pattern of the secondary veins in having narrow, elongated and polygonal meshes near the midrib and the central part of the lamina, and shorter and narrower meshes near the leaf margin where veins are bifurcated. However, they differ from *G. zeilleri* by the angles at which the secondary veins reach the leaf margins (= divergent angles), ranging from 42 ° to 45 °, and in the form of limb that appears wider and, it seems, shorter than the forms included in *G. zeilleri.*

Due to the fragmentary specimens with no apex preserved, and few differences compared to those described for *G. zeilleri*, the specimens are classified here as *Glossopteris* aff. *G. zeilleri*. Due to the evanescent nature of the midrib, the described forms could be considered as a transition between the genera *Gangamopteris* and *Glossopteris*, as was also suggested by Feistmantel (1879) for the *Glossopteris decipiens* species.

FINAL REMARKS

Previous studies recorded the presence of *Gangamopteris*, *Samaropsis*, *Cordaicarpus* and *Cordaites*, unidentified remains such as algae and a gymnosperm cone from the Cambaí Grande Outcrop. However, this study confirmed the presence of the genus *Glossopteris* from the Cambaí Grande paleoflora (Table 1) for the first time. *Glossopteris* aff. *G. zeilleri* is distinguished by the presence of a sharp midrib from the base to the middle portion of the leaf. The presence of this species in the Cambaí Grande Outcrop increases the possibility of correlation of this association with paleofloras younger than those found in the Itararé Group, since *Glossopteris* is of common occurrence in the Rio Bonito Formation (Rösler, 1978; Bernardes-de-Oliveira, 1980; Iannuzzi and Souza, 2005). These palaeobotanical data support the new position of the Cambaí Grande Outcrop (Figure 1).

Nevertheless, it is clear that in the Cambaí Grande Outcrop, the *Gangamopteris* dominates the glossopterid assemblage both in number of specimens and morphospecies. This dominance of *Gangamopteris* over *Glossopteris* is typically recorded in associations found in Itararé Group and has been used as an indicator of older stratigraphic position within the "*Glossopteris* Flora" succession, such as in the Paraná Basin (Rösler, 1978; Bernardes-de-Oliveira, 1980; Iannuzzi and Souza, 2005) and in India, where this same dominance of *Gangamopteris* is marked in Talchir and Karhabari formations, and the lower part of the Barakar Formation (Pant and Singh, 1968; Chandra, 1991; Maheshwari, 1991; Tewari and Srivastava, 2000; Maheshwari and Bajpai, 2001; Tewari, 2007, 2008; Srivastava and Agnihotri, 2010; Singh et al., 2012; Tewari et al., 2012). Similar pattern with *Gangamopteris* predominating in lower (Permian) stratigraphic intervals is also seen in Australia (Retallack, 1980; McLoughlin, 1994a, 1994b).

However, it should be noted that the amount of plant remains recovered in Cambaí Grande Outcrop are extremely

Table 1. Previous paleobotanical content from the Cambaí Grande Outcrop cited by Pinto (1955), Cazzulo-Klepzig et al. (1980a, 1980b), Guerra-Sommer and Cazzulo-Klepzig (1981), Cazzulo-Klepzig and Guerra-Sommer (1985), comparing with the present contribution.

Paleobotanical Record	Pinto (1955)	Cazzulo-Klepzig et al. (1980a, 1980b), Guerra-Sommer and Cazzulo-Klepizig (1981), Cazzulo-Klepzig and Guerra-Sommer (1985)	Present Contribution
Indeterminate algae		X	X
Gangamopteris sp.	X	X	X
Gangamopteris obovata		X	
Gangamopteris angustifolia		X	
Gangamopteris buriadica		X	
Gangamopteris cyclopteroides			X
Gangamopteris revoluta			X
Gangamopteris cf. *mosesi*			X
Glossopteris sp.	X		
Glossopteris aff. *zeilleri*			X
Phyllotheca sp.	X		
Cordaites sp.		X	X
Samaropsis sp.		*X	
Cordaicarpus sp.		X	X
Gymnosperm cone		X	X

*Information cited only in Cazzulo-Klepzig et al. (1980b).

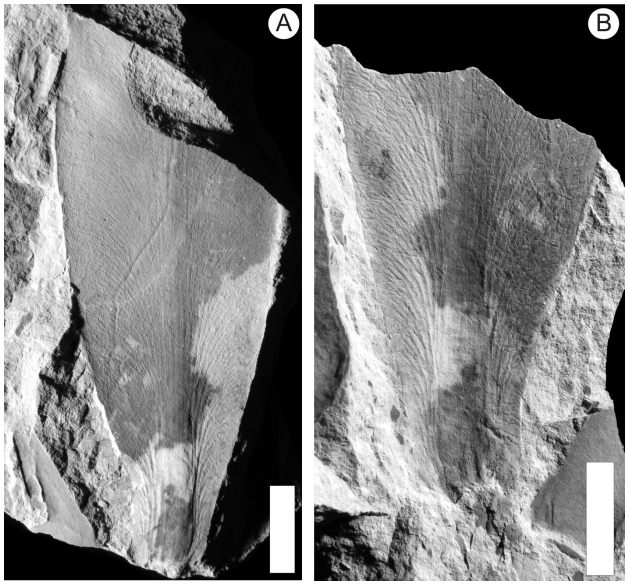

Figure 5. *Glossopteris* aff. *G. zeilleri* Pant and Gupta: (A) UMVT 4184 A. (B) UMVT 4184 B, specimens presenting: i) non persistent median venation in the preserved upper portion of the leaf lamina and sharp in the basal portion; ii) clear secondary venation with narrow, elongate and polygonal meshes close to the midrib and middle part of the lamina, and short and narrow meshes near the leaf border where the veins bifurcate many times increasing the veins density; iii) dichotomies, oblique and "X"-type transverse cross connections veins arranged between the secondary veins running parallel to the leaf margin. Scale bars = 1 cm.

small. Thus, it is possible that the existing plant fossil collections in the institutions provide a greater number of *Gangamopteris* leaves due to simple bias sampling, which does not necessarily reflect the actual proportions of these leaves in the original flora. Another possibility is that the greater abundance of *Gangamopteris* type leaves is taphonomically controlled by the fact that they inhabit areas closer to the shoreline. According to Retallack (1980), plants with gangamopteroid foliage leaves are more common in communities inhabiting along the coast in coastal plain environments, at least in the Sydney Basin, Australia.

Finally, it should be noted that the presence of *Gangamopteris cyclopteroides* Feistmantel, typically found in India (Feistmantel, 1879), in the Lower Permian sequence of the Paraná Basin, in the upper portion of the Itararé Group and in the Rio Bonito Formation, confirms its simultaneous occurrence in Lower Gondwana horizons of India and Brazil (see Tybusch and Iannuzzi, 2008, to check distribution in Itararé group). This species has a stratigraphic distribution confirmed for the Lower Permian in India, having been marked for the Talchir, Karhabari and Barakar formations (Srivastava and Agnihotri, 2010), with doubtful records in Kulti (early Late Permian) and Raniganj (Late Permian) formations (Maheshwari, 1991; Srivastava and Agnihotri, 2010; Singh et al., 2012). Therefore, considering that the present study reports the only reliable record of the species, a clear correspondence exists between the stratigraphic range of *G. cyclopteroides* in the Paraná Basin and in the Indian Gondwana sequence, thus suggesting a correlation between the upper portion of the Itararé Group, the Rio Bonito Formation, and the Talchir and Karhabari formations, and the lower portion of the Barakar Formation, as previously proposed by Bernardes-de-Oliveira (1980). The record of this Indian species is an addition to the records of other typical Indian forms like *Cheirophyllum* sp., *?Kawizophyllum* sp., *Giridia* spp. (Silva and Iannuzzi, 2000; Iannuzzi et al., 2009, 2010; Boardman and Iannuzzi, 2010) and marks the Lower Permian in the Paraná Basin which may indicate the existence of a floristic interchange between these two Gondwanan regions during the Early Permian times.

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