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Upper Pennsylvanian lycopsids from interglacial taphoflora of Itararé Group, Paraná Basin, Brazil

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ABSTRACT

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The Pennsylvanian strata of the Itararé Group are present on the northeastern border of the Paraná Basin, i.e. northern part of Paraná State towards north of São Paulo. The Pennsylvanian lycopods of the Itararé Group are represented by diverse megafossils, megaspores and microspores. The present study deals with the lycopsid megafossils from the third interglacial level of the paleofloristic succession of the Itararé Group in the northeastern border of the Paraná Basin, i.e. *Paranocladus-Ginkgophyllum-Brasilodendron* association (PGB as.) recovered from its type locality Volpe ranch, in Monte Mor municipality, SP. The megafossils belong to the taxa *Bumbudendron millani, Bumbudendron* cf. *B. paganzianum, Brasilodendron pedroanum, Brasilodendron* sp., *Leptophloeum* cf. *L. sanctae-helenae,* and *Cyclodendron* sp. The diversity and abundance of the megafossils (sometimes forming coal beds in a glacial context) indicates climatic ameliorations of an interglacial phase of the "time Itararé". They represent paleoecological hydro-hygrophyllous communities of a fluviatile-lacustrine depositional environment. The biostratigraphical distribution of these taxa and their association with *Paranocladus, Ginkgophyllum* and *Buriadia* suggests a paleofloristic correlation with the *Krauselcladus - Asterotheca* Phytozone of northwestern Argentinean paleofloristic zonation. The lycophytic megaspores recorded earlier from this level suggest a diachronic correlation with the Permian Talchir and Karharbari associations of Indian Gondwanan flora. Comparison with late Paleozoic lycopsids and associated megaspores of Argentina and India are in consonance with the modern studies aiming to achieve knowledge of Gondwana biostratigraphy in a wider perspective.

Key-words—Kasimovian-Gzhelian, Lycopods, Brazilian Gondwana, Monte Mor (SP), PGB Association.

इतारैर समूह, पराना द्रोणी, ब्राज़ील के अंतःहिमानी टेफोफ्लोरा से प्राप्त ऊपरी पैन्सील्वेनियाई लाइकोप्सिड

सांद्रा ईको मुने, मैरी ई.सी. बर्नान्डीज-डी-ऑलीवीरा एवं रजनी तिवारी

सारांश

इतारैर समूह पैन्सील्वेनियाई पट्टीदार केवल पराना द्रोणी उत्तरपूर्वी सीमा, पराना राज्य के उत्तरी भाग, उत्तर की ओर से साओ पॉलो राज्य में विद्यमान हैं। इतारैर समूह के पैन्सील्वेनियाई लाइकोपॉड विभिन्न स्थूलजीवाश्मों, स्थूलबीजाणुओं एवं सूक्ष्मबीजाणुओं से रुपायित हैं। मौजूदा अध्ययन का पराना द्रोणी अर्थात मांटे मॉर नगर पालिका, एस पी में इसी तरह की उपबस्ती वॉल्पे रंच से प्राप्त *पैरनोक्लैडस-गिंकगोफिल्लम-ब्रसिलोडेंड्रान संघ (पी जी बी)* की उत्तरपूर्वी सीमा में इतारैर समूह के पुरापादप अनुक्रम के तृतीय अंतः हिमानी से प्राप्त लाइकोप्सिड स्थूलजीवाश्मों से संबंधित है। स्थूलजीवाश्म *बंबुडेड्रॉन मिलैनाई, बी.* तुल्य *बी. पगैन्ज़ियैनम, ब्रसिलोडेंड्रॉन पैड्रोएनम, एफ. ब्रसिलोडेंड्रान* जाति, *लेप्टोफ्लोलियम* तुल्य *एल. संकटे-हेलेने* और *सायक्लोडंड्रान* जाति टैक्सा के हैं। स्थूलजीवाश्मों की विविधता एवं बहुलता (हिमानी परिप्रेक्ष्य में कभी कोयला संस्तर गठित) "इतारैर काल" की अंतः हिमानी प्रावस्था के जलवायविक सुधार इंगित करती हैं। वे नदीय-सरोवरी निक्षेपणीय पर्यावरण का जल-आर्द्रताफायल्लस समुदाय रुपायित करते हैं। इन टैक्साओं के जैव स्तरिक वितरण एवं उनकी *पैरनोक्लैडस, गिंकगोफिल्लम व बुरिआडिया* के साथ

उनकी बंधुता उत्तरपश्चिमी अर्जेंटियाई पुरापादप अनुक्षेत्र के *क्रॉसेल्क्लेडस-एस्टेरोथेका* पादपमंडल के संग पुरापादप सहसंबंध सुझाती है। इस स्तर से पूर्व में अभिलिखित लाइकोफ़ाइटी स्थूलबीजाणु भारतीय गोंडवाना पेड़-पौधों के पर्मियन तल्चीर एवं करहरबारी बंधुताओं के साथ द्विचिरकाली सहसंबंध सुझाते हैं। अर्जेंटीना और भारत के अंतिम पुराजीवी लाइकोप्सिड एवं संघटित स्थूलबीजाणुओं के साथ तुलनाएं बृहत परिप्रेक्ष्य में गोंडवाना जैवस्तरक्रमविज्ञान की ज्ञान प्राप्ति के उद्देश्य से आधुनिक अध्ययनों के साथ सहमत हैं।

संकेत-शब्द—कासिमोवियन-ग्ज़ेलियन, लाइकोपॉड्स, ब्राज़ीली गोंडवाना, मांटे मॉर (एसपी), पी जी बी संगुणने।

Licófitas do Pensylvaniano Superior Provenientes da Tafoflora Interglacial do Grupo Itararé, Bacia do Paraná, Brasil

RESUMO

Os estratos pensilvanianos do grupo Itararé estão presentes apenas na margem nordeste da bacia do Paraná partindo da região setentrional do estado do Paraná até a porção norte do estado de São Paulo. As licófitas pensilvanianas do grupo Itararé estão representadas por diversos megafósseis, megásporos e micrósporos. O presente estudo refere-se a macrofósseis licofíticos do terceiro nível interglacial da sucessão paleoflorística do Grupo Itararé na margem nordeste da bacia do Paraná, isto é, associação (PGB as.) *Paranocladus-Ginkgophyllum-Brasilodendron* coletados em sua localidade tipo Sítio Volpe, no município de Monte-Mor, SP. Os megafósseis pertencem aos taxa *Bumbudendron millani, B.* cf. *B. paganzianum, Brasilodendron pedroanum,* aff. *Brasilodendron* sp., *Leptophloeum* cf. *L. sanctae-helenae,* e cf. *Cyclodendron* sp. A diversidade e abundância dos macrofósseis (as vezes formando camadas de carvão em um contexto glacial) indicam melhorias climáticas de uma fase interglacial do tempo Itararé. Elas representam comunidades paleoecológicas hidro-higrófilas de um ambiente sedimentar fluvio-lacustre. A distribuição bio-estratigráfica destes taxa e suas associações com *Paranocladus, Ginkgophyllum e Buriadia* sugerem uma correlação paleoflorística com a fitozona *Krauselcladus – Asterotheca* do zoneamento paleoflorístico do noroeste argentino. Os megásporos licofíticos registrados anteriormente neste nível sugerem correlação diacrônica com as associações permianas de Talchir e Kaharbari da flora gondvânica indiana. Comparações com licófitas neopaleozóicas e megásporos associados da argentina e Índia estão em consonância com estudos modernos empenhados na conquista de conhecimentos da bioestratigrafia gondvânica em uma perspectiva mais ampla.

Palavras-chave—Khasimoviano-Gzheliano, Licófitas, Gondwana Brasileiro, Monte Mor (SP), Association PGB.

INTRODUCTION

The studies on the Brazilian Lower Gondwana lycopods were initiated by Carruthers (in Plant, 1869), who described *Flemingites pedroanus* from Rio Bonito Formation (Guatá Group) in Candiota Mine, Rio Grande do Sul State (RS). Thereafter, several workers reported lycopsids from the Itararé, Guatá and Passa Dois groups of Parana Basin (Renault, 1890a, b; Zeiller, 1898; White, 1908; Read, 1941; Maack, 1947). These workers drew affinities of these lycopsid forms with those of the Euramerican Flora. Edwards (1952) merged all the known Brazilian lycophytes with the genus *Lycopodiopsis* Renault. Kräusel (1961) re-examined all the specimens described earlier by previous workers. On the basis of observations of these specimens and study of new specimens collected by him, he revised the Brazilian and South African Late Palaeozoic lycopsids and reported the taxa *Lycopodiopsis pedroanus* (Carruthers) Edwards, *L. derbyi* Renault, *Lycopodiopsis* sp. and *Lycopodiophloios dolianitii* Kräusel from the Permian Brazilian material. Later, based on isolated occurrences, Millan (1972, 1980, 1985) reported lycopsids from the Itararé Group, in Monte Mor (SP).

Chaloner *et al*. (1979) proposed a new genus and combination *Brasiliodendron pedroanum* (Carruthers) Chaloner, Leistkow & Hill in a revision based on the lectotype *Lycopodiopsis pedroanus* (Carruthers) Edwards. Kräusel also made a new combination, viz. *Lepidodendron pedroanum* (Carruthers) Zeiller (based on the material deposited in the paleontological collection of the British Natural History Museum) from Rio Bonito Formation. Lejal-Nicol & Bernardes-de-Oliveira (1979) recorded a new species *Cyclodendron brasiliensis* from Treviso (SC), Siderópolis Member of Rio Bonito Formation of Paraná Basin. A preliminary revision of the early Gondwanan lycophytes from the Parana Basin was carried out by Oliveira-Babinski and Sommer (1984). Later, Ricardi-Branco (1997) reported *Brasilodendron pedroanum* from the Rio Bonito Formation (Triunfo Member) in a study of the surface features of different levels of decortications of the stems. Jasper and Guerra-Sommer (1998) registered the existence of fragments of *in situ* lycopsid axes from the Rio Bonito Formation (late Sakmarian after palynological analyses of Jasper *et al.,* 2006), Rio Grande do Sul State (RS). They were cormose radicular systems, i.e. non stigmarian. These authors observed the presence of diverse types of leaf cushions on the same specimen which vary from elliptical (*Brasilodendron* type) to rhomboid (*Lycopodiopsis* type). On the basis of presence of two types of leaf cushions on the same specimen these authors interpreted that probably distinct morphotaxa represent different stem-levels of one single form. Jasper *et al.* (2006) maintained the genus *Brasilodendron* for specimens known only by the leaf cushions from Pennsylvanian to Cisuralian (Itararé Group and Rio Bonito Formation), taking

into account the dominance of lycopsid spores and the presence of lycopsid megaspores in the palynological assemblage of coal lenses associated with the lycophyte level. Considering that the coals of the South Brazil are mainly hypoautochthonous these authors concluded that *Brasilodendron* could have been dominant in the hypoautochthonous plant-association which constituted the peat.

Alarcon (1998) studied the lycophytic material from the Corumbataí Formation, Artemis (Piracicaba, SP) and revised the species *Lycopodiopsis derbyi* Renault which was earlier recorded by Mendes (1952) from this outcrop. According to Alarcon (1998) and Alarcon and Bernardes-de-Oliveira (1999) the name *Lycopodiopsis derbyi* Renault should be restricted to the silicified stem forms which have characteristic anatomical features preserved and were originally described from late Palaeozoic of Piracicaba (SP). Accordingly, the indiscriminate use of this taxon for all the other lycophytic material, with or without preserved anatomy from any locality or any stratigraphical unit of the Parana Basin would create a nomenclatural problem.

The lycopsids present in the Lower Gondwana sequence of Parana Basin, belong to the Family Lycopodiopsidaceae of the Order Lepidodendrales and to the Family Lycopodiaceae of the Order Lycopodiales (Chaloner, 1967). The family of arborescent lycopods (Lycopodiopsidaceae) is characterized by the presence of helically arranged leaves as is evident by arrangement of leaf cushions on branches and stems and, in the fertile forms, sporophylls are inserted directly on the main stem. The taxa recorded from the Parana Basin are *Lycopodiopsis* Renault 1890a, b, *Brasilodendron* Chaloner *et al.*, 1979, *Cyclodendron* Kräusel 1928 and *Lycopodiophloios* Kräusel 1961. Additionally, the genus *Tundrodendron* Neuburg 1960 known from the Upper Permian of Angara Province was also included in this family (Chaloner, 1967).

The herbaceous lycopodiales were registered in Brazil by Ricardi-Branco and Bernardes-de-Oliveira (2002) from the upper portion of the Itararé Group, in Cerquilho Municipality,

TAXA	ITARARÉ GROUP
Bascaudaspora canipa Owens, 1983	X
Cirratriradites veeversii Playford, 1971	X
Cristatisporites connexus Potonié & Kremp, 1955	X
Cristatisporites inconstans Archangelsky & Gamerro, 1979	X
Cristatisporites crassilabratus Archangelsky & Gamerro, 1979	■
Cristatisporites indignabundus (Potonié & Kremp) Staplin & Jansonius, 1964	■
Cristatisporites inordinatus (Menéndez & Azcuy) Playford, 1978	X
Cristatisporites menendezii (Menéndez & Azcuy) Playford emend. Césari, 1985	X
Cristatisporites spinosus (Menéndez & Azcuy) Playford emend. Césari, 1985	■
Cristatisporites röslerii Ottone, 1989	X
Densosporites annulatus (Loose) Smith & Butterworth, 1967	X
Densosporites triangularis Kosanke, 1950	X
Foveosporites hortonensis (Playford) Azcuy, 1975	X
Kraeuselisporites volkheimerii Azcuy, 1975	X
Lundbladispora braziliensis (Marques-Toigo & Pons) Marques-Toigo & Picarelli, 1984	■
Lundibladispora riobonitensis Marques-Toigo & Picarelli, 1984	■
Vallatisporites arcuatus (Marques-Toigo) Archangelsky & Gamerro, 1979	■
Vallatisporites ciliaris (Lüber) Sullivan, 1964	■
Vallatisporites punctatus (Marques-Toigo) comb. Nov.	X
Vallatisporites spinosus Cauduro, 1970	■
Vallatisporites vallatus Hacquebard, 1957	X

Fig. 1—Table shows sporomorph taxa of lycopsid affinities in the Itararé Group (Souza, 2006). ■ indicates the taxa additionally present in Monte Mor Assemblage (Jha *et al.* 2010).

AGE	PENNSYLVANIAN		
	BASHKIRIAN	MOSCOVIAN	KASIMOVIAN
PARANÁ BASIN	ITARARÉ GROUP		
	CAMPINAS (SP)	BURI (SP)	MONTE MOR (SP)
Banksisporites dijkstrae (Singh, 1953) Tewari & Maheshwari, 1992	*		* 2,3
Banksisporites endosporitiferous =(*Duosporites endosporitiferous* (Singh) Pierhart in Trindade & Sommer, 1966	*	* 4 5 6 7 8	* 2 3 4
Banksisporites tenuis (Dijkstra, 1955) Glasspool, 2003	* 1		* 2
Banksisporites utkalensis (Pant & Srivastava, 1961) Tewari & Maheshwari, 1992	*		* 2 3
Banksisporites labiosus (Dijkstra, 1955) Glasspool, 2003 (= *Trileites labiosus* Irindade, 1970)			* 2 3
Banksisporites vulgatus (Dijkstra,1955) Glasspool, 2003 (= *Trileites vulgatus Dikstrae)*			* 2
Biliarisporites spinosus (Singh, 1953) Bharadwaj & Tiwari, 1970	*		
Bokarosporites psilatus Bharadwaj & Tiwari, 1970	*		
Bokarosporites rotundus Bharadwaj & Tiwari, 1970	*		*
Duosporites perversus (Dijkstra,1971)Pierart, 1989	*		
Duosporites sp.a	*		
Duosporites sp.b			*
Sublagenicula tripartites (Trindade, 1970) Mune & Bernardes-de-Oliveira,2007			* 2 3
Lagenicula horrida Zerndt, 1934	*		
Lagenicula sp.	*		
Lagenoisporites brasiliensis (Dijkstra, 1955) Trindade, 1970	* 1	* 4 5 7	* 2 3 4
Lagenoisporites cf. hispanicus (Dijkstra, 1955) Piérart, 1961		*	*
Lagenoisporites nudus (Nowak & Zerndt, 1936) Potonié & Kremp,1955		*	*
Lagenoisporites sinuatus (Dijkstra, 1955) Trindade, 1957	* 1	* 5	* 3 4
Lagenoisporites rugosus (Loose, 1932) Potonié & Kremp 1955	*		*
Lagenoisporites scutiformis Trindade (1970)			* 2 3
Lagenoisporites sp.	*		
Setosisporites sp.			* 2 3
Calamospora sp.	* 1		* 2 3

SP, NE border of the Parana Basin (Asselian / Sakmarian) and by Salvi *et al.* (2008) from the Rio Bonito Formation (just at the end of the coal interval in the southernmost region of the Brazilian Parana Basin, Guatá Group, in Quitéria outcrop of Encruzilhada do Sul Municipality, RS, Sakmarian, after Jasper *et al.*, 2006) as genus *Lycopodites*.

Besides, lycopsid megaspores and microspores are also recorded from the Parana Basin by Alarcon and Bernardes-de-Oliveira (1999). Accordingly, highly diversified lycopsid forms including both macrofossils and microfossils are represented in the Tubarão Supergroup of the Parana Basin. This group, constituted of Permo-Carboniferous sediments deposited in glacial, interglacial and postglacial conditions, includes a number of complex lithostratigraphic units. Its glacial and interglacial deposits are included in the Itararé Group and are better represented in the outcrops of the northeast border of the basin, where older horizons of the group are also encountered.

In the Itararé Group, a high specific diversity of lycopsid zonate microspores, has been recorded by Daemon (1974), Pons (1975), Arai (1980), Guerra-Sommer *et al.* (1980), Lima *et al.* (1983), Marques-Toigo and Picarelli (1984), Dias (1993), Souza (1997, 2000, 2006), Mune and Bernardes-de-Oliveira (2007, 2009) and Mune *et al.* (2010) (Fig. 1).

The megaspores of the Itararé Group are less diverse as compared to the microspores (Trindade & Sommer, 1966; Trindade, 1970; Lima-Ferreira & Sommer, 1982; Amaral, 2000; Amaral & Ricardi Branco, 2004; Mune *et al.,* 2010). This may be due to the reason that megaspores are related almost only to the heterosporous lycopsid forms. Their composition is showed in Fig. 2.

The Pennsylvanian lycopsid megafossils of the Itararé Group have been systematically analyzed / revised by Millan (1972, 1980, 1985), Oliveira-Babinski and Sommer (1984), Alarcon (1998), Iannuzzi (1999, 2001), Mune (2005), Mune and Bernardes-de-Oliveira (2002, 2007) and are restricted to the Volpe Ranch taphoflora of Monte Mor, SP. Further revision has been attempted in this paper.

This paper presents a taxonomic revision and complements the lycopsid components list from Volpe Ranch taphoflora, Monte Mor Municipality, São Paulo, in an interglacial level of the Itararé Group. Based on the present and previous studies, some biostratigraphic considerations are drawn. The material (deposited in the National Museum of the Federal University of Rio de Janeiro / UFRJ) earlier studied by Millan (1972, 1980, 1985) and new material collected from this area (Mune *et al.,* 2001) under the Thematic Project

Fig. 2—Lycopsid megaspores present in the Itararé Group with exception of the genus *Calamospora*. Data sources: 1= Amaral & Ricardi-Branco (2004); 2= Mune & Bernardes-de-Oliveira (2007); 3= Trindade (1970); 4= Trindade & Sommer (1966); 5= Trindade (1959a, b); 6= Trindade (1960); 7= Bharadwaj & Tewari (1970); 8= Glasspool (2003).

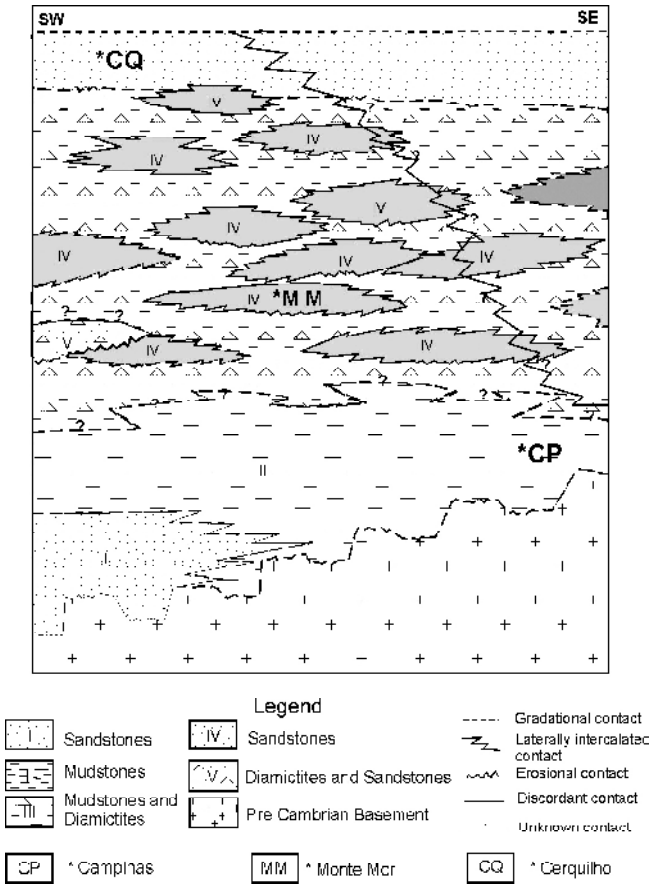

Fig. 3—Seven lithostratigraphical informal units of the Itararé Group in ascending order (Souza Filho, 1986), including the level of the studied fossil locality.

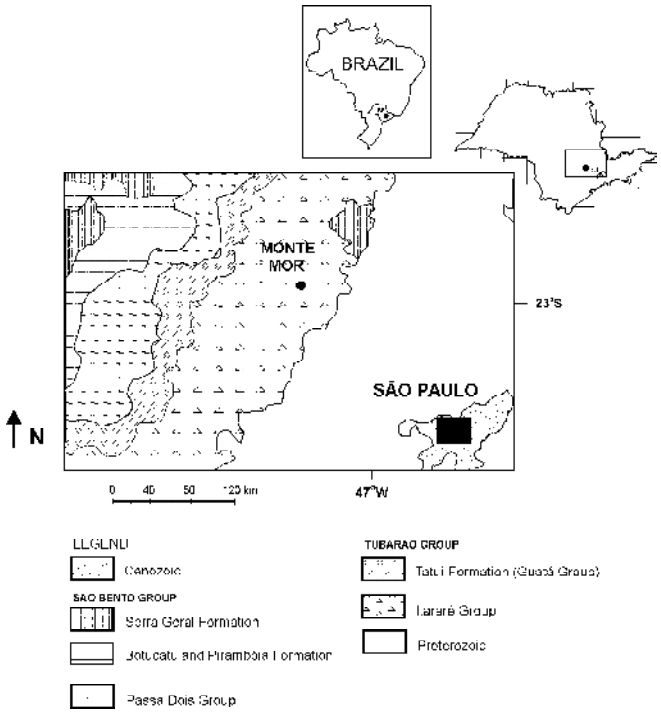

Fig. 4—Map of Monte Mor Municipality, São Paulo State showing plant fossil locality.

FAPESP 97/03639-8 (deposited in the Institute of Geosciences of the University of São Paulo, IGc/USP) was examined.

STRATIGRAPHIC AND GEOLOGIC SYNTHESIS ON THE MONTE MOR TAPHOFLORA AND AREA

The occurrence located in the middle part of the Itararé Group corresponds to the type-locality of the Taphoflora "A" of Rösler (1978) and is characterized by the presence of common elements *Paracalamites, Paranocladus*, *Lycopodiopsis pedroanus* and *Samaropsis*. Additionally, *Botrychiopsis*, *Noeggerathiopsis* and *Buriadia* are present.

The Monte Mor flora occurring on the northeastern border of Parana Basin is rich in lycopsids and conifers and appeared in one of the interglacial phases of the Itararé Group before the emergence of glossopterids, and is considered pre-glossopterid palaeoflora (Bernardes-de-Oliveira *et al.* 2005).

Souza (2000, 2006), in palynostratigraphic studies of northeastern border of the Parana Basin, recorded this palynoassemblage in the *Ahrensisporites cristatus* Biointerval Palynozone (AcZ), which is the lowermost palynozone of the Itararé Group. He correlated this palynoassemblage with the occurrences of Buri, Itapeva, Araçoiaba da Serra, Campinas and the subsurface palynoassemblages at the base of the Lagoa Azul Formation. Additionally, this palynozone, was partly correlated with the informal intervals G (Daemon & Quadros, 1970) and Pre-G (Lima *et al.,* 1983), defined for the basin. It was also correlated with the *Ancistrospora* Zone or *Raistrickia-Plicatipollenites* Subzone of the Paganzo Group (Argentina) and to some extent with the *Kraeuselisporites volkheimeri-Circunplicatipollis plicatus* Superzone of the Tarija Basin (Di Pasquo 1999). According to Souza (2000, 2006) the age of this palynozone is Pennsylvanian, possibly Westphalian (= Upper Bashkirian and Moscovian).

Mune and Bernardes-de-Oliveira (2009) and Jha *et al.* (2010), on the basis of the presence of *Scheuringipollenites maximus* and *Crucisaccites monoletus* in the palynological assemblage, have included this microflora in the *Crucisaccites monoletus* Interval Zone (CmZ) of Souza (2006) which is upper Pennsylvanian (= Kasimovian- Gzhelian) in age.

The megafloral assemblage of the Monte Mor taphoflora corresponds to the third association of the megafloristic succession, i.e. *Paranocladus-Bumbudendron-Ginkgophyllum* association (PGB as) of Parana Basin (Bernardes-de-Oliveira *et al.*, 2005). This is possibly correlated to the *Krauselcladus* - *Asterotheca* Phytozone (Carrizo & Azcuy, 2006) of the Northwestern Argentinean paleofloristic zonation or Interval Zone (Archangelsky & Cuneo, 1991) of

the Paganzo Basin, based on the relative abundance of conifers which are absent in the first association of scheme proposed by Bernardes-de-Oliveira *et al*. (2005).

In a detailed geological mapping of the Pennsylvanian area including Campinas and Monte Mor localities, Souza Filho (1986) recognized the following informal lithostratigraphic units in ascending order: Unit I – upward granodecrescent sandstones; Unit II- mudstones; Unit III- mudstones and diamictites; Unit IV- sandstones; Unit V- diamictites and sandstones; Unit VI- sandstones with wave marks and Unit VII– red diamictites (Fig. 3).

The Monte Mor area, with its carbonaceous levels is included in the Unit IV (Souza Filho, 1986). It is constituted of sandstone sediments which occur at different levels in the Unit III. The lithology of the Unit IV consists of conglomeratic sandstones, medium to fine grained sandstones, conglomeratic mudstones and coal beds. This area corresponds to a facies of deltaic lobs with wave cross-bedded sandstones including deposits of proximal deltaic front or tidal plain and fluvial channels of deltaic plains, under a supraglacial facies of till of ablation flux and a subglacial facies with tillites and pebble pavements. In this deltaic lob facies, the mudstones with coal, muddy sandstones and greyish mudstones are rich in organic material, coal and plant remains that were deposited in a continental environment of flood plain, almost in a final sequence of pro-delta ambience before the installation of a new glacial phase.

MATERIAL AND METHODS

The samples were collected from the Itararé Group outcrop located on the left margin of a creek in Volpe Ranch at 20 m from the mine entrance, in the northeastern area of the Monte Mor Municipality (SP) (latitude 22°50'548 S and longitude 47°16'759 W) (Fig. 4).

The columnar section of the outcrop in Volpe Ranch shows the fossiliferous levels, located in the lower portion of a sequence of carbonaceous shale, mudstones, coal, siltstones and sandstones overlapped by diamictites (Fig. 5).

The lycopsid material was collected from two levels of this outcrop: the first one corresponds to the foot-wall of the Monte Mor coal horizon and the second corresponds to the hanging-wall of the same horizon. This occurrence was initially registered by Barbosa and Almeida (1949). However, systematic study of the plant fossils was initiated only in 1972, by Millan which continued for more than one decade (Millan, 1975, 1977, 1978, 1980, 1981a, b, 1985, 1987). The present investigation is based on the lycophytic material initially studied by Millan (1972, 1980, 1985) and on the new material collected by two of the authors (SM and MECB) and other researchers (Mune *et al*., 2001). The material was studied under a stereomicroscope and drawings were made using camera lucida (Carl Zeiss - Axiophot II). The photographic documentation was carried

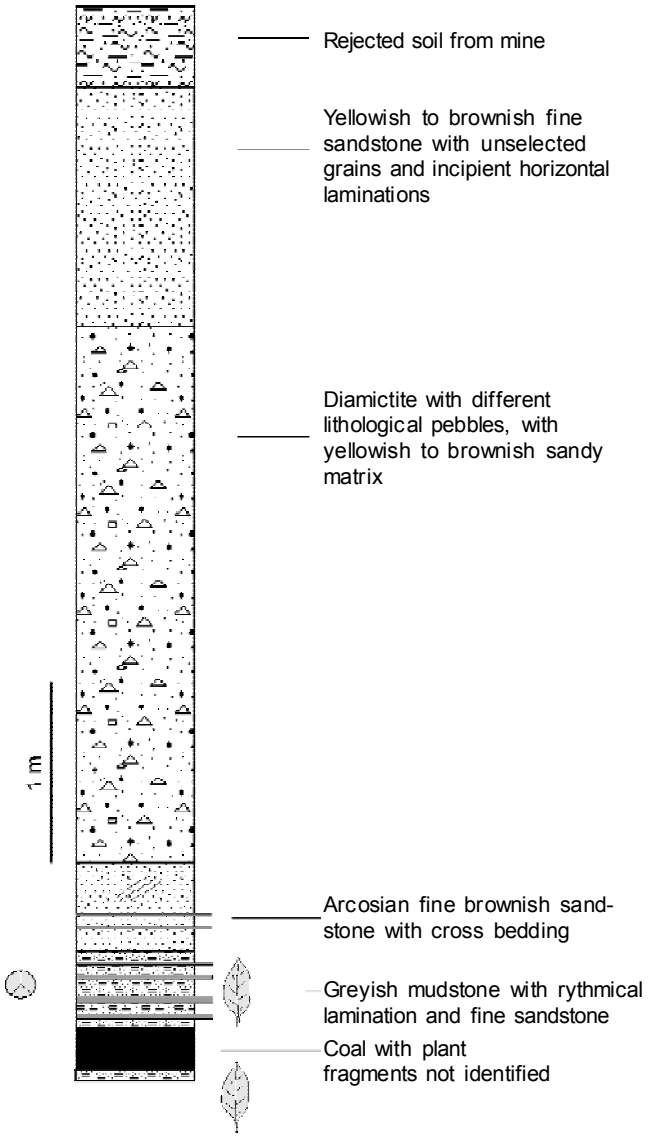

Fig. 5—Columnar section of the exposed levels on creek margin, Volpe Ranch.

out with a Canon Camera EOS - 300 of the Paleobotany Laboratory of IGc/USP.

The lycopsid material is catalogued under the numbers: MN/UFRJ – 801Pb to -805Pb; -812Pb, -814Pb, -1088Pb to -1093Pb of the Palaeobotanic Collection of National Museum, Universidade Federal do Rio de Janeiro-MN/UFRJ, and GP/3E 9074a/b, GP/3E 9135 to GP/3E 9140 of the Scientific Collection from Geosciences Institute, Universidade de São Paulo –IGc/USP.

SYSTEMATICS

The attribution of taxa to a family level is not possible since the reproductive structures are not preserved. In the

present work, the inclusion of the taxa in the Family Lycopodiopsidaceae as proposed by Chaloner (1967) is followed. All the genera described here are included under the Order Lepidodendrales as proposed by Jasper and Guerra-Sommer (1998) and Taylor *et al.* (2009), who included the genus *Brasilodendron* in the Order Lepidodendrales on the basis of lepidodendroid morphological characteristics.

Class—LYCOPSIDA

Order—LEPIDODENDRALES

Genus—BUMBUDENDRON Archangelsky *et al.,* 1981

Type Species—*Bumbudendron paganzianum* Archangelsky *et al.,* 1981

Bumbudendron millani (Arrondo & Petriella) Arrondo & Petriella, 1985

(Pl. 1.1, 2, 3)

Synonymy:

1972 - *Lycopodiopsis* sp. Type A. Millan, p. 40-41 Pl. V. 4, Pl. IX.2.
1972 - *Lycopodiopsis pedroanus* (Carruthers) Edwards emend. Kräusel. Millan, (*part*), p. 29, Pl. II.6, Pl. III.2.
1975 - *Lycopodiopsis* sp. A. Millan, p. 3.
1977 - *Lycopodiopsis* sp. A. Millan, p. 84.
1979 - *Lycopodiopsis millani* Arrondo & Petriella. Arrondo & Petriella, p. 121-133, Pl. II.1-5.
1980 - *Brasilodendron pedroanum* (Carruthers) Chaloner, Hill & Leitskow. Millan, p. 107-112, Pl. I.5, Pl. II.2.
1985 - *Bumbudendron millani* (Arrondo & Petriella) Arrondo & Petriella. Arrondo & Petriella, p. 169-171, Pl. 1.
1987 - *Lycopodiopsis* sp. AMillan, p. 834 and p. 838.
1998 - *Bumbudendron* cf. *B. nitidum* (Arrondo & Petriella) Arrondo & Petriella. Alarcon, p. 3, Pl. 1.1.
1999 - *Bumbudendron* cf. *B. nitidum* (Arrondo & Petriella) Arrondo & Petriella. Alarcon & Bernardes-de-Oliveira, p. 37, 39, figures 1.2, 2.
2002 - *Bumbudendron millani* (Arrondo & Petriella) Arrondo & Petriella. Iannuzzi (personal communication).

Description—Stem fragments preserved as impressions, small, measure ~ 4.0 cm in length and ~1 cm in maximum width, fusiform, spirally disposed foliar cushions, elongate and narrow, length (6 to 8 mm) by width (1.5 to 2 mm) ratio of cushions 4 : 1, leaf base scars in apical position on the cushion, cushion ridges/crest outlines well developed, presence of infra-foliar bladder evidenced by fine, elongate base, phyllotaxy lepidodendroid, without defined orthostic angle of ~ 50°.

Comparison—Stem fragments are comparable to *Bumbudendron millani* (Arrondo & Petriella, 1985) in shape of foliar cushions, outline and apical position of the foliar scars and position of the scar of the foliar bundle. Though the cushions are slightly bigger in size, their length/width ratio is closely comparable to that of *Bumbudendron millani.* The cushions are smaller than those of *Bumbudendron nitidum*. In presence of well developed crest outline of cushions with elongate base and infra-foliar bladder, the specimens are similar to those of *Bumbudendron millani*. Hence, they are being named here as *Bumbudendron millani* (Arrondo & Petriella) Arrondo & Petriella.

Locality—Volpe Ranch, Monte Mor Municipality, São Paulo State.

Stratigraphic and Geographic Distribution—Brazil – Paraná Basin, Itararé Group (Pennsylvanian = Kasimovian-Gzhelian) – Volpe Ranch, Monte Mor (SP); Argentina – Paganzo Basin, Lagares Formation (Pennsylvanian) and Callingasta-Uspallata Basin, Santa Máxima Lower Formation (Pennsylvanian).

Repository—Specimens Numbers MN/UFRJ - 802Pb and - 803Pb belong to the scientific collection of the National Museum of the Federal University of Rio de Janeiro-UFRJ and Specimen Number GP/3E 9137, to the scientific collection of the Institute of Geosciences, University of São Paulo-USP.

Bumbudendron* cf. *B. paganzianum Archangelsky *et al.,* 1981

(Pl. 1.4)

Synonymy:

1972 - *Lycopodiopsis pedroanus* (Carruthers) Edwards emend. Kräusel. Millan, p. 30-31 (*part*), Pl. IV. 1, 3, 4, Pl. IX.1.
1975 - *Lycopodiopsis pedroanus* (Carruthers) Edwards emend. Kräusel. Millan, p. 03.
1977 - *Lycopodiopsis pedroanus* (Carruthers) Edwards emend. Kräusel. Millan, p. 84 (*part:* Volpe Ranch, SP).
1980 - *Brasilodendron pedroanum* (Carruthers) Chaloner, Hill & Leitskow. Millan, p. 107-112 (*part*), Pl. 1.1, 4, Pl. II.1.
1987 - *Brasilodendron pedroanum* (Carruthers) Chaloner, Hill & Leitskow. Millan, p. 834 (*part*).
1998 - *Bumbudendron* cf. *B. paganzianum* Archangelsky, Azcuy & Wagner. Alarcon, p. 3, Pl. 1.1.
1999 - *Bumbudendron* cf. *B. paganzianum* Archangelsky, Azcuy & Wagner. Alarcon & Bernardes-de-Oliveira, p. 37, 39, figures 1.2, 2.
2002 - *?Bumbudendron* sp. Iannuzzi (personal communication).

Description—Stem fragments preserved as impressions, measuring more than 12 cm in length and 0.7 cm in maximum width, leaf cushions smooth, well marked contour in upper region and faint in basal region, where visible length / width ratio of cushions 2.5 : 1, area between two cushions usually plain, with slightly longitudinal ornamentation visible in

Specimen DGP MN 814Pb, foliar scars subapical, occupy total width of cushions, cushions apparently pentagonal in shape, apical portion of cushions with three sides and basal portion with two convergent sides (Specimen DGP MN 1088Pb).

Comparison—The specimens compare well with *Bumbudendron paganzianum* (Archangelsky *et al.*, 1981) mainly in shape of smooth leaf cushions, well marked in upper region, phyllotaxy lepidodendroid, interarea wide and plain with longitudinal ornamentation (similar to fig. 4 of Archangelsky *et al.*, 1981). However, since the details of foliar traces and lanceolate intrafoliar bladder have not been observed, the specimens are being described here as *Bumbudendron* cf. *B. paganzianum*.

Locality—Volpe Ranch, Monte Mor (SP).

Stratigraphic and Geographic Distribution—Brazil – Paraná Basin, Itararé Group (Pennsylvanian) – Volpe Ranch, Monte Mor (SP); Argentina – Paganzo Basin, Jejenes Formation (Pennsylvanian) (Iannuzzi & Rösler, 2000), Lagares Formation (Pennsylvanian), type locality Bum Bum (Province La Rioja), (Archangelsky *et al.*, 1981). Calingasta-Uspallata Basin, Santa Máxima Lower Formation (Pennsylvanian) Iannuzzi & Rösler, (2000).

Repository— Specimen Numbers DGP MN 814Pb, DGP MN 1088Pb and DGP MN 1089Pb of the scientific collection of the National Museum of the Federal University, Rio de Janeiro-UFRJ.

Genus—LEPTOPHLOEUM Dawson, 1861

Type species—*Leptophloeum rhombicum* Dawson, 1861

Leptophloeum* cf. *L. sanctae-helenae Anderson & Anderson, 1985

(Pl.1.11)

Synonymy:

1972 - *Lepidodendron pedroanum* (Carruthers) Zeiller emend. Millan. Millan, p. 8-27, Pl. II. 4, 5, Pl. III.1, 3.

1973 - *Leptophloeum australe* (McCoy) Walton. Plumstead, Pl. II.3a, 3b.

1975 - *Lepidodendron pedroanum* (Carruthers) Zeiller emend. Millan. Millan, p. 3, 11.

1985 - *Lepidodendron pedroanum* (Carruthers) Zeiller emend. Millan. Millan, p. 613-617 Pl. 1.1-3 a, b.

1985 - *Leptophloeum sanctae-helenae* Anderson & Anderson. Anderson & Anderson, p. 96, fig. 3; Pl. 19. 1a, 6, Pl. 20. 1a, 1b.

1998 - (*?) Cyclodendron brasiliensis* Lejal-Nicol & Bernardes-de-Oliveira. Alarcon, p. 3 fig. 1.1.

1999 - (*?) Cyclodendron brasiliensis* Lejal-Nicol & Bernardes-de-Oliveira. Alarcon & Bernardes-de-Oliveira, p.37, 39, figures 1.2, 2.

2002 - (*?) Cyclodendron / Lycopodiopsis* sp. - Iannuzzi (personal communication).

Description—Only one specimen present in collection, measures more than 6.5 cm in length and more than 5 cm in width, leaf cushions prominent, roundly rhomboid to rhomboid, closely adjacent, arranged in vertical rows, with pronounced square upper angle and rounded lower angle, measuring ~8 mm in length and ~10 mm in width, helically arranged, seasonally differentiated zones absent, foliar scars circular to oval, eccentrically located toward cushion apex, parichnos and ligular scars not visible.

Comparison—The specimen apparently resembles *Leptophloeum australe* (McCoy) Walton from Orange Free State, Africa (Plumstead, 1973, Pl II. 3a, 3b). Plumstead (1973) considered it as a typical species of pre - *Glossopteris* flora in glacigene sediments. Anderson and Anderson (1985) placed this species partially in *Leptophloeum sanctae-helenae.* The specimen here described is comparable with *Leptophloeum sanctae-helenae* (Anderson & Anderson, 1985) in nature and arrangement of leaf cushions and shape and location of leaf scars. However, this species is reported from the Permian Lower Ecca Group of North Karroo Basin.

Locality—Volpe Ranch, Monte Mor (SP).

Stratigraphic and Geographic Distribution—Brazil – Paraná Basin, Itararé Group (Pennsylvanian = Kasimovian-Gzhelian) – Volpe Ranch, Monte Mor (SP).

Repository—Specimen Number DGP MN - 801Pb of the scientific collection of the National Museum of the Federal University, Rio de Janeiro-UFRJ.

PLATE 1 →

1. *Bumbudendron millanii* (Arrondo & Petriella) Arrondo & Petriella 1985, GP/3E 9137.
2. Detail of figure 1, enlarged to show leaf cushions. Photostereomicroscopy Carl Zeiss Stemi SV6, 5 x 2.5.
3. *Bumbudendron millanii* (Arrondo & Petriella) Arrondo & Petriella 1985, DGP MN 803 Pb.
4. *Bumbudendron* cf. *B. Paganzianum* Archangelsky *et al.,* 1981, DGP MN 1088 Pb b.
5. *Brasilodendron pedroanum* (Carr.) Chaloner *et al.,* 1979, GP/3E 9135.
6. *Brasilodendron pedroanum* (Carr.) Chaloner *et al.,* 1979, DGP MN 805 Pb b.
7. Cf. *Cyclodendron* sp, DGP MN 1093 Pb.
8. Aff. *Brasilodendron* sp, GP/3E 9139.
9. Part of figure 8. Detail from leaf cushions and false scars.
10. Detail of epidermic features, GP/3E 9139.
11. *Leptophloeum* cf. *L. sanctae helenae* Anderson & Anderson 1985, DGP MN 801 Pb.

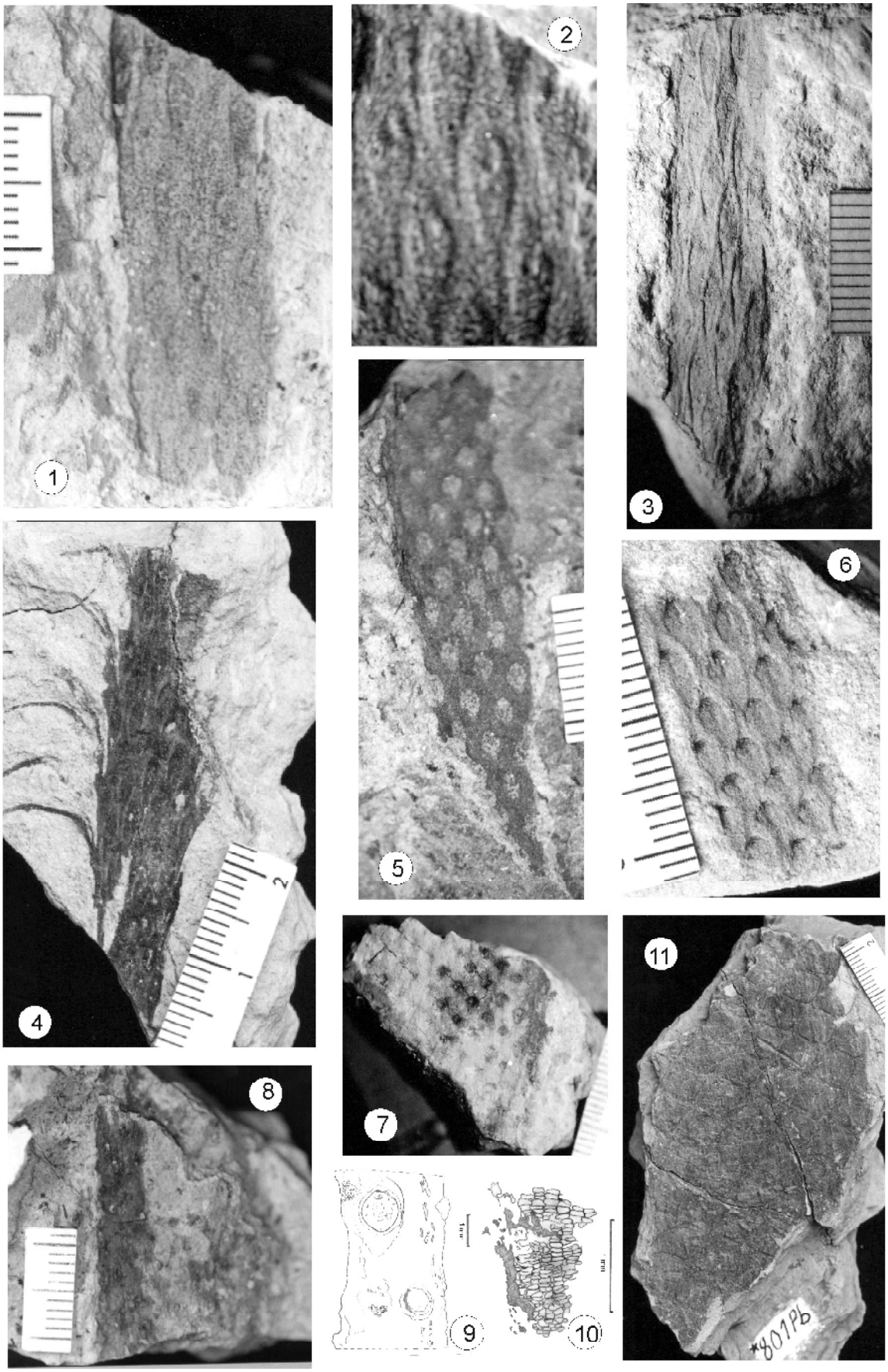

PLATE 1

Genus—BRASILODENDRON Chaloner *et al.,* 1979

Type species—*Brasilodendron pedroanum* (Carruthers) Chaloner *et al.,* 1979

Brasilodendron pedroanum (Carruthers) Chaloner *et al.,* 1979

(Pl. 1.5, 6)

Synonymy:

1972 - *Lycopodiopsis pedroanus* (Carruthers) Edward emend. Kräusel. Millan, p. 27-34 (*part*), Pl. II. 7 and 9 (*not)* Pl. II. 6 and 8, Pl. III. 2, Pl. IV. 1-4).

1975 - *Lycopodiopsis pedroanus* (Carruthers) Edward emend. Kräusel. Millan, p. 3 (p*art*).

1980 - *Brasilodendron pedroanum* (Carruthers) Chaloner, Leistkow & Hill. Millan, p. 105-113, Pl. 1. Figs 2, 3, 7 and 8 (not PL I Figs, 1,4-6; PL II Figs 1, 2).

1987 - *Brasilodendron pedroanum* (Carruthers) Chaloner, Leistkow & Hill. Millan, p. 834, 838.

2002 - *Brasilodendron* cf. *B. pedroanum* Iannuzzi (personal communication).

Description—Six impressions of stem fragments measuring ~2 to 9 cm in length and 0.9 to 1.8 mm in width preserved, fusiform foliar cushions present which measure 2.8 to 5 mm in length and 1.2 to 2.5 mm in width, cushions with slightly sigmoidal apex and base, foliar scar decurrent, leaves have parallel course to stem after emergence, are perpendicular, long and narrow, incomplete, measure 6 to 19 mm in length and 0.3 to 0.8 mm in width; cuticle recovered from the inter area of Specimen GP/ 3E 9135 is thick, with short pentagonal to rectangular cells.

Remarks—Millan (1972, 1975) recorded *Lycopodiopsis pedroanus* (Carruthers) Edward emend. Kräusel in the Volpe Ranch taphoflora. Millan (1980), treated this species as a synonym of *Brasilodendron pedroanum* (Carr.) Chaloner, Leistkow & Hill as suggested by Chaloner *et al.* (1979). The cuticular data and foliar details of some of the specimens of the present assemblage ascertain the similarity of this species with *Brasilodendron pedroanum.* However, Millan (1972, 1980) had reservations about some specimens which are placed here as synonyms of other species. The shape of the leaves and phyllotaxy in the Specimens GP/3E 9074 a,b, are very similar to the specimens described by Chaloner *et al.* (1979, Pl. II, Figs 2-3). The presence of the megaspores of *Lagenoisporites brasiliensis* (Dijkstra, 1955) Trindade, 1970 compressed against the cauline fragment (GP/3E 9136A) and in association with other specimens confirm their possible affinity with *Brasilodendron pedroanum* as suggested by Chaloner *et al.* (1979).

Locality—Volpe Ranch, Monte Mor (SP).

Stratigraphic and Geographic Distributions— Brazil – Paraná Basin, Itararé Group (Pennsylvanian, Volpe Ranch, Monte Mor (SP), Guatá Group, Rio Bonito Formation, Lower Permian, Cambuí, PR (Read, 1941) and Candiota, RS (Chaloner *et al.,* 1979); Argentina - Paganzo Basin, Jejenes and Tupe (Archangelsky & Cúneo, 1991; Iannuzzi & Rösler, 2000).

Repository—Specimen Numbers DGP MN 804Pb and DGP MN 805Pb, Scientific collection of the National Museum of the Federal University, Rio de Janeiro-UFRJ and Specimen Numbers GP/3E 9135; GP/3E 9136 a, b (IGc/USP), scientific collection of the Geosciences Institute, University of São Paulo-USP.

Brasilodendron sp.

(Pl. 1.8,9, 10)

Description—Cauline fragment partially preserved as cast, impression and as replacement by limonite, measuring 3.2 cm in length and 1.4 cm in maximum width, leaf cushions not defined, apparently fusiform in shape, elongated longitudinally, infra foliar bladder absent; lepidodendroid phyllotaxy without defined orthostic, cushions closely set without inter areas; limonitized epidermis of cushion surface shows horizontally disposed cells with respect to its length, cells measure 0.15 mm in length and 0.04 mm in width, converge slightly towards foliar scar which is subcircular in shape, in transverse view scar of foliar base well delimited by a ring constituted by 3 cell layers (0.12 mm wide), probably corresponding to the surface attachment of the leaf epidermis and hypodermis; leaf scar located centrally, apparently, a ligular scar present in apical portion of foliar cushions, cushions measure 1.44 mm in diameter.

Remarks—The specimen shows characteristic features of the genus *Brasilodendron*, viz. shape and arrangements of cushions, and centrally located foliar scars in them. However, the area occupied by leaf scars is much smaller than that of foliar cushions. Additionally, the specimen shows epidermal features similar to those of *Lycopodiophloios* Kräusel (= *Cyclodendron* Kräusel in Rayner, 1985, Pl. 1.8). Its indistinct cushions are comparable with those of the genus *Lycopodiopsis*. Though, the specimen is broadly comparable with the genus *Brasilodendron,* the horizontal arrangement of the epidermal cells is not observed in this genus.Hence it is described here as *Brasilodendron* sp.

Locality—Volpe Ranch, Monte Mor (SP).

Stratigraphic and Geographic Distribution—Brazil—Paraná Basin, Itararé Group (Pennsylvanian), Volpe Ranch, Monte Mor (SP).

Repository—Specimen Number GP/3E 9139, Scientific Collection of Geosciences Institute, University of São Paulo-USP.

MILLAN 1972 - 1985	PRESENT STUDY	SPECIMEN
Lycopodiopsis sp. Type A (*in* Millan, 1972), Pl. V. 4, Pl. IX. 2. *Lycopodiopsis pedroanus* (Carruthers) Edw.emend Kräusel, 1975 (*in* Millan,1972), Pl. II. 6, Pl. III.2. *Brasilodendron pedroanum* (Carruthers) Chaloner, Leistikow & Hill. (*in* Millan, 1980), Pl. I. 5, Pl. II. 2. *Lycopodiopsis* sp. Type A (*in* Millan, 1987), p. 834 and 838.	*Bumbudendron millanii* Archangelsky, Azcuy & Wagner 1981	DGP MN 802 Pb, DGP MN 803 Pb, GP/3E 9137
Lycopodiopsis pedroanus (Carruthers) Edw.emend Kräusel. (*in* Millan, 1972), Pl. IV. 1, 3, 4, Pl. IX. 1 *Brasilodendron pedroanum* (Carruthers) Chaloner, Leistikow & Hill. (*in* Millan, 1980), Pl. I. 1, 4, Pl. II. 1.	*Bumbudendron cf. B. paganzianum* Archangelsky, Azcuy & Wagner, 1981	DGP MN 814 Pb, DGP MN 1088 Pb, DGP MN 1089 Pb
Lepidodendron pedroanum (Carruthers) Zeiller emend Millan. (*in* Millan, 1972), Pl. II. 4, 5, Pl. III. 1, 3 . (*in* Millan, 1985) Pl. I. 1- 3 a, b.	*Leptophloeum cf. L. sanctae-helenae* Anderson & Anderson, 1985	DGP MN 801 Pb
Lycopodiopsis pedroanus (Carruthers) Edw.emend Kräusel. (*in* Millan, 1972), Pl. II. 7 - 9 *Brasilodendron pedroanum* (Carruthers) Chaloner, Leistikow & Hill. (*in* Millan, 1980), Pl. I. 7, 8.	*Brasilodendron pedroanum* (Carruthers) Chaloner, Leistikow & Hill, 1979	DGP MN 804 Pb, DGP MN 805 Pb, DGP MN 823Pb GP/3E 9074 a/b GP/3E 9135, GP/3E 9136 a/b, GP/3E 9140
	Brasilodendron sp.	GP/3E 9139
Lycopodiopsis derbyi Renault. (*in* Millan, 1972), Pl. III. 4, Pl.IV. 5, 6, Pl. V. 1-3.	*Cyclodendron* sp.	DGP MN 812 Pb, DGP MN 1090 Pb, DGP MN 1091 Pb DGP MN 1092 Pb DGP MN 1093 Pb

Fig. 6—List of Pensylvannian lycopsids from Volpe Ranch, Monte Mor (SP), Itararé Group, including the specimens described/revised by Millan (1972, 1980, 1985) and those of the present study.

Genus—CYCLODENDRON Krausel, 1928

Type species—*Cyclodendron leslii* (Seward, 1903) Kräusel, 1928

Cyclodendron sp.

(Pl.1.7)

Synonymy:

1972 - *Lycopodiopsis derbyi* Renault. Millan, p. 35-41, Pl. III. 4, Pl. IV. 5, 6, Pl. V.1-3.
1975 - *Lycopodiopsis derbyi* Renault. Millan, p. 03.
1977 - *Lycopodiopsis derbyi* Renault. Millan, p. 84.
1987 - *Lycopodiopsis derbyi* Renault. Millan, p. 834.
1999 - (=*Lycopodiopsis derbyi* undetermined) Alarcon & Bernardes de Oliveira. p. 37, 39, Table 1. 2 and 2.

Description—Specimen Numbers DGP MN 812Pb, 1090Pb and 1093Pb measure 2.4-9.3 cm in length and 2.3-3.3 cm in width, show circular to oval, sometimes rhomboidal, helically arranged scars of foliar bases, with different well marked growth zones, without development of foliar cushions, scars of foliar bases sometimes show circular border.

Remarks—The specimens are morphologically similar to the genus *Lycopodiopsis* Renault, mainly with its species *L. derbyi*. However, the different stratigraphical positions (Kasimovian/Gzhelian and Guadalupian/Lopingian ages) and the absence of anatomical features impede the identification

with this genus. The morphological features described, herein and nature of a few leaves preserved in the Specimen Number DGP MN 1091Pb suggest affinity with the genus *Cyclodendron* Kräusel 1928. However, sporangia and micro sporangiophores similar to those found in the genus *Cyclodendron* are absent. The specimens are also comparable in shape and arrangement of leaf scars with *Cyclodendron leslii* (Seward) Kräusel [=*Lycopodiopsis leslii* (Seward) Srivastava & Chandra] reported by Srivastava and Chandra (1992) from Karharbari Formation (Early Permian) of Chirimiri and Ganjra Nala section, South Rewa Gondwana Basin, Madhya Pradesh, India.

Locality—Volpe Ranch, Monte Mor (SP).

Stratigraphic and Geographic Distribution—Brazil - Paraná Basin, Itararé Group, Volpe Ranch (Kasimovian / Gzhelian), Monte Mor (SP).

Repository—Specimens Numbers DGP MN 812Pb, DGP MN 1090Pb, DGP MN 1091Pb, DGP MN 1092Pb and DGP MN 1093Pb, Scientific collection of the National Museum of the Federal University, Rio de Janeiro-UFRJ.

DISCUSSION

Based on diagnostic characteristics of morphology, phyllotaxy and detailed features of the foliar cushions, Thomas and Meyen (1984) proposed a key for identification of the Late Palaeozoic lycopsid morphogenera of isolated cauline axes, preserved as impressions or compressions from Angara region. The same criteria of classification has been followed for the Monte Mor material. The lycophyte species of Monte Mor (SP) identified earlier by Millan (1972-1987) and those systematically analyzed in the present paper, are listed in Fig. 6, with their respective synonymy.

The lycopsid components of Monte Mor taphoflora are *Bumbudendron millani, Bumbudendron* cf. *B. paganzianum, Brasilodendron pedroanum, Brasilodendron* sp., *Leptophloeum* cf. *L. sanctae-helenae,* and *Cyclodendron* sp.

Considering the views of Jasper and Guerra-Sommer (1998), Alarcon (1998), Alarcon and Bernardes-de-Oliveira (1999), it is suggested here that the generic name *Brasilodendron* should be restricted to only those forms which extend from the Pennsylvanian to Early Permian within the Tubarão Supergroup (Itararé and Guatá groups) and are known solely by their external morphology while, on the contrary, the name *Lycopodiopsis* should be reserved for the Middle to Late Permian forms of the Passa Dois Group, which have both morphological and anatomical features preserved.

Mune and Bernardes-de-Oliveira (2007), in palaeoecological analysis, opined that the megafloral assemblage of Monte Mor consists of (a) meso-xerophytic communities, e.g. Cordaitales (*Noeggerathiopsis*) and Coniferales (*Paranocladus*), (b) hygro-mesophytic to mesophytic communities represented by Progymnosperms (*Botrychiopsis plantiana*) and probably Ginkgoales (*Ginkgophyllum*) indicating plain of flooding and (c) hydro-hygrophytic communities related to the edges of lakes, peat bogs, flood plains like lycophytes (*Brasilodendron, Bumbudendron*, etc.) of the present study. In taphonomic analysis, the lycophytes of the foot-wall of the coal (parautochthonous assemblage) could represent hydro-hygrophilous arbustive communities in pure associations, probably related to tidal plains or to brackish environments. Dense associations of *Brasilodendron* type arborescent lycopsids were components of the peat forming plant communities in the southern Parana Basin according to Jasper *et al.* (2006) and Cazzulo-Klepzig (2002). On the other hand, the lycopsids from the hanging-wall of the Monte Mor coal represent a mixed assemblage (parautochthonous-allochthonous) with sphenophytes, pteridosperms, cordaites, conifers and seeds probably deposited on fluviatile flooding plains or on the borders of interdistributary channels of deltaic plains. These lycophytic elements constituted part of an interglacial flora intercalated into the median sedimentary package of the Itararé Group (Gondwanan glacial sequence of Paraná Basin). This interglacial flora could have developed in the latitudes between 30° and 60° S in cold palaeoclimatic conditions. Although the retrieval of the glaciers and the probable proximity of the marine environment, provided conditions of climatic improvement where a relatively abundant vegetation could develope giving origin to coal beds in spite of the fact that they were not very thick. The relative abundance and diversity of lycophytes in the taphoflora of the Monte Mor suggests climatic improvement, as inferred by Guerra-Sommer *et al.* (1995) for the southern coal of the Paraná Basin.

The relation with Argentinean phytostratigraphy can be established (Mune & Bernardes-de-Oliveira, 2007) on the basis of presence of several Pennsylvanian floristic elements like *Bumbudendron millanii* (Arrondo & Petriella) Arrondo & Petriella, 1985 from the Lagares Formation (Azcuy *et al.*, 1999), Paganzo Basin, *Bumbudendron* cf. *B. paganzianum* Archangelsky *et al.* 1981 from the Paganzo Basin (Jejenes and Lagares formations) and from the Callingasta-Uspallata Basin (Santa Máxima Lower Formation). All of these elements are Bashkirian-Moscovian in age, which suggests correlation with the NBG Zone of Archangelsky and Azcuy, 1985. However, Mune and Bernardes-de-Oliveira (2007) interpreted these forms as probably relictual in Monte Mor taphoflora on the basis of presence of well defined Voltziales (conifers) like *Paranocladus* and *Buriadia,* along with *Botrychiopsis plantiana* (Carruthers) Archangelsky and Arrondo, 1971 and *Samaropsis* cf. *S. cuerdai* Gutierrez *et al.* 1992 which suggest better biostratigraphic correlation with the *Kräuselcladus –Astherotheca* Phytozone of Carrizo and Azcuy, 2006, (ex- Interval Zone of Archangelsky & Cúneo, 1991) in the Paganzo Basin (see Azcuy *et al.*, 2007).

In Paraná Basin, the genus *Brasilodendron*, apart from being present in the Itararé Group of Monte Mor, is present in Sakmarian of Triunfo Member (the lower stratus of the Rio Bonito Formation) in Paraná State (Ricardi-Branco, 1997) and

in the Rio Bonito Formation of the Rio Grande do Sul State (Jasper *et al.,* 2006). In Argentina, it appears in the Bashkirian-Moscovian of the Tupe and Jejenes formations in Paganzo Basin (Azcuy *et al*., 1999; Iannuzzi & Rösler, 2000).

Leptophloeum australe, though, a characteristic form of the Upper Devonian of Australia, was recorded by Plumstead (1973) from the Late Palaeozoic *Glossopteris* flora of South Africa. Later, Anderson and Anderson (1985) identified the species *L. sanctae-helenae* from Lower Ecca Group of the North Karroo Basin. This form is registered for the first time from Brazil in the present study.

The genus *Cyclodendron* which is a characteristic genus of the Permian of South Africa, was recorded earlier, in Brazil, by Lejal-Nicol and Bernardes de Oliveira (1979) from the Rio Bonito Formation (Siderópolis Member-Artinskian) and in the present study from the Itararé Group. In India, the genus is known from the Karharbari Formation (Early Permian; Srivastava & Chandra, 1992), Barren Measures Succession (early Late Permian; Kar, 1968) and Kamthi Formation (Late Permian/Early Triassic; Chandra & Rigby, 1981). *Cyclodendron* is the only lycopsid megafossil genus which is known from the Permian (Lower Gondwana) of India and is represented by the species *C. leslii* (Seward) Kräusel (Surange, 1966). Srivastava and Chandra (1992) proposed a new combination for *Cyclodendron leslii* of the Indian Lower Gondwana as *Lycopodiopsis leslii* (Seward). However, this specimen appears to be similar to *Cyclodendron leslii.* Some specimens identified in this paper as *Cyclodendron* sp. resemble closely to the specimen described by Srivastava adn Chandra (1992, Pl. 1, figs 4, 5) from the Karharbari Formation of South Rewa Gondwana Basin.

The Early Carboniferous lycopsid floral elements recorded from the extra peninsular region of India from Kashmir (Pal & Chaloner, 1979; Singh *et al*., 1982; Pant & Srivastava, 1985) comprise the taxa *Archaeosigillaria minuta, A. subcostata, Archaeosigillaria* sp., *Aspidiaria, Cyclostigma* sp. cf. *C. pacifica, Cyclostigma ungeri, Lepidodendron gundensis, Lepidodendropsis fenestrata, L. liddarensis, Lepidodendropsis* cf. *peruviana, Lepidodendropsis* cf. *sigillarioides, Lepidodendropsis* sp., *Lepidosigillaria* cf. *quadrata, Knorria* sp. 1, *Knorria* sp. 2, *Pseudobumbudendron chaloneri, Pseudobumbudendron meyenii* and *Lepidostrobus kashmirensis*. Since no Pennsylvanian deposits are registered from peninsular India, there is no evidence of common species of lycopsid megafossils between India and Brazil during that time. However, presence of the genus *Cyclodendron* in the Itararé Group and Guatá Group (Pennsylvanian and Lower Permian of Parana Basin) and in Permian of India and South Africa reflects on the stratigraphic and evolutionary history of the plant. The genus appeared in Early Carboniferous, flourished during the Permian Period and probably extended up to the Triassic.

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