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Palaeoclimatic implications of Lycophyta in the Gondwana of Southern Brazil

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Abstract - The Lycophyta played an important role in the floral associations developed during Permian times in the Gondwana area of South Brazil (State of Rio Grande do Sul). The lycophyte affinities of certain palynomorphs (*Lundbladispora*, *Vallatisporites*, *Cristatisporites*), and the impressions of compressed molds of lycophytes, suggest that the climax of Lycophyta took place under coal-measure conditions in a warm, seasonal, climate. At some levels, dense thickets of arborescent forms have been found "in situ"; their cormose rooting systems are non-stigmarioid. The changes in climatic and palaeoecological conditions that occurred during Late Permian times are reflected by a rapid decrease of pteridophytic spores, particularly those related to Lycophyta and the concomitant increase in gymnosperm saccate pollen. During the uppermost Late Permian the flora became strikingly impoverished, glossopterids occurred as complementary elements and lycophytes became dominants. These palaeontological data which are corroborated by facies analysis, indicate a very warm, semiarid climate to the southern portion of Paraná Basin.

Resumo - As Lycophyta desempenharam importante papel para o desenvolvimento das associações florísticas durante o Permiano no Gondwana do sul do Brasil (Estado do Rio Grande do Sul). As afinidades botânicas de palinóforos como *Lundbladispora*, *Vallatisporites*, *Cristatisporites*) e impressões e compressões de Lycophyta sugerem que o climax deste grupo ocorreu durante a deposição das camadas de carvão, em clima quente e sazonal. Em alguns níveis, densas associações de formas arborescentes foram encontradas "in situ". Seu sistema radicular cormoso é do tipo não estigmarióide. As modificações nas condições climáticas e paleoecológicas que ocorreram no Permiano Superior são evidenciadas por um rápido declínio de esporos de pteridófitas, particularmente os referidos a Lycophyta, e aumento concomitante de pólenes sacados de gimnospermas. No topo do Permiano Superior a composição florística sofreu um rápido empobrecimento; as glossopterídeas ocorrem como elementos complementares e as Lycophyta voltam a dominar. Estes dados paleontológicos, corroborados por dados de análises faciológicas, indicam clima muito quente, semi-árido. Os resultados obtidos neste trabalho referem-se exclusivamente à parte sul da Bacia do Paraná, Estado do Rio Grande do Sul.

INTRODUCTION

The intracratonic Paraná Basin, with a total area of 1.700.00 km² (1.100.000 km² of which correspond to Brazil) is situated in east-central South America. It contains Palaeozoic, Mesozoic and, locally, also Caenozoic sediments. The present study is based on data from Permian sediments in the southern part of this basin in Rio Grande do Sul state, Brazil (Fig. 1), comprising, in agreement with Schneider *et al.* (1974), the following lithostratigraphic units: (Fig. 2).

Figure 1 - Location of the gondwana rocks in Rio Grande do Sul (Southern Brazil).

Figure 2 - Stratigraphic column of the Paraná Basin (Brazil). (Modif. Schneider *et al.*, 1974).

Itararé Group, Guatá Group (Rio Bonito and Palermo Formations) and Passa Dois Group (Irati, Estrada Nova and Rio do Rasto Formations - Fig. 2).

The macropalaeobotanical and palynological data have made it possible to establish a climatic evolution; the increase in lycophyte remains up-sequence is considered to be a parameter of warming. Lithological characters have been used as supplementary data and have corroborated the information supplied by micro and megafloral data.

A comparison between the Late Palaeozoic floral elements of the Brazilian portion of the Paraná Basin and those of other Gondwana areas reveals an overall similarity between Notoafroamerican taphofloras with an important lycophyte contribution. In the Australo/Indian Province this group is poorly represented in the micro and megafloristic associations (Taylor & Taylor, 1989).

A review of Permian lycopods recorded from southern part of the Paraná Basin shows high proportion of specimens represented by isolated vegetative shoots preserved as impressions. Unfortunately, the poor preservation does not frequently offer an adequate basis for generic designations. Fragments of lycopods are assigned in literature as *Lycopodiopsis* "sensu lato" following a general tendency to attribute Permo-Carboniferous Gondwana lycophytes to this genus.

The first Lycophyta described from the Gondwana of Rio Grande do Sul was identified as *Flemingites pedroanum* by Carruthers (1869). Later, the type-material of this genus has been redefined as *Lepidodendron pedroanum* (Zeiller, 1895, White, 1908, Lundqvist, 1919), *Lycopodiopsis pedroanum* (Edwards, 1952) and, most recently, as *Brasilodendron pedroanum* (Chaloner *et al.*, 1979). Another genus described from south Brazilian strata is *Lycopodiophloios* (Kräusel, 1961), but this form probably corresponds to a different level of decortication of *Lycopodiopsis* or *Brasilodendron*.

More accurate observation of some samples, hitherto undescribed, reveals a great diversification among Permian Gondwana lycophytes in southern Brazil. However, a formal description of megafossil taxa is outside the scope of this paper.

An abundance of lycophytes in the plant communities of Rio Grande do Sul is also apparent from the palynological analysis, taking into account the palaeobotanical affinities of the spores, according to Azcuy (1978), Doubinger (1959), Gould & Delevoryas (1977), Boureau & Doubinger (1975).

Paleobotanical samples (Pb) and palynological slides (MP-P) are registered and deposited at the Museum of Paleontology, Instituto de Geociências, UFRGS.

Megafloristic data were based on Guerra-Sommer & Cazzulo-Klepzig (1993).

LYCOPHYTE REMAINS AS EVIDENCE OF PALAEOCLIMATIC EVOLUTION

The lower part of the Late Palaeozoic Gondwana succession in the State of Rio Grande do Sul, southern Brazil is characterized by glacial sediments comprising mainly tillites and diamictites as a general rule. Sedimentary

structures in diamictites indicate peri- and proglacial lake conditions (Itararé Group - Sakmarian/Artinskian), according to Piccoli (1989).

In the associated rhythmic deposits the palynological assemblage is composed primarily of pollen grains belonging to *Potonieisporites*, *Caheniasaccites*, *Cannanoropolis*, *Plicatipollenites*, *Protohaploxypinus* and *Vittatina*, and trilete spores such as *Lundbladispora*, *Vallatisporites*, *Punctatisporites*, *Granulatisporites*, etc., as well as palynomorphs of unknown affinities (*Portalites*, *Pilasporites*, *Tetraporina*). The high proportion of pollen grains indicates that gymnosperms were the predominant floral elements in this position of the basin. Pteridophytes were mere accessories (Cazzulo-Klepzig, *et al.*, 1980).

On the other hand, the megafloral remains recovered from sandy sediments corresponding to the Facies Suspiro - (Piccoli, 1989) of the Itararé succession mainly belong to the glossopterids, e.g. *Rubidgea*, *Gangamopteris*, with some *Glossopteris* (Pl. 1, Fig. 3). Relicts such as *Botrychiopsis plantiana* (Carruthers) Archangelsky and Arrondo (Pl. 1, Fig. 2) are still important components of this taphoflora, which represents an association similar to the present-day "taiga", suggesting cold climatic conditions (Retallack, 1980). Pteridophytic megafossils, including Lycophyta, were not registered in this periglacial palaeoflora (Cazzulo-Klepzig & Guerra-Sommer, 1983).

With the retreat of the ice-caps, the glaciogene sedimentation was replaced by fluviodeltaic depositional systems, represented by a thick succession of sandstones, siltstones, and coal seams (about 60-70 m), belonging to the Rio Bonito Formation (Paim *et al.*, 1983). The taphofloras of the basal siltstones are characterized by the presence of *Botrychiopsis plantiana* and articulates (*Phyllothea indica* Bumbury, Pl. 1, Fig. 1), a hygrophile assemblage which occurs in bands associated with glossopterids, *Glossopteris*, *Gangamopteris*, *Rubidgea*. The association of *Botrychiopsis plantiana* with *Phyllothea indica* is considered to indicate a climatic amelioration (Guerra-Sommer, 1979) Lycophyta have not been recorded in these deposits.

Microfloral assemblages are still dominated by saccate pollen (*Caheniasaccites*, *Potonieisporites*, *Cannanoropolis*, *Plicatipollenites*, *Protohaploxypinus*, *Vittatina*). However, there is a gradual increase in the proportion of Sporites, which indicates that, with the retreat of the glaciers, the Pteridophyta found favourable conditions, allowing them to proliferate. Trilete lycophyte spores are represented mainly by the genera *Lundbladispora*, *Cristatisporites*, *Vallatisporites* and *Kraeuselisporites* (Marques-Toigo, 1988).

The river system that drained the alluvial basins allowed peat formation to take place in subsiding backswamp areas, marshes and lakes (coal-bearing strata - Piccoli *et al.*, 1986).

The micro and macrofloral assemblages of the coal seams and associated strata show different vegetational patterns in the different coalfields. However, the microfloras of the South Brazilian coal measures are mainly characterized by a dominance of pteridophytic spores. The principal trilete spore genera are *Punctatisporites*, *Leiotriletes*, *Calamospora*, *Granulatisporites*, *Cyclogranisporites*, *Horriditriletes*, *Apiculatisporites*, *Anapiculatisporites*,

Plate 1

Figure 1- *Phyllothea indica*. - Pb 2815 (Rio Bonito Formation, Quitéria outcrop)
Figure 2- *Botrychiopsis plantiana*. - Pb 2112 (Rio Bonito Formation, Papaleo outcrop)
Figure 3- *Glossopteris* sp. - Pb 2858 (Rio Bonito Formation, Quitéria

outcrop)
Figure 4- *Sphenopteris* cf *ischanovensis* - Pb 2530 (Rio Bonito Formation, Faxinal Coalmine)
Figure 5- *Ginkgoophytopsis kidstonii* - Pb 25 (Irati Formation, Pantano Grande region).

Lundbladispora, *Vallatisporites* and *Cristatisporites*. The rare monolete spores are represented by *Laevigatosporites* and *Punctatosporites*. Saccate gymnosperm pollen are represented mainly by *Sheuringipollenites*, *Vesicaspora*, *Caheniasaccites*, *Cannanopolis* and *Potonieisporites*. The most common forms of *Striatiti* are the genera *Protohaploxylinus* and *Vittatina*. Algae and/or related elements occur in several coal seams: these are *Botryococcus*, *Tetraporina*, *Portalites*, *Pilasporites*, *Quadrisporites* and *Brazilea* (Marques-Toigo, 1988).

Taking into account the quantitative analysis and the botanical affinities of the diagnostic species of *Lundbladispora*, *Cristatisporites*, and *Vallatisporites*, Marques-Toigo & Correa da Silva (1984) suggested that the peat-forming vegetation of the South Brazilian coals was composed mainly of herbaceous plants and shrubs related to Lycophyta: "*Lundbladispora* - *Punctatisporites* - *Portalites* Association" and "*Cristatisporites* - *Vallatisporites* Association".

The *Sheuringipollenites*/*Caheniasaccites* Association and other mono and bisaccate forms would represent a gymnosperm vegetation, mainly belonging to *Glossopteridophyta*, *Coniferophyta* and *Cordaitophyta*. In this association lycophyte spores are poorly represented.

The megafloral assemblages of coal-bearing strata reveal an important compositional change, as is evident from the presence of filicoid fronds, i.e. *Sphenopteris* cf. *ishanovens* Zalessky (Pl. 1, Fig. 4) *Rodhea* sp. and *Eucopteris meridionalis*, Dolianiti which is of pteridophytic or pteridosperm affinity (Guerra-Sommer, 1989). These fossils correspond most likely to herbaceous plants that formed the understorey of arborescent gymnosperm stands. The latter are mainly glossopterids, and, to a lesser extent, also cordaitaleans. On the other hand, herbaceous articulates (*Phyllothea*) dominate in the hygrophilous assemblages. (Guerra-Sommer *et al.*, 1991)

Recent studies on the coal-bearing strata of Rio Grande do Sul (Rio Bonito Formation - Artinskian/Kungurian) have revealed the presence of "in situ" cormose lycophyte bases forming dense thickets above coal seams (Piccoli *et al.*, 1991). These lycophyte bases are in organic connection with radial appendices which functioned as roots (Pl. 3, Fig. 2).

These radial appendices, which are arranged perpendicularly to the trunk, show spiny surface excrescences (Pl. 3, Fig. 5). In the upper part of these bases, the cushions become elongate rhomboidal (Pl. 3, Figs. 3, 4). The cormose bases cut across different lithologies, ranging from mudstones to sandstones. Filicoid fronds ("*Rodhea*" sp.) and fragments of glossopterids and *Cordaites* were identified from these sediments. Sedimentological and palaeontological data from these plant beds suggest an evolution from swampy conditions to an alluvial plain environment with periodic flooding (Guerra-Sommer, 1989).

Cormose lycophyte bases have been described from the Palaeozoic sediments of Euroamerica (e.g. *Chaloneria cormosa*, Pigg and Rothwell, *Protostigmaria eggertiana* Gennings, *Selaginella fraipontii* Schlanker and Leisman,

Cormophyton mazonense Pigg and Taylor. Meyen (1987) suggested that Gondwana lycophytes, with cormose bases should be ranged with the Chaloneriaceae rather than the Lepidocarpaceae.

"In situ" casts of lycophyte trunk bases, lacking stigmarian axes, were described by Cúneo & Andreis (1983) from Permian strata of the Central Patagonian Basin, Argentina. The characters of this association are quite similar to those referred to in the present paper. According to Cúneo & Andreis (*op. cit.*) these fragments were remains of an arborescent lycophyte forest that developed in a floodplain environment under frost-free climatic conditions. The dense thickets of arborescent lycophytes with cormose bases, occurring in the roof of coal seams, are found associated with fernlike fronds. The predominance of herbaceous articulates in hygrophilous environments suggests a change from cool temperatures to a milder season climate. The dominance of lycophyte spores in these strata reinforces the suggestion of a climatic improvement.

In the upper part of the Rio Bonito Formation a gradual change from fluvial to coastal sedimentation may be inferred from the presence of fine-grained sandstone sequences with hummocky, wavy and parallel lamination, representing lagoonal washover fan, tidal flat, tidal inlet, foreshore, and upper-shore facies (Palermo Formation, according to Lavina *et al.*, 1985).

The upper part of this succession is composed of siltstones and sandstones, laid down as storm deposits. Lycophyte remains, preserved as molds and casts (Pl. 3, Fig. 1), are the most megafloral elements found in these environments (Cazzulo-Klepzig & Guerra-Sommer, 1985).

Different lycophyte morphotypes can be recognized in the samples: the most common one of these corresponds to stem and/or branch fragments with a lepidodendroid phyllotaxy, and distinctly elongated leaf cushions without proper leaf scars (Pl. 2, Figs. 3, 6, 7, 8). The leaves are supposed to have been attached to the topmost part of the leaf cushion. This type is similar to *Lepidodendropsis* Krausel and *Brasilodendron* Chaloner, Leistikow & Hill.

Another type, which is less abundantly represented, shows leaf cushions of hexagonal shape, isodiametric to elongate with very narrow intereareas. Evidence of leaf scars can be observed at some levels (Pl. 2, Figs. 1, 4). These characters are reminiscent of *Lycopodiopsis* Kräusel and *Angarodendron* Meyen. Impressions of *Glossopteris*, and of *Paracalamites* are found associated. The composition of the associated palynoflora shows changes in percentages between the trilete spores and saccate *Striatiti* in relation with those of the coal seams. The increase and diversity of *Striatiti* in this assemblage may be considered as marking the beginning of important floral and climatic changes. The palynoflora appears to reflect contributions from a gymnosperm-dominated "upland" flora producing disaccate, monosaccate and *Striatiti* pollen, mixed in with trilete spores from a more localised flora of pteridophytes, mainly Lycophyta (*Lundbladispora* and *Cristatisporites*), which grew in an area marginal to the site of deposition (Cazzulo-Klepzig *et al.*,

Plate 2

Figures 1, 4 - Compressed stem: leaf cushions hexagonal shaped, isodiametric to elongated; intercushions areas narrow, leaf scars evident - Pb 1288 (Palermo Formation, São Sepé outcrop)
Figures 2, 5 - Fragment with lepidodendroid phyllotaxy, broad intercushion areas - Pb 3292 (Estrada Nova Formation, Cerro Chato outcrop)
Figure 3 - Fragment with lepidodendroid phyllotaxy elongated leaf cushions,

leaf scars absent - Pb 1229 (Palermo Formation, São Sepé outcrop)
Figure 6 - Fragment with lepidodendroid phyllotaxy elongated leaf cushions (median line evident) leaf scars absent - Pb 1104 (Palermo Formation, São Sepé outcrop)
Figures 7, 8 - Fragment with lepidodendroid phyllotaxy, leaf scars present - Pb 1123 (Palermo Formation, São Sepé outcrop).

1989).

Overlying the Palermo Formation deposits a palaeoenvironmental change from shallow water to restricted marine conditions, associated with lagoonal, lacustrine and coastal swamp areas, is marked by dark grey to black and brown oil shales, light to dark grey shales (non-bituminous) and carbonates (Irati Formation - Kazanian/Tatarian, according to Lavina, 1982). Mudstones and silty sandstones, indicate shallow water platform facies, (Estrada Nova Formation - Tatarian, Fig. 2).

The palynological assemblages from Irati Formation are dominated by *Striatiti* (*Protohaploxypinus*, *Lueckisporites*, *Striatopodocarpites*, *Vittatina*) and algal remains (*Botryococcus*), whilst trilete lycophyte spores are rare (Cazzulo-Klepzig *et al.*, *op. cit.*). According to Foster (1979), a high proportion of taeniae in the pollen grains among the saccates indicates a defense mechanism against desiccation. It is therefore suggested that the *Striatiti* were adapted to drier climatic conditions.

The megafloral assemblage of the Irati Formation is represented by varied wood remains corresponding mainly to picnoxylic tree trunks of gymnosperm affinity, with a diaphragmatic pith: *Polysolenoxylon*, *Scleromedulloxylon*, *Arachnomedulloxylon*, *Septomedulloxylon* (Pessoa, 1985). The growth rings in these wood remains are thick; the layers being very thick in relation to those of late wood. Detached roots of *Vertebraria* type are common in this flora, which has been related to swampy-brackish environments under warm climatic conditions (Mussa *et al.*, 1980). Ginkgophyta (*Ginkgoophytopsis kidstonii*) become common elements in the megaflora (Backeuser *et al.*, 1982) illustrated in Plate 1, Figura 5.

A gradual return to continental conditions is suggested by the presence of variegated sandstones, siltstones and mudstones, deposited as coastal to fluvial sediments which cover carbonate deposits (Estrada Nova and Rio do Rasto Formations, Upper Permian - Lavina, 1992).

The megafloras are dominated here by impressions and casts of lycophyte stems, which are abundant but poorly preserved (*Lycopodiopsis*), and detached lepidodendroid leaves. Rare glossopterid fragments can be identified in these bands (Lima & Cunha, 1976). A common characteristic of the lycophyte fragments in this assemblage is a typically lepidodendroid phyllotaxy, with broad interareas, and the absence of a ligule (Pl. 2, Figs. 2, 5). In some remains, the basal parts of acicular leaves are found in organic connection with the cushions (Pl. 2, Fig. 1). Kräusel (1961) described *Lycopodiophloios* from these strata as a genus distinct from *Lycopodiopsis*.

The sudden impoverishment of *Glossopteris* and the dominance of lycophytes can be attributed to the increasingly warmer climatic conditions during the Permo-Triassic transition. This agrees with sedimentary facies (red beds) indicating aridity. Palynological assemblages are not recorded from these beds.

The most representative genera of pollen and spores which occur throughout the studied succession are illustrated on Plates. 4 and 5.

FINAL CONSIDERATIONS

In evaluating the parameters supplied by mega- and microflora associated with different sedimentary facies in the Permian sediments of the State of Rio Grande do Sul southern part of the Paraná Basin (Brazil), it has become evident that the palaeofloral evolution was related to climatic conditions.

Since the palaeobotanical and palynological data are insufficient on their own to produce a complete outline of the palaeoclimatic changes, lithological data were also taken into account.

The homogeneous composition of Early Permian floral assemblages, in the southern part of the basin, which are dominated by herbaceous to shrub-like plants considered to be relicts from the rigorous climate of an Ice Age (e.g. *Botrychiopsis plantiana*) suggests the persistence of a cold climate. The dominance of *Rubidgea* and *Gangamopteris* leaves with a palmate venation, associated with glossopterids with pinate venations seems to indicate a gradual warming. Diamictite-tillite sequences are indicative of glaciogene sedimentation, but there is no evidence of permafrost in these basal strata. Lycophyte megafossils are registered from these levels. In the microfloral assemblages lycophyte spores are present only as accessory elements (*Lundbladispora*, *Vallatisporites*), and this suggests that the Lycophyta were not a flourishing group in cold climates.

Upwards coal and coal-bearing strata (Coalfields Capané, Candiota, Iruí, Pantano Grande, Faxinal, Leão-Butiá, Charqueadas-Santa Rita, Chico-Lomã e Santa Terezinha), suggests improved climatic conditions. The palynological assemblages of coals are dominated by *Cingulicavati* trilete spores, thus suggesting that the peat-forming mires were generally populated by a lycophyte vegetation rather than gymnosperms. The low diversity of forms and the abundance of some genera (*Lundbladispora*, *Cristatisporites*, *Kraeuselisporites*, *Vallatisporites*) among miospores of Rio Bonito Formation in the southern part of the Paraná Basin suggest a low-diversity swamp flora dominated by Lycophyta (Marques-Toigo & Correa da Silva, 1984).

In coal-bearing strata pinnate glossopterid related to forms relate to *Glossopteris* are common; *Gangamopteris* and *Rubidgea* (palmate forms) are poorly represented. A sudden enrichment of articulates and filicoids is characteristic. Compressed trunks of lycophytes become common elements (*Lycopodiopsis*, *Brasilodendron*). In the roof of some coal seams dense thickets of arborescent lycopods with cormose bases provide evidence that the climax of Lycophyta took place during the deposition of this coal-bearing strata. Additionally, the presence of marls at the top of the coal-bearing deposits is a lithological indicator of climatic warming (Guerra-Sommer *et al.*, 1991).

Therefore, it appears that the cool seasonal climate of early Permian times changed into a moist seasonal interval during the Artinskian-Kungurian. This climatic change was significant for the meso-hygrophile to hygrophile vegetation that originated the biomass of the Gondwana South Brazilian

Plate 3

Figure 1 - Mold of Lycophyta trunk partially enclosed in the sediments - Pb 1185 (Palermo Formation, São Sepé outcrop).
Figure 2 - Lycophyta cormose basis - Pb 3088 (Rio Bonito Formation, Quitéria outcrop).

Figures 3,4 - Elongated cushions from the top of the cormose basis - Pb 3088.
Figure 5 - Details of the radial appendices showing accute excrescences - Pb 3088.

coals. Thus, the dominance of pteridophytic spores in the peat-forming assemblages is not only due to ecological conditions but also reflects an adaptation to climatic improvement.

Changes in palaeoenvironmental conditions can be inferred on palaeobotanical and palynological grounds in the succession which overlies the coal-bearing rocks. Conditions leading to peat formation disappeared; the major floral changes indicates a shift in climatic regime as shown by the increase of gymnospermic plants adapted to a seasonal climate.

The microfloral succession also reflects important changes related to sudden increase in saccate gymnosperm pollen.

A dramatic change in climate conditions occurred during the uppermost Permian. The flora became strikingly impoverished, glossopterids became accessory elements, lycophytes (both arborescent and shrub-like forms) are dominant (*Lycopodiopsis*, *Lycopodiophloios*). These palaeobotanical records suggest a warmer, semiarid interval, and this is apparently confirmed by the presence of red sandstones indicative of long, dry seasons alternating with more rainy seasons with a moderate precipitation.

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REFERENCES

- Azcuy, C.L. 1978. Posible significado paleoecológico de microfloras Gondwánicas del Paleozóico superior, especialmente argentinas. *Ameghiniana*, **15** (1 - 2): 85-95.
- Backeuser, Y.; Silveira J.B.R. & Guerra-Sommer, M. 1984. Revisão da tafoflora do afloramento Km 89-90 da Rodovia BR 290, Rio Grande do Sul, Brasil. *Anais, 33º Congresso Brasileiro de Geologia*, Rio de Janeiro, SBG, **2**:1062-64.
- Boureau, E. & Doubinger J. 1975. Pteridophyta. In: Boureau, E. *Traité de Paléobotanic*. **4** Fasc. 1, pt. 1. 772 p.
- Carruthers, W. 1869. On the plant remains from the Brazilian coal beds with, remarks on the genus *Flemingites*. *Geol. Mag.* **6** (58): 151-155.
- Cazzulo-Klepzig, M. 1979. Estudo da tafoflora do Membro Morro Pelado na sua localidade - tipo. *Pesquisas*, **11**:225-303.
- _____. & Guerra-Sommer, M. 1983. Relationship between the Taphoflora of the Itararé Group, Paraná Basin, Southern Brazil and the Permo Carboniferous boundary. *Dixième Congrè International de Stratigraphie et Geologie du Carbonifère*, Madrid, Espanha. *Compte Rendu*, **4**:395-402.
- _____. & _____. 1985. Palaeofloristic succession in the Paraná Basin, Rio Grande do Sul, Southern Brazil. *Memórias, 6º Congresso Latinoamericano de Geologia*, Bogotá, Colombia, **1**:177-92.
- _____.; _____. & Marques-Toigo, M. 1980. Estudo macro e microflorístico do Grupo Itararé (Bacia do Paraná), RS. *Anais, 31º Congresso Brasileiro de Geologia*, Balneário de Camboriú, SBG. **5**:3027-34.
- _____.; Piccoli, A.E.M. & Marques-Toigo, M. 1989. Reconhecimento de um marco estratigráfico com significado paleoecológico no Permiano da Bacia do Paraná (Grupos Guatá e Passa Dois). *Anais, 11º Congresso Brasileiro de Paleontologia*, Curitiba, Paraná, **2**:972-81.
- Chaloner, W.G.; Leistikow, K.V. & Hill, A. 1979. *Brasilodendron* gen. nov. and *B. pedroanum* (Carruthers) comb. nov., a Permian lycopod from Brazil. *Rev. Paleobot. Palynol.*, **28**:117-136, pl. 1-4.
- Cuneo, R. & Andreis, R.R. 1983. Estudio de un bosque de licófitas de la formación Nueva Lubecka, Permico de Chubut, Argentina. Implicaciones paleoclimaticas y paleogeograficas. *Ameghiniana*, **20**(1-2):132-40.
- Doubinger, J. 1959. Palynologie et Paléobotanique. *Pollen et Spores*, **1**(2):279-309.
- Edwards, W.N. 1952. *Lycopodiopsis*, a southern hemisphere lepidophyte. *The Palaeobotanist*, Lucknow, **1**:159-64.
- Foster, C.B. 1979. Permian plant microfossils of the Blair Athol Coal Measures, Baralaba Coal Measures and Basal Formation of Queensland. *Geol. Survey Queensland*, Brisbane, **372**(45):1-154, 41 est., 4 Figs., 10 tab.
- Gould, R.E. & Delevoryas J. 1977. The biology of Glossopteris: evidence from petrified seed-bearing and pollen-bearing organs. *Alcheringia*, **1**:387-399.
- Guerra-Sommer, M. 1989. Megafloras ocorrentes em horizontes associados a carvão no Rio Grande do Sul. IV Simp. Sul-bras. de Geologia, Porto Alegre, Brasil. *Acta Geologica Leopoldensia*, **29**(2):93-122.
- _____. & Cazzulo Klepzig M. 1993 - Biostratigraphy of the Southern Brazilian Neopalaeozoic Gondwana sequence: a preliminary palaeobotanical approach. 12 Congrès International de la Stratigraphie et Geologie du Carbonifere et Permian, Buenos Aires, *Comptes Rendus XII, ICCP*, **2**:61-72.
- _____.; Marques-Toigo, M. & Corrêa da Silva, Z.C. 1991. Original Biomass and coal deposition in Southern Brazil (Lower Permian, Paraná Basin). *Bulletin Soc. Geol. France*, **162**(2):227-37.
- Holz, M. 1987. Leques aluviais - Faciologia e ocorrência em sedimentitos do Supergrupo Tubarão (Eopermiano) da Bacia do Paraná no Rio Grande do Sul. *Acta Geologica Leopoldensia*, **25**:65 - 104.
- Kräusel, R. 1961. *Lycopodiopsis derbyi* Renault und einige andere Lycopodiales aus den Gondwana schichten. *Palaeontographica B.*, **109**:62-92, pl. 32-41.
- Lavina, E.L. 1992. Geologia Sedimentar e Paleogeografia do Neopermiano e Eotriássico (Intervalo Kazaniano-Scythiano) da Bacia do Paraná. Curso de Pós-graduação em Geociências, Universidade Federal do Rio Grande do Sul. Tese de Doutorado. 160p.
- _____.; Nowatzki, C.H.; Araujo dos Santos, M. & Leão, H.Z. 1985. Ambientes de sedimentação do Supergrupo Tubarão na região de Cachoeira do Sul, RS. *Acta Geologica Leopoldensia*, **21**:5-76.
- Lima e Cunha, M.C. 1976. Contribuição à paleontologia estratigráfica do Grupo Passa Dois no Rio Grande do Sul. *Acta Geologica Leopoldensia*, **1**(1):1-48.
- Lundqvist, G. 1919. Fossile Pflanzen der *Glossopteris* Flora aus Brasilien. *Kungl. Svenska Vetenskaps Akademiens Handlingar*, **60**(3):1-36.
- Marques-Toigo, M. 1988. Palinologia, bioestratigrafia e paleoecologia do neopaleozóico da Bacia do Paraná nos E. do R.G. Sul e Santa Catarina, Brasil. Curso de Pós-graduação em Geociências, Universidade Federal do Rio Grande do Sul. Tese de Doutorado. 259 p.
- _____. & Corrêa da Silva, Z.C. 1984. On the origin of gondwanic south Brazilian coal measures. *Comun. Serv. Geol. Portugal*, **70**(2):151-60.
- Meyen, S.V. 1987. *Fundamentals of Palaeobotany*. Chapman and Hall, 432 p.

Plate 4 (all figures x 700)

- Figure 1 - *Punctatisporites gretensis* forma minor Hart 1965 MP-P 343
Figure 2 - *Calamospora* sp MP-P 3573
Figure 3 - *Leitriteles virkii* Tiwari 1965 MP-P 343
Figure 4 - *Granulatisporites micronodosus* Balme & Hennelly 1956 MP-P 238
Figure 5 - *Lundbladispota braziliensis* (Pant & Srivastava) Marques-Toigo & Pons 1975 MP-P 343
Figure 6 - *Kraeuselisporites apiculatus* Jansonius 1962 MP-P 2007
Figure 7 - *Vallatisporites arcuatus* (Marques-Toigo) Archangelsky &

- Gamerro 1979 MP-P 2573
Figure 8 - *Cristatisporites* sp MP-P 2008
Figure 9 - *Botryococcus braunii* Kutzing 1849 MP-P 314
Figure 10 - *Tetraporina horologia* (Staplin) Balme 1963 MP-P 3402
Figure 11 - *Portalites gondwanensis* Nahuys, Alpern & Ybert 1968 MP-P 343
Figure 12 - *Pilasporites calculus* (Balme & Hennelly) Tiwari & Navale, 1967 MP-P 340.

- Mussa, D.; Carvalho, R.G. & Santos, P.R. 1980. Estudo estratigráfico e paleoecológico em ocorrências fossilíferas da Formação Irati, Estado de São Paulo, Brasil. *Boletim IG/ USP*, **11**:142-48.
- Paim, P.S.G.; Piccoli, A.E.M.; Sarturi, J.A.D.; Munaro, P. & Granitoff, W. 1983. Evolução paleogeográfica do Supergrupo Tubarão na área de Mariana Pimentel-Faxinal, Guaíba, RS. *1º Simpósio Sul-Brasileiro de Geologia*, Porto Alegre, Atas : 140-60.
- Pessoa, R.H.C. 1985. Madeiras gimnospérmicas no Irati do Estado do Rio Grande do Sul: observações sobre a anatomia, sistemática e paleoecologia. Coletânea de Trabalhos Paleontológicos, DNPM, *Série Geologia* 27, *Paleontologia e Estratigrafia*, **2**:623-39.
- Piccoli, A.E.M. 1989. Relações estratigráficas entre as Facies Budó e Suspiro (Grupo Itararé) nas folhas de Vila Nova, Lagoa da Meia Lua e Suspiro, RS. *Pesquisas*, **22**:45-52.
- _____; Lopes, R.C. & Camozzato, E. 1986. Análise paleoambiental das jazidas de carvão do Estado do Rio Grande do Sul. *Acta Geologica Leopoldensia*, **22**:35-54.
- _____; Menegat, R.; Guerra-Sommer, M.; Marques-Toigo, M. & Porscher, C. 1991. Faciologia da sequência sedimentar nas folhas de Quitéria e Várzea do Capivarita, R.S. *Pesquisas*, **18**(1):311-43.
- Retallack, G.J. 1970. Late Carboniferous to Middle Triassic megafossil floras from the Sidney Basin. *Geological Survey of New South Wales Bull*, **26**:384-430.
- Schneider, R.L.; Mühlmann, H.; Tommasi, E.; Medeiros, R.A.; Daemon, R.F. & Nogueira, A.A. 1974. Revisão estratigráfica da Bacia do Paraná. *Anais, 28º Congresso Brasileiro de Geologia*, Porto Alegre, Brasil, SBG, **1**:41-65.
- Taylor, N.T. & Taylor E.L. 1989. *Antarctic Paleobiology - its role in the reconstruction of Gondwana*. Springer-Verlag eds., New York, 261 pp., 74 ill.
- White, I.C. 1908. Relatório sobre as "coal measures" e rochas associadas do sul do Brasil. *Relatório Final da Comissão de Estudos das Minas de Carvão de Pedra do Brasil*. Imprensa Nacional, Rio de Janeiro. p.1-300.
- Zeiller, R. 1895. Note sur la flore fossile des gisements houillers du Rio Grande do Sul (Brésil Meridional). *Bulletin Société Géologique de France*, **3**:602-29, lam. 8-10. serie 3

Plate 5

(all figures x 700)

- Figure 1 - *Potonieisporites* sp MP-P 3844
 Figure 2 - *Plicatipollenites malabarensis* (Potonié e Sah) Foster 1975 MP-P 2A
 Figure 3 - *Caheniasaccites ovatus* (Bose e Kar) Archangelsky e Gamero 1979 MP-P 1534
 Figure 4 - *Protohaploxypinus* sp MP-P 3572

- Figure 5 - *Protohaploxypinus* sp MP-P 3844
 Figure 6 - *Lueckisporites virkkiae* (Potonié e Klaus) Klaus 1967 MP-P 411
 Figure 7 - *Vittatina* sp MP-P 343
 Figure 8 - *Striatopodocarpites* sp MP-P 2344
 Figure 9 - *Fusacarpites* sp MP-P 317
 Figure 10 - *Scheuringipollenites maximus* (Hart) Tiwari 1973 MP- 324.