EARLY PERMIAN PALAEOFLORAS FROM SOUTHERN BRAZILIAN GONDWANA: A PALAEOCLIMATIC APPROACH

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ABSTRACT In the parameters supplied by the taphofloras from different sedimentary facies in the Early Permian sedimentary sequences of the southern part of the Paraná basin, Brazil, it has become evident that the palaeofloristic evolution was related to palaeoclimatic and palaeoecological evolution. The homogenous composition of Early Permian floral assemblages, which are characterized mainly by herbaceous to shrub-like plants considered to be relicts from the rigorous climate of an ice age (e.g. Botryochypsis plantiana) suggest the persistence of the cold climate. The dominance of Rubidgea and Gangamopteris leaves with palmate venation associated with glossopterid fronds with interregional unconformities and partially eroded. Each megasequence consist of lithological packages formally individualized as lithostratigraphic units by different authors.

PALEOFLORISTIC SUCCESSION The lower part of the Early Permian Gondwanan succession in the Southern Brazil is characterized by sediments comprising mainly sandstones and siltstones, deposited in a marked periglacial climate. The megafossil remains recovered from glaciocontinental sediments related to lowlands (Milani et al. in press) and included into Itarare Group are assigned to Glossopteridales (Gangamopteris obovata, Gangamopteris buriatica, Gangamopteris angustifolia, Rubidgea lanceolata, Rubidgea obovata, Glossopteris indica Schimp 1874, Glossopteris communis, Feistmantel 1896). With the retreat of ice caps, the glaciogene sedimentation was replaced by fluviodeltaic and estuarine facies. The taphofloras of the basal siltstones of this sequence recovered from the lower section of Papaleo outcrop (Pasqualini et al. 1986) are characterized by the presence of B. plantiana associated with articulate Glossopteris indica Bubunri 1861, conifers (Buriadia sp.), and glossopteris with palmate venation. Gangamopteris, Cordaites and protoglossopterids (Rubidgea) occur as minor elements.

The increasing of herbaceous articulates in this level in relation to those of the basal Permian sequences, and evidences of foliar phytopagy point out to a climate amelioration. The depositional sequence grades upward to more restricted environment conditions that allowed the formation of peat swamps, formed in lagoons protected by barriers under regading regime (Holz 1998, Milani et al. 1997).

Detailed studies of "roof-shale" floras have revealed some vegetation heterogeneity in roof-shale floras within any one coalfield in Southern Brazilian Gondwanas. Some floristic assemblages contains dominant elements of gymnosperm affinity whereas a rich pteridophytic association is registered in others.

The presence of a rich coalfield compressed flora from a "tonstein" proposed by Milani et al. (in press) for the Paraná basin. These authors, using sequence stratigraphy, characterize six megasequences for the Paleozoic and meso-cenozoic strata of the Southern Brazil, through the inceasing of herbaceous articulates in this level in relation to those of the basal Permian sequences, and evidences of foliar phytopagy point out to a climate amelioration. The depositional sequence grades upward to more restricted environment conditions that allowed the formation of peat swamps, formed in lagoons protected by barriers under regading regime (Holz 1998, Milani et al. 1997).

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The presence of a rich coalfield compressed flora from a "tonstein" layer associated with a coal seam in the Fastinal Mine allowed the identification of an autochthonous taphoflora characterized by the predominance of arborescent gymnosperm forms (Guerra-Sommer 1989, 1992). Fragments of leaves, branches and feminine reproductive

INTRODUCTION The intracratonic Paraná basin, with a total area of 1.700.000 Km² (1.100.000 Km² of which correspond to Brazil) is situated in east central South America. It contains Palaeozoic, Mesozoic and locally, also Cenozoic sedimentary rocks. In southern Brazil the major coal-bearing strata occur in the intracratonic Paraná basin, in isolated coalfields located along the margin of the Precambrian shield, from the southernmost part of the state of Rio Grande do Sul, through Santa Catarina to the north of the state of Paraná. The coal measures are considered to range in age from Artinskian to Kungurian (Burjack 1978) and occur in the Rio Bonito Formation, included in the Carboniferous-Early Triassic Sequence (regressive package - Fig. 1).

Economic interest in coal seams in the Southern Brazilian Gondwana sequence led to the documentation of the megafossil composition of the coal-bearing strata at the end of the XIX Century and at the beginning of the XX (Plant 1869, Carruthers 1869, Feistmántel 1876-1886, Zeiller 1895, Seward 1903, Arber 1905). While some early studies (Milani et al. 1991) these aflorizations are characterized by the presence of a rich coalfield compressed flora from a "tonstein" layer associated with a coal seam in the Fastinal Mine allowed the identification of an autochthonous taphoflora characterized by the predominance of arborescent gymnosperm forms (Guerra-Sommer 1989, 1992). Fragments of leaves, branches and feminine reproductive

Figure 1 - Location of the Gondwana Sequence in Rio Grande do Sul, southern Brazil (modified after Scherer et al. 1999)
Figure 2. a - Rubidgea sp. (Papaléo outcrop, lower horizon, Rio Bonito Formation) x 0.5; b - Gangamopteris sp., (Acampamento Velho outcrop, Itarare Group) x 1; c - Rubidgea sp. (Acampamento Velho outcrop, Itarare Group) x 0.5; d, g, h - Gangamopteris buriadica (Acampamento Velho outcrop, Itarare Group) x 1; e - Glossopteris sp., evidence of herbivory (roof-shale, Faxinal mine, Rio Bonito Formation) x 0.8; f - Glossopteris sp. (Quiteria outcrop, Rio Bonito Formation) x 0.4; i, j - Glossopteris occidentals (roof-shale - Faxinal mine - Rio Bonito Formation) x 1.
Figure 3 - a - Sphenopteris cf. ischanovensis (roof-shale, Faxinal mine, Rio Bonito Formation) x 2; b - Phyllotheca indica (Papaléo outcrop, roof-shale, Rio Bonito Formation) x 0.8; c-f - Glossopteris communis (Papalpéo outcrop, roof-shale, lower horizon) x 1-2; d - Gingkoites eximia (Faxinal outcrop, Itarare Group) x 1.5; e - Gondwanostachys sp. (Quitieria outcrop, Rio Bonito Formation) x 2; g, h - Brasilodendron pedroanum (Quitieria outcrop, roof-shale) x 0.2; i - Cordaïtes sp. (Papaléo outcrop, roof-shale, upper horizon) x 0.5; j - Botrychiopsis plantiana (Papaléo outcrop, lower horizon, Rio Bonito Formation) x 1.
structures of glossopterids constitute 70% of the whole population (Glossopteris brasiliensis Guerra-Sommer 1992, G. papillosa Guerra-Sommer 1992, G. similis-intermittens Guerra-Sommer 1992, Phanostigma sensu Rigby 1963, Platycardia sp.), coroallean leaves (Rufforia gondwanensis Guerra-Sommer 1989) occur as a subordinate group (20%); very delicate filicoid fronds (Sphenopteris cf. 'antracophylic' fronds) might cross-cutting the laminar represent herbaceous forms that lived under the canopy. Epicyvascular analyses on cuticles of glossopterid revealed xeromorphic patterns, similar to those from Ranigaj coal fields. Studies on recent fronds suggest that such features may be related to nitrogen restriction, that occurs nowadays in temperate climate swamps (Lotscher 1969). On the other hand, phylogamy evidence leaves with incised lobes suggests that the climate was mild. (Guerra-Sommer 1995)

The coroallean leaves found in this association are assigned on the basis of their epidermic patterns to Rufforia MEYEN, a typical Angara flora form, which is the most important element in the peat-forming plant association in the Late Paleozoic coals in Angara Province (Meyen 1987).

Herbaceous articulates of hygrophytic habit such as Phyllotheca indica, and its fertile structures like Gondwanostachys, predominate in a megaflora recovered from an antracophytic association at Pantano Grande region near the Leao Mine (Guerra-Sommer et al. 1995). Glossopterids of meso-hygrophytic habitat are important forms (Glossosporidium communis, G. browniana, G. occidentalis White 1908, Gangamopteris mosesii Dolianti 1954, and Rubidgea sp.). Feminine reproductive structures (Arberia minasica (White) Rigby 1972) are common elements. Coroallean leaves (Coroaitaeas hislopiai) and seeds (Coroaecarpus irapuaini Oliveira 1977 and Sarnarospix sp) are less frequent. Delicate filicoid fronds (Sphenopteris sp. Rhodoecrinum sp.) occur as complementary elements. Damaged secondary shoots of Burjadia are rare in this association.

At the upper section of the Papaleo outcrop (Burjack et al. 1982) antracophytic florae associated with two minor coal seams are dominated by arborescent glossopterids with pinnate venation (Glossopteris of Brasiendendron pedravenni, Chuloner, Leistickow, Hill 1979) are important elements in the antracophytic association of the upper coal seam. Fronds of Pecopteris sp. with fertile structures corresponding to Asterochtea sp. were registered in this level by Iannuzzi and Vieira (1997). On the other hand, the occurrence of impressions of Coroaitaeas leaves in barren strata from the yellow sandstones to siltsstones suggest that different taxa in the group would be adapted to distinct habitats, in wet and dry environments.

Arborescent basalm stumps of Lycophyta in situ cross-cutting the stratification are the dominant higrophylous element in an autochthonous antracophyte megafossil association at Quiteria region. The basal portions of these stems related to Brasielodendron and Lycophytum are depicted as a rounded cornlike structure with roots. Filicoid forms are also represented, as well as to Botrychopsis sp and conifers fragments, representing sterile and fertiles shoots. Casts of lycophytes compressed longitudinally occur in the sequence, parallel to bedding, which is the basal portions of glossopterids and coroallean leaves. Jasper & Guerra-Sommer (1998) using taphonomic criteria corroborate the hypothesis of lagoon-barrier system for deposition of the sequence.

Transgressive surface erosion is observed at the top of coalbearing strata. Above this lag there is a package of storm generated sandstones, covered by offshore shales probably corresponding to the maximum flooding surface of the sequence in Southern Brazilian Gondwana (Milani et al. in press). In lithostratigraphic terms, the transgressive surface corresponds to the base of Palermo Formation.

The most significant taxa of Early Permian sequences in South Brazilian Gondwana are illustrated in figs. 2 and 3. All material mentioned in this paper is kept at the Palaeobotany section, Institut of Geociences, UFRGS.

FINAL CONSIDERATIONS Palaeobotanical data allowed to establish a climatic evolution during the deposition of Early Permian sequences in South Brazilian Gondwana. It is, therefore, likely that a change of ice occur from the subarctic to the mid-latitude, cyclic interval during coal deposition. This climatic change should be significant to the wetland vegetation which developed in lowlands at the time of the deposition of the peats. Thus, the colonization by arborescent Lycophyta, Filicophyta and herbaceous Sphenophyta indicates not only the ecological conditions but also an adaptation to climatic improvement.

It is important to observe that the paleobotanical data here presented allow to indicate a mild climate at the time of deposition of roof-shale florae in the Southern Brazilian Gondwana. This assumption is in discordance with the inference of a cold temperate climate suggested before (Rigby 1970, Bernardes de Oliveira 1977), but in accordance to Gastaldo et al. (1996) which affirm that the temperate areas of Gondwana throughout the Permian was warmer than hypothesized by climatic models. Comparing Early Permian palaeoflora of Southern Brazilian Gondwana with global ice extent based upon tills and icerrafted deposits becomes clear that the correlation of Sakonian-Kungurian floras was markedly influenced by the waning of a Permian ice age.

The importance of arborescent lycophyte trunks and stems in roof-shale florae suggested that this group of plants could be important elements in the original biomass of some peat-forming coals in South Brazilian Gondwana. This inference is in accordance with the dominance of lycophyte spores in coal bed assemblages (Marques-Toigo & Correa da Silva 1984) and according with Archangelsky & Cesari (1990) with the linkage between these spores and an arborescent habitat based on ultrastructural studies of exine.

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