DANIAN MICROFLORAL PROVINCES IN ARGENTINA

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ABSTRACT

Two major palaeophytogeoprovinces could be recognized during the Danian in Argentina, based on the palynological record both at the genus or species level and at the palaeocommunity level. In the north *Verrustephanoporites simplex* Leidelmeyer 1966 (Ulmaceae) is associated mostly with tropical and subtropical families. *Nothofagidites* pollen in the south is mostly associated with temperate families. In central and northwest Argentina a subprovince with "triprojectate" pollen (*Mtchedlishvilia*) could be distinguished. Warm and humid climatic conditions are indicated for the Ulmaceae Phytogeoprovince and more temperate conditions for the *Nothofagidites* Phytogeoprovince. A brief consideration of the Mesozoic-Cenozoic palaeogeographic and geodynamic evolution of southern South America is also given.

Keywords: Pollen, palaeophytogeoprovinces, Danian, Argentina.

RESUMEN

Dos grandes paleofitogeoprovincias pueden ser reconocidas durante el Daniense en Argentina basadas en el registro palinológico a nivel genérico o específico y a nivel de paleocomunidades. La presencia de *Verrustephanoporites simplex* Leidelmeyer 1966 (Ulmaceae) en el norte está asociada con familias tropicales y subtropicales, y el polen de *Nothofagidites* en el sur está asociado mayormente con familias templadas. En el centro y noroeste podría delimitarse una subprovincia con polen "triprojectate" (*Mtchedlishvilia*). Las condiciones climáticas habrían sido cálidas y húmedas en la Fitogeoprovincia de Ulmaceae y más templadas en la Fitogeoprovincia de *Nothofagidites*. Se da además una breve consideración sobre la paleogeografía y evolución del sur de Suramérica.

Palabras clave: Polen, paleofitogeoprovincias, Daniense, Argentina.

INTRODUCTION

The aim of this paper is to distinguish and characterize palynological assemblages of the Danian of southern South-America and placing them into a paleoclimatic context. Based on the palynological record at the genus or species level, and at the paleocommunity level, the outlines of palaeophytogeoprovinces for the Danian in Argentina are proposed. The contribution starts with a brief consideration of pre-Danian (Triassic, Jurassic and Cretaceous) argentinian palynological assemblages. The study is based on a compilation of both published information and data from our own recent research. A brief consideration of the Mesozoic-Cenozoic palaeogeographic and geodynamic evolution of southern South America is also given.

PALYNOLOGICAL ASSEMBLAGES

TRIASSIC-JURASSIC

From a palynological viewpoint, the uniformity of Jurassic and earliest Cretaceous floras appears to be more apparent than real (Batten, 1984).

Liassic microfloras are known from the southern and northern part of the Neuquén Basin. They show great differences from those of the Middle to Upper Triassic, of

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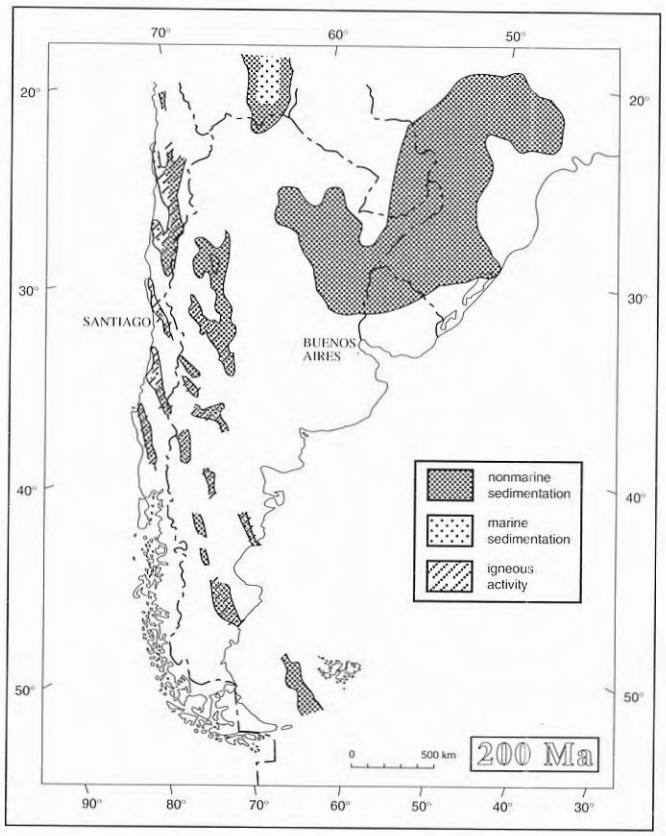

Figure 1. 200 Ma (mid-Late Triassic) palaeogeographic reconstruction (from Uliana and Biddle, 1988).

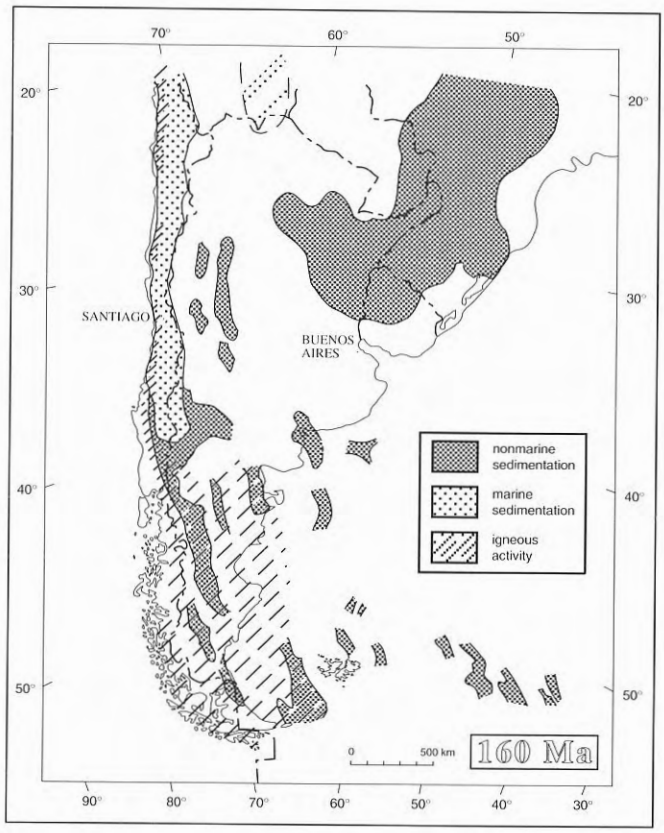

Figure 2. 160 Ma (Mid-Jurassic) palaeogeographic reconstruction illustrating Jurassic extension and volcanism (from Uliana and Biddle, 1988).

Ischigualasto Basin and Cuyana Basin (Herbst, 1965, 1970, 1972; Jain, 1968; Yrigoyen and Stover, 1969; Zavattieri, 1986, 1987) and other areas (Río Negro Province, Pöthe de Baldis, 1975; Ottone *et al.*, 1992; Mendoza Province, Volkheimer and Papú, 1993). Dolby and Balme (1976) suggested to include these Argentinian palynological assemblages into the Ipswich Flora, characterized by the abundance of bisaccate pollen (*Alisporites* and *Falcisporites*), monosulcate pollen (*Cycadopites*) with trilete spores (*Osmundacidites, Dictyophyllidites, Aratrisporites*, among others). The Ipswich flora of eastern Australia is Gondwanaland distributed.

The Mid-Late Triassic successions in westcentral Argentina are mostly non-marine. Middle-Late Triassic accumulations in central Chile, westcentral and southern Argentina were deposited within a complex system of rapidly subsiding and faultbounded troughs with NNWSSE orientation (Rolleri and Criado, 1968; Charrier, 1979; Criado, 1979; De Guisto *et al.*, 1980) (Fig. 1). The first record of fossiliferous marine (invertebrates) Triassic from Argentina is from Atuel River, Mendoza (Riccardi *et al.*, 1997).

Early Jurassic eustatic rise induced regional flooding (Cisternas, 1979; Chong and Hillebrandt, 1985) beyond the boundaries of the Triassic troughs and lead to the development of a linear marine belt fringing the continental slab in northern and central Chile (Cecioni, 1970; Riccardi, 1983). The Neuquén Basin is located at the southern end of the more extensive Chilean Basin. Although a Hettangian marine transgression is recorded at the Atuel River (Mendoza), it is not until the Pliensbachian that it reaches the central and southern Neuquén Basin (Fig. 2).

Most of the studied microfloras from Neuquén Basin came from ammonite bearing marine strata. All Jurassic and Cretaceous microfloras are characterized by the predominance of the genus *Classopollis* (Pflug) Pocock and Jansonius, a common feature with contemporary microfloras of other parts of the world (Volkheimer and Pöthe de Baldis, 1982).

Microfloral similarities indicate close gondwanic relations between Australia and South America, specially in the Liassic (Quattrocchio *et al.*, 1996). The Upper Sinemurian Lower Toarcian is characterized by the presence of *Classopollis classoides* (Pflug) Pocock and Jansonius, and the absence of the *Callialasporites* "complex". *Microcachryidites antarcticus* Cookson is registered since the Lower Bajocian. Significant increase in abundance of *Microcachryidites antarcticus* and a corresponding decline of the *Callialasporites* "complex" (*C. dampieri* (Balme) Dev, *C. trilobatus* (Balme) Dev, and *C. microvelatus* Schulz), were registered in the Tithonian. A similar situation was observed in the Tithonian of Australia (Helby *et al.*, 1987).

The Jurassic magmatic paroxysm was the immediate predecessor of a largescale Gondwanaland disaggregation

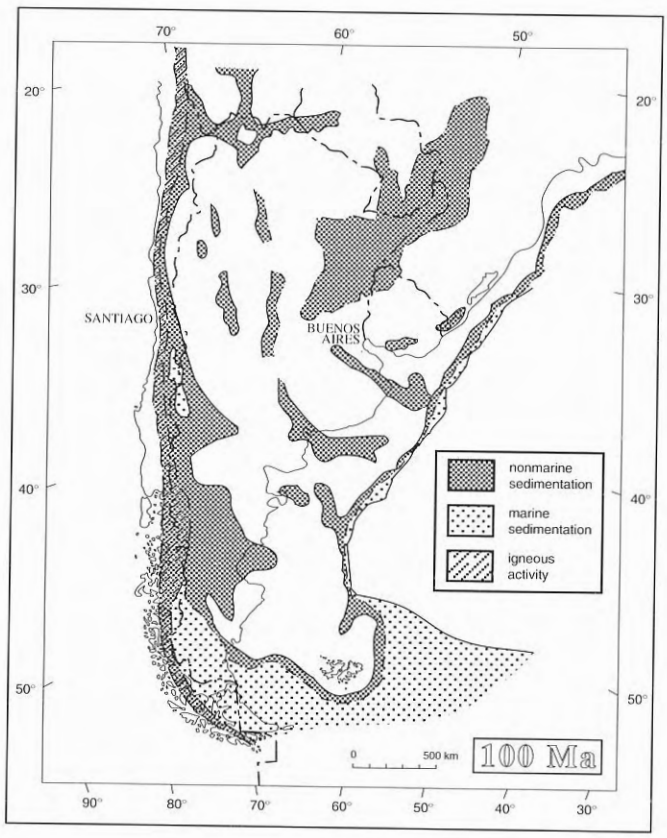

Figure 3. 100 Ma (Mid-Cretaceous) palaeogeographic reconstruction illustrating mid-Cretaceous adjustments in spreading regime, batholithic emplacement, and full opening of the South Atlantic (from Uliana and Biddle, 1988).

(Uliana and Biddle, 1988). Those basins close to the western margin of South America continued to accumulate marine deposits during the Neocomian. Large areas of the southern South American interior became depositional sites for non-marine clastic material.

The Late Jurassic to Neocomian sequence records active crustal stretching in areas along the present margins of the South Atlantic. By 130 Ma the first oceanic floor was formed in the South Atlantic (Rabinowitz and LaBrecque, 1979; Gerrard and Smith, 1982).

LATE JURASSIC-EARLY CRETACEOUS

Microfloras of Late Jurassic and Early Cretaceous age have been studied from the Neuquén Basin. The Tithonian-Berriasian microfloras are very similar and correspond to the **Equisetosporites-Trisaccites Assemblage** (Volkheimer and Pöthe de Baldis, 1982). For the HauterivianBarremian and parts of the Aptian a **Cyclusphaera psilata** subprovince is established within the Southern Gondwana province (Brenner, 1976). By the high percentages of *Classopollis* and the common presence of bisaccates, trisaccates and cosmopolite trilete spores like *Gleicheniidites, Trilobosporites, Densoisporites* and *Pilosisporites*, this palynofloristic subprovince differs from the tropical province of Northern Gondwana (Volkheimer, 1980).

In austral Patagonia (Santa Cruz Province) the Barremian-Aptian (Archangelsky and Gamerro, 1965, 1966a, b, c, and 1967) is characterized by *Cyclusphaera psilata* Volkheimer and Sepúlveda, elements in common with Australia (*Cicatricosisporites hughesii* Dettmann; *Alisporites grandis* (Cookson) Dettmann and *Podocarpidites ellipticus* Cookson) and species present also in non Gondwanic areas (*Sestrosporites pseudoalveolatus* (Couper) Dettmann, *Rouseisporites reticulatus* Pocock, and *Clavatipollenites hughesii* Couper). Archangelsky *et al.*, (1984) defined four palynozones for the Cretaceous of southern Argentina. These zones range from the late Berriasian or Valanginian to the early Aptian, with no apparent time break.

In San Luis Basin, the microfloras of Aptian to Pre-Albian age (Prámparo, 1989) are transitional between the Northern Gondwana and Southern Gondwana provinces. It presents a high percentage of plicate grains, low diversity and percentage of bisaccate pollen and spores of Pteridophyta, and various species of the genus *Afropollis*, characteristic of **Northern Gondwana Province**. It presents 30 % of *Classopollis* and angiosperms, but not as abundant as in the **Southern Gondwana Province**. It cannot be included into the Sub-Province of *Cyclusphaera psilata* because this species is not present.

The areal distribution of the mid-Cretaceous lithofacies reflects several major palaeogeographic modifications compared with previous time slices. By Albian time spreading across the Mid Atlantic Ridge system had produced a continuous band of oceanic crust between Africa and South America (Fig. 3).

The Neuquén Basin became dominated by evaporites and red beds (Digregorio and Uliana, 1980). The *Stephanocolpites-Huitrinipollenites* Assemblage is recognized for the Albian (Volkheimer and Salas, 1975). The first appearance of *Stephanocolpites mastandreai* Volkheimer and Salas, and *Huitrinipollenites transitorius* Volkheimer and Salas defined the lower limit.

LATE CRETACEOUS

Sedimentary accumulation during the Late Cretaceous was characterized by a trend towards enlargement of depositional sites and an increase in the amount of marine influence (Uliana and Biddle, 1988). The Late Cretaceous flooding of the Argentine margin during a period of tectonic quiescence, when the continental interior was devoid of large topographic barriers, produced a spectacular increase in the size of the areas under marine influence (*e.g.* Malumián *et al.*, 1983, Salfity *et al.*, 1985).

The palynological register in the south of South America and the western part of Antarctica is associated with *Nothofagidites* spp. in the **Nothofagidites Microfloral Province**. The oldest register of the genus *Nothofagidites* ("fusca" and "menziesi" types) are from Fortin General Roca locality, Río Negro Province, of

Middle Maastrichtian age (Romero, 1973, p. 301). *Grapnelispora evansi* Stover and Partridge characterizes the Upper Campanian-Maastrichtian in the Neuquén Basin (Allen and Jagüel formations, Palamarczuk and Gamerro, 1988) and including the Tertiary boundary in Antarctica (Macellari *et al.*, 1987) in López de Bertodano Formation, originally defined from Seymour Island (Vicecomodoro Marambio Island) was subsequently identified on James Ross, Vega, Humps, Cockburn and Snow islands (Rinaldi, 1982). Palamarczuk and Gamerro (1988) considered that *G. evansi* is associated with transitional to continental environments. In Neuquén Basin it is associated with fresh water algae: *Pediastrum* sp., *Botryococcus* sp. and massulae of *Azolla* (Palamarczuk and Gamerro, 1988). López de Bertodano Formation (Antarctica) reflects shallow marine shelf environments (Pirrie *et al.*, 1992). The genus *Grapnelispora* is not mentioned for Tierra del Fuego Island for this age (Menéndez and Caccavari de Filice, 1975), probably due to the marine character of the deposit.

Grapnelispora sp. 1 (Sepúlveda, *et al.*, 1989) is reported for the Late Cretaceous in Neuquén Basin, in the central valley of Chubut and in Río Negro Province (Papú, 1993). This genus is not mentioned for Coli Toro Formation (Río Negro Province) assigned to the Lower to Middle Maastrichtian (Bertels, 1969) and Campanian-Maastrichtian in its type locality and to the Paleocene in Puesto Arana locality (Pöthe de Baldis, 1984).

During the Late Cretaceous and Paleogene, a southern high latitude, cool temperate, biogeographic province extended from Patagonia in South America, across Antarctica (mainly Western Antarctica) to New Zealand and southeastern Australia. This Weddellian Province (Zinsmeister, 1979, 1982) includes shallow marine faunas, as well as the terrestrial biotas (Case, 1988, 1989; Askin, 1989) (from Baldoni and Askin, 1993). The Weddellian vegetation is characterized by podocarpaceous conifer-Proteaceae-*Nothofagus* forest (and specially *Lagarostrobus/Phyllocladidites mawsonii* pollen) which dominated the preserved floras during the Campanian through Paleocene and *Nothofagus* was more abundant in the Eocene (from Baldoni and Askin, 1993).

The lower portion of the Lefipán Formation at Barranca de los Perros, Chubut Province, is Maastrichtian in age, based on invertebrate faunas (Association I, Medina *et al.*, 1990) and palynofloras. The Lefipán flora is considered marginally Weddellian as it contains some endemic Weddellian Province species, but does not reflect the "typically Weddellian" forest vegetation. (from Baldoni and Askin, 1993).

PALEOCENE

Continental basin of NW Argentina (Salta Group Basin)

The continental Danian is registered in NW of Argentina, Salta Group Basin, Tunal Formation (Quattrocchio *et al.*, 1988). An Early Paleocene age is assigned considering the pollen assemblage: First appearance of *Mtchedlishvilia saltenia* Moroni (1984). An interval zone extends from the first appearance of *Mtchedlishvilia saltenia* to the first appearance of *Rousea patagonica* Archangelsky, 1973 (Mealla Formation) in Salta Group Basin (Quattrocchio *et al.*, in press). The presence of *Simpsonotus* (Mammalia, Henricosborniidae) in Mealla Formation and the absence of other Casamayoran mammals allowed the correlation between Mealla Formation with the Riochican Age of Patagonia, conventionally assigned to a Middle to Late Paleocene age (Pascual *et al.*, 1978).

The characteristic association present in Tunal Formation is: *Mtchedlishvilia saltenia* Moroni associated with *Verrustephanoporites* cf. *simplex* Leidelmeyer *Pandaniidites texus* Elsik, *Gemmatricolpites subsphaericus* Archangelsky and *Clavatricolpites* cf. *gracilis* González Guzmán.

In Tilian locality, Tunal Formation, both local and inland assemblages are recognized. The grabens and positive structural elements which governed the Salta Group sedimentation control the characteristic of the microfloristic assemblages. Due to the assignation of *Verrustephanoporites* cf. *simplex* to *Phyllostylon*, Ulmaceae (78-88.5%), Quattrocchio *et al.*, 1988, the paleoenvironment of Tunal Formation could be similar to the present Transitional Forest (350-500 m over sea level) in Yungas Province, Amazónico Dominion (Cabrera, 1976) where this tree is dominant.

The presence of Podocarpaceae (*Podocarpidites marwickii* Couper) and Anacardiaceae (*Retitricolporites* sp. A) and Rutaceae (*Rhoipites* sp. A) could indicate an association similar to the Montane Forest District, located in the upper part (1200-2500 m o.s.l.) of the Yungas Province. The interval between both mentioned districts is occupied by the Cloudy Forest District (550-1600 m o.s.l.). This district could be suggested in our register by the presence of Aquifoliaceae (*Gemmatricolpites subsphaericus* Archangelsky).

The climatic conditions of Yungas Province are humid and warm with principally summer rain. In consequence these could be the climatic conditions during Tunal Formation deposition. The presence of Haloragaceae (*Myriophyllumpollenites* spp.) and Chlorophyceae (*Pediastrum* sp.) reflect a lake environment for the Tunal Formation.

The Transitional Forest would be more impoverished in "Faja Gris" of Mealla Formation (Ulmaceae 10-29 %) with respect to that of Tunal Formation. Taking into account the palynological and sedimentological results, the analyzed profile would be located in the "calcareous pelite plain" sub-environment defined by Gómez Omil *et al.*, (1989) for the "Faja Gris". "Faja Gris" constitutes a rapid flood and further dessication in an extremely shallow basin (Gómez Omil *et al.*, 1989). The Mealla Formation was assigned to the Thanetian (Quattrocchio *et al.*, 1997), considering the tectonosedimentary study of Gómez Omil *et al.* (1989) along with the paleofloristic changes observed during the Paleocene in Salta Group Basin (Quattrocchio *et al.*, 1997).

A new palaeogeographic change could be suggested by the dominance of dry and higher montane communities (dominance of Rutaceae, *Rhoipites* sp. A) in the Maíz Gordo Formation with respect to the Mealla Formation (Faja Gris). The lithofacies (lithofacies 1 and 2 of Gómez Omil *et al.*, 1989) characterizes a shallow lake also corroborated by the palynological analysis: presence of Oenotheraceae (*Corsinipollenites menendezii* Quattrocchio) and *Pediastrum*, (Volkheimer *et al.*, 1984)).

Following Pascual *et al.*, (1981), Maíz Gordo has a Late Paleocene age (Riochiquense Mammal age), with *Corydoras revelatus* (Poeciliidae), *Podocnemis* (Pelomedusidae), Crocodylidae, Henricosbornidae, *Simpsonotus* (Notoungulata). The microflora from the upper part of the Maíz Gordo Formation contains species restricted to the Paleocene with Eocene forms (Quattrocchio and Volkheimer, 1990).

Marine basins

The Danian transgression is characterized by foraminiferal Midway type assemblages, in Septentrional Patagonia (Colorado and Neuquén basins) by rotaliids, buliminids in San Jorge Gulf and nodosarids in Austral Basin (Malumián and Caramés, 1993).

Pöthe de Baldis (1984), taking into account the palaeomicroplankton assemblages, postulated that the Paleocene sea would be homogeneous in northern Patagonia and different from the southern register (Salamanca Formation) of Santa Cruz and Chubut provinces in the Atlantic area of Australian affinity. Those differences would have a paleoenvironment or paleoclimate controls (Quattrocchio and Sarjeant, 1996).

The palynologically fertile levels In Colorado Basin correspond to the Danian Zone P1b (*Morozovella pseudobulloides*) of foraminifers and WP3 (Martini, 1971) of calcareous nannoplankton.

The section studied is Lower Paleocene. It corresponds to the Subzone *Cerodinium diebeli-Palaeoperidinium pyrophorum* (Quattrocchio and Sarjeant, 1996) in the Palynozone D of Gamerro and Archangelsky (1981) and may be correlated with the "Worldwide Dinoflagellate Zone" of *Ceratiopsis diebeli-Palaeoperidinium pyrophorum* (Williams, 1977) and the offshore eastern Canada dinoflagellate zone of *Palaeoperidinium pyrophorum* (Williams, 1975; Williams and Bujak, 1977).

Among the terrestrial species, *Classopollis classoides* (Pflug) Pocock and Jansonius, dominates the spectrum (up to 80% calculated over the sum spores + pollen), with *Verrustephanoporites simplex* Leidelmeyer (19.4 %). The floral assemblage is also characterized by the abundance and diversity of angiosperm pollen. And the relatively high diversity of pteridophyte spores as well as bisaccate pollen of podocarpaceous affinity. Among the pteridophytes, the spores of gleicheniaceous and cyatheaceous affinity are particularly diverse.

The paleoenvironment conditions would be similar for those inferred for the NW of Argentina for the Danian, with a forest of Ulmaceae (*Verrustephanoporites simplex*) near the site of deposition of Pedro Luro Formation and the presence of elements of the cloudy forest (Myrtaceae, Olacaceae and Palmae) and montane forest (Podocarpaceae, Rutaceae, Anacardiaceae and Haloragaceae). A palustrine environment is suggested due the presence of *Mtchedlishvilia saltenia* Moroni (1984).

The composition of the Pedro Luro Formation assemblages indicates warm palaeotemperatures (subtropical-tropical) specially due to the presence of Ulmaceae, Anacardiaceae, Aquifoliaceae, Olacaceae, Bombacaceae, Palmae, Restionaceae, etc. With the presence of temperate (Gunneraceae, Hamamelidaceae) to cool (Proteaceae, Fagaceae) elements (Quattrocchio and Ruiz, in press).

The marine assemblage indicates that the Pedro Luro Formation in the studied section was deposited under relatively warm open marine conditions (Quattrocchio and Sarjeant, 1996).

The Upper Paleocene has not been registered in the basin.

In Patagonia during the Paleocene (Danian, Salamanca and Bororó formations) there was a general retraction of the genus *Nothofagidites* and increase during the Late Paleocene (Thanetian, Rio Chico Formation) and a great expansion during the Eocene (Rio Turbio Formation). Probably due to the creation of new habitats related with the first movements that lifted the Andes Ridge (from Romero, 1973) .

In Patagonia the first testimonies of the Atlantic Marine ingression correspond to the Salamanca Formation (Archangelsky, 1973). Pedro Luro and Salamanca formations are correlated based on the similarity of their microfloristic association (Ruiz and Quattrocchio, 1996). In those basins the first appearance of *Rousea patagonica* Archangelsky is registered. The characteristic association includes: *Syndemicolpites petriellai* Archangelsky, *Rhoipites baculatus* Arch., *Rhoipites minusculus* Arch., *Restioniidites pascualii* Arch., *Polyporina romeroi* Arch., *Ulmoideipites patagonicus* Arch. (= *Verrustephanoporites simplex*) and others.

The Paleocene vegetation in SE Chubut was composed of several communities: mangrove, swamp woodland, tropical rain forest, mossy forest, *"Araucaria"* woodland and sclerophilous forest (or savanna). The dominant climate has been "Cfa" type (subtropical humid) of Köppen classification (from Petriella and Archangelsky, 1975).

Classopollis is present in Paleocene levels in Patagonia (up to 50 %). This genus is not found in the register of the Upper Paleocene and upwards. Then, the extinction of the Cheirolepidiaceae family occurred during the Paleocene. It is difficult to explain the absence of the genus in sediments of the Upper Cretaceous in Patagonia, considering that it is one of the dominant elements in the palaeofloristic assemblages of the Lower Cretaceous. Possibly, the ecologic conditions produced the temporal retraction of the Cheirolepidiaceae to the montane areas with more dryness. This type of

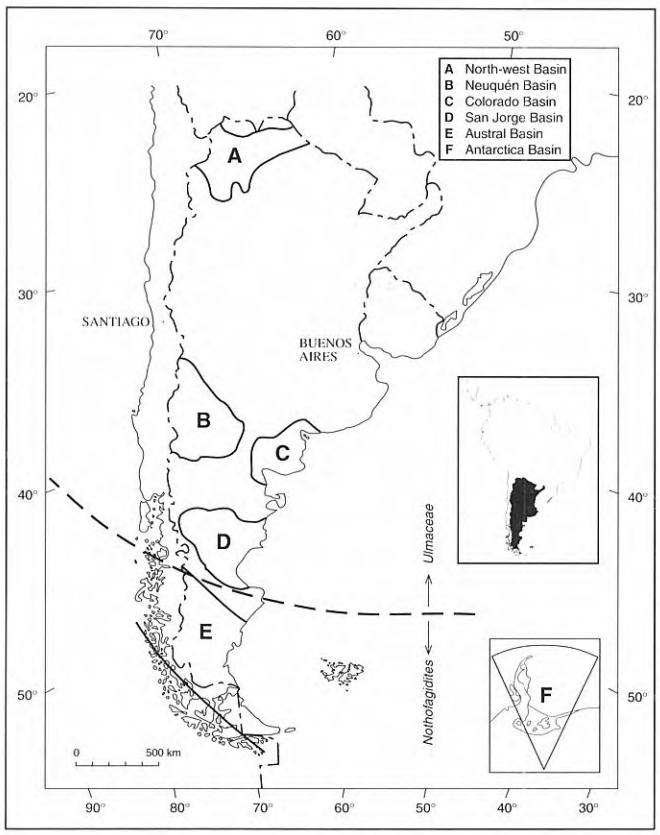

Figure 4. Proposed Danian palaeophytogeoprovinces for Argentina.

environment is registered in the Lower Paleocene in San Jorge Gulf. This environmental situation made possible the development of the last representatives of the family which extinguished later with the climate change (from Archangelsky and Romero, 1974).

On the other hand, *Classopollis* was recently discovered in the NW Argentine Basin, in the Maíz Gordo Formation, Salta Group (Thanetian, Upper Paleocene). It is a north migration in Argentine of this genus (Quattrocchio and Del Papa, inédit.; Petrulevicius, 1996).

Antarctica: Vicecomodoro Marambio (Seymour) Island

In López de Bertodano Formation (Maastrichtian including the Cretaceous/Tertiary boundary (Macellari *et al.*, 1987) marine paleomicroplankton is dominant, but *Nothofagidites* spp. (mainly "brassi" type), podocarpaceous species (*Podocarpidites, Microcachryidites, Phyllocladidites* and *Dacrydiumites*) some proteaceous pollen and pteridophyte spores (*Perotrilites, Lycopodiumsporites, Baculatisporites* and *Azolla*) are present. The dominant palynomorphs in the lower part of the Sobral Formation (Paleocene) are dinoflagellates, accompanied by a poor assemblage composed of *Nothofagidites* sp. proteaceous pollen and pteridophyte spores (Baldoni and Barreda, 1986). Due to the presence of Fagaceae the paleoenvironmental conditions would be temperate and humid during the Upper Cretaceous-Paleocene in this section of the Vicecomodoro Marambio Island (Baldoni and Barreda, 1986) .

The terrestrial plants do not present great changes in the Cretaceous/ Paleogene transition in contrast to the planktonic organisms (planktonic foraminifers) and ammonites which were drastically affected by the Mesozoic finally events (Macellari *et al.*, 1987).

Proposed palaeophytogeoprovinces

The delineation of past floral provinces for the Danian has been made taking into account qualitative and quantitative palynological data. Each characteristic assemblage reflects vegetation types and differences in climate.

Two major palaeophytogeoprovinces could be recognized during the Danian in Argentina: the presence of Ulmaceae pollen in the north (North-west Basin, Colorado Basin and San Jorge Basin) associated mostly with tropical and subtropical families and *Nothofagidites* pollen in the south (southern Patagonia, and Antarctica), mostly associated with temperate families. (A few specimens of *Nothofagidites* (1%) are found in the north Colorado Basin.) Fig. 4.

It could be distinguished a subprovince in the palaeophytogeoprovince of Ulmaceae, with "triprojectate" pollen (*Mtchedlishvilia*): Northwest Basin and Colorado Basin.

The climatic conditions would be warm and humid in the Ulmaceae Palaeophytogeoprovince and more temperate in the Southern Palaeophytogeoprovince of *Nothofagidites*.

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