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Evolution of the Austral-Antarctic flora during the Cretaceous: New insights from a paleobiogeographic perspective

Evolución de la flora austral-antártica durante el Cretácico: Una nueva mirada desde una perspectiva paleobiogeográfica

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ABSTRACT

Forest environments have continuously existed in Antarctica since the late Paleozoic and only disappeared from this continent since the Neogene. Nevertheless, the structure of these forests underwent substantial evolutionary changes. During the late Cretaceous, forests dominated by conifers and pteridophytes were gradually replaced by angiosperm-dominated forests. Elements common to these Antarctic forests are important constituents of the recent Valdivian Forest. During the Turonian stage of the Late Cretaceous, the Antarctic Peninsula and Patagonia were reconnected by a land bridge after a separation since the end of the Jurassic. Using biogeographic tools applied to the palynological and leaf imprint record, outcrops of Campanian-Maastrichtian age were studied from the Snow Hill, James Ross and Seymour (Marambio) Islands in the James Ross basin, Antarctica; Skua Bay, Half Three Point, Price Point and Zamek Hill on King George Island, Antarctica, and Rocallosa Point, Cerro Guido, Las Chinas, Dorotea Hill, Cazador Hill and La Irene in Chilean-Argentinian Patagonia, comparing the current distribution and the paleogeography, as well as the influence of potential areas of endemism and vicariants events. The analysis indicates that vegetation evolved under environmental conditions subject to intense volcanic and climatic disturbances, with changes from a period with extreme greenhouse climate (Turonian-Campanian) to strong cooling during the Maastrichtian. We suggest that a continuous forest existed in southern South America and Antarctica, which was shaped during the Latest Cretaceous by the presence of marine basins and and intermittent connection and disconnection of the flora.

Key words: Antarctica, Cretaceous, Magellan's basin, paleobotany, Patagonia.

RESUMEN

Se sabe que al menos desde fines del Paleozoico ambientes boscosos habrían existido en la Antártica y habrían desaparecido de ella solo a fines del Terciario. Sin embargo, la estructura no ha sido la misma, evolucionando desde un bosque dominado por coníferas y pteridófitas durante el Cretácico Inferior, a bosques dominados por angiospermas a partir del Cretácico Superior, con elementos comunes a los constituyentes actuales de la Selva Valdiviana. Durante el Turoniano la Península Antártica y Patagonia se reunieron por un puente terrestre rompiendo millones de años de desconexión, y gracias a una variedad de ambientes de sedimentación, se han conservado numerosos vestigios de la flora que cubrió ambos subcontientes. Mediante herramientas biogeográficas aplicadas al registro palinológico y de improntas foliares, afloramientos campaniano-maastrichtianos de islas Snow Hill, James Ross y Seymour (Marambio), en la cuenca de James Ross, Antártica; bahía Skúa, punta Half Three, punta Price y cerro Zamek, en la isla Rey Jorge, Antártica; y punta Rocallosa, cerro Guido, Las Chinas, cerro Dorotea, cerro Cazador y La Irene en la Patagonia chileno-argentina, se estudió la relación entre la distribución actual y la paleogeografía, considerandolos potenciales eventos vicariantes y áreas de endemismo establecidas. Reconstrucciones paleoecológicas muestran que los elencos vegetacionales habrían evolucionado en el marco de ambientes sometidos a intensa perturbación volcánica y climáticamente habrían estado sometidos a uno de los lapsos más cálidos de la historia natural, pero con fuertes pulsos de enfriamiento durante el Campaniano y Maastrichtiano. Se sostiene que entre el Maastrichtiano y el Eoceno, existió un continuo forestal entre Patagonia y Sudamérica que habría sido modelado por la presencia de las cuencas marinas finicretácicas y la intermitente conexión-desconexión de las floras.

Palabras clave: Antártica, Cretácico, cuenca de Magallanes, paleobotánica, Patagonia.

INTRODUCTION

Forest ecosystems have existed in Antarctica since the Late Paleozoic (Axelrod 1984, Hunt & Poole 2003, Taylor et al. 1992) evolving mainly in conditions warmer than the present, until the Neogene (Cantrill 2001, Francis & Poole 2002), when a sharp drop in temperature occurred at the Oligo-Miocene boundary. The structure of vegetation, however, underwent considerable changes, from forests dominated by conifers and pteridophytes during the Early Cretaceous (Falcon-Lang et al. 2001) to forests dominated by angiosperms, similar to Valdivian forests of southern Chile. These last conditions gradually established during the Late Cretaceous, after the massive radiation of angiosperms throughout Gondwana. Common elements of these Upper Cretaceous floras of Antarctica are now well represented in different types of modern Chilean forests (Dutra & Batten 2000, Poole et al. 2001, Cantrill & Poole 2002, Leppe et al. 2007). Deposits of Late Cretaceous and Paleogene age are well recorded from the James Ross Basin and the Fildes Peninsula Group, King George Island, as well as from the Magallanes basin in southern Patagonia (Cantrill 1997, 2000, Torres et al. 1997, Césari et al. 1999). Paleoecological reconstructions indicate that floristic casts have evolved in the context of environments under intense volcanic disturbance (Poole et al. 2001). Climatically, the Late Cretaceous was one of the warmest periods of the Phanerozoic, with warm pulses during the Turonian and cold events during the Maastrichtian (Huber 1998). Low temperatures near to the end of the Cretaceous were again followed by an increase in temperature, or climatic optimum, during the Paleocene and Eocene (Upchurch et al. 1998).

A terrestrial connection during the Campanian-Maastrichtian between South America and Antarctica is crucial to understand the establishment of a new structure in the austral vegetation. Upper Jurassic-Lower Cretaceous taxa evolved isolated in both Antarctic and Patagonian communities until the reestablishment of a terrestrial bridge between both landmasses during the Turonian (Pankhurst & Smellie 1983, Smellie et al. 1984). During the Campanian-Maastrichtian this connection led to a new mixed Antarctic-Patagonian biota predecessor of modern southern South American temperate forests. Recently, new arguments have extended the discussion about the origins and persistence of these southern temperate biota, particularly of the Valdivian forest, a broadleaf and mixed forest ecoregion on the west coast of southern South America, mostly in Chile and western Argentina (Poole et al 2003, Povilauskas et al. 2008). Several authors have pointed out that the Valdivian forest is the closest equivalent to Upper Cretaceous-Paleogene forests from Antarctica (Axelrod 1984, Francis & Poole 2002, Cantrill 2001, Poole et al. 2003), but this hypothesis was based only on a few taxa or localities. During the past 10 years, however, enormous volumes of multidisciplinary data were published on paleomagnetism, sedimentary provenance, paleobiogeography, molecular phylogeny and paleoecology, among many other disciplines. These datasets offer alternative or complimentary explanations to the complex relationship between the geological and biological evolution of the Antarctic-Patagonian region, from which integrated studies have been scarce.

Geological setting

Movements of two major plates of the former Gondwana continent, South America and Antarctica, control the modern tectonic scenario in the region. These are in turn linked to four minor plates: Scotia, Drake, South Sandwich and South Shetland (Augusto et al. 2007). The Late Cretaceous was the time when the final breakup of Gondwana occurred and led to the isolation of Antarctica. Paleontological data indicate that the Antarctic Peninsula was adjacent to southern South America during almost all of the Mesozoic, allowing for an active migration and exchange of terrestrial faunal and floral assemblages. This interchange between South America and the Antarctic Peninsula ceased during the Paleogene when a shallow seaway developed, but the final continent separation did not occur until the early Neogene with the development of deep sea conditions in the Drake passage (Zinsmeister 1987).

The Austral Basin is located in southern South Patagonia and is composed of three sub-basins (Suarez et al. 2009). The Rocas Verdes Basin was active during the Late Jurassic and Early Cretaceous and was formed by an extensional tectonic regime associated with the separation of southern Gondwana (Dalziel & Cortés 1972, Suarez 1979, Dalziel 1981). The closure of the Rocas Verdes Basin during the mid-Cretaceous was accompanied by the collision of the Cape Horn Microplate with South America (Dalziel 1981). This is the moment when deposition started in the Magallanes Basin (Suarez et al. 2009). The Magallanes Basin was initially filled with turbiditic siliciclastic sediment (Natland et al. 1974, Fildani et al. 2007, Pardo et al. 2012), with the proto-Andes as the main source of sediment infill (Fildani et al. 2007). The Upper Cretaceous sediment sequence of the Magellanes basin the Última Esperanza Province reflects gradual shallowing towards slope and subsequently to shallow marine environments prograding to the south. Deltaic environments first occured in the Lago Argentino area. An example of the massive retrogradational marine deposits in the Magallanes Basin is exposed in the Tres Pasos Formation, Ultima Esperanza Province, equivalent to Rosa and Fuentes Formations in the Seno Skyring and Brunswick Peninsula area (Fig. 1). In this region deep marine environments were gradually replaced by

shallow marine and finally alluvial fan deposits known as Dorotea Formation, in Chile, or Cerro Cazador Formation in Argentina (Macellari et al. 1989, Malumián & Caramés 1997). These formations were assigned to the Upper Campanian-Maastrichtian based on ammonite occurrences (Macellari 1988, Macellari et al. 1989, Malumián & Caramés 1997). The top of the sediment sequence is still known as Cerro Dorotea Formation in Chile, while coeval sediments on the Argentinian side adjacent to the northern border of the Última Esperanza Province are known as the La Irene Formation. This latter unit corresponds to sandstone and conglomerate deposited in a meandering river environment. The Calafate Formation unconformably overlies the La Irene Formation (Macellari et al. 1989) and is now also considered to be Maastrichtian in age (Marenssi et al. 2004). This unit represents alluvial to estuarine deposits and is equivalent to the top of the sediment sequence known from Cerro Guido and Las Chinas in the Última Esperanza Province.

The Antarctic Peninsula allocates the remnants of a continental margin to the southeast and of a magmatic arc of Meso-Cenozoic age to the northwest, the latter resulting from the subduction of oceanic plate

Locality	м	AGALLA	ANES BA	SIN, PATAGONI	4	ANTARCTIC PENINSULA									
Locality	Argentin	ia		Chile		King Geo	rge Island	Γ							
Age	Lago Argentino	Ult Espe	Ultima speranza Skyring Bay Of Fildes Peninsula Magellan Admiralty E		Admiralty Bay		James Ross Island	Seymour Island	Snow Hill Island						
Maastrichtian	Calafate Fm. Chorrillo Fm.	Cerro Dorotea Em. Cerro	Dorotea		Río Blanco Fm.	Jasper Hill	Zamek Fm.		Lopez de Bertodano	Lopez de Bertodano Fm.	Lopez de Bertodano Fm.				
70,6 m.a	La Irene Fm. Cerro Fortaleza Fm.	Cazador Fm.	Fm.	Fuentes	Santa Ana Fm.	Half Three Point Fm.	Llano Point Fm.	nbio Gp.	Snow Hill Island Fm.	Snow Hill Island Fm.	Snow Hill Island Fm.				
Campanian	Alta Vista Fm.	Tres Pa	isos Fm.	Rosa Fm.	Rosa Fm.			Marar			777				
Santonian	Cerro Toro Fm.	Cerro T	oro Fm.	Barcarcel Fm.	Barcarcel Fm.				Santa Marta Fm.	Santa Marta Fm.					
85.8 m.a									Hidden Lake Fm.	(11					

References	MACELLARI,1988, MACERALLI et al 1989, MALUMIAN et al 1996	MACELLARI,1988	BIRKENMAJER & ZASTAWNIAK 1989, BIRKENMAJER, 2001	HATHWAY, 2000	ELLIOT 1998, CRAME <i>et al</i> , 199, RIDING & CRAME 2002	PIRRIE et al, 1996
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Fig. 1: Correlation of the main Upper Cretaceous Formations of the Magallanes Basin, considering both Argentinian and Chilean nomenclature, and James Ross Basin and King George Island of the Antarctic Peninsula. Macellari 1988, Macellari et al. 1989, Malumián et al. 1997, Birkenmajer & Zastawniak 1989, Birkenmajer 2001, Hathway 2000, Elliot 1988, Crame et al. 1991, Riding & Crame 2002 and Pirrie et al. 1997.

Correlación de las principales formaciones del Cretácico superior de la Cuenca de Magallanes (considerando la nomenclatura chilena y argentina) y la Península Antártica (considerando la cuenca de James Ross y la isla Rey Jorge). Macellari 1988, Macellari et al. 1989, Malumián et al. 1997, Birkenmajer & Zastawniak 1989, Birkenmajer 2001, Hathway 2000, Elliot 1988, Crame et al. 1991, Riding & Crame 2002 and Pirrie et al. 1997.

also known from Price Point, presenting a dominance of angiosperms, and from Skua Bay where the megaflora, though poorly preserved. is dominated by ferns. The Skua Bay flora may be slightly younger than assemblages identified in other Upper Cretaceous localities on King George Island, and they are markedly different to assemblages of the Zamek Hill Formation at Admiralty Bay, which is exceedingly rich in Nothofagus (Dutra & Batten 2000). In contrast, the James Ross Basin in the northeastern part of the Antarctic peninsula (Figs. 1-2) developed in a back-arc location in response to the south-eastward-directed subduction of proto-Pacific oceanic lithosphere beneath the Antarctic Peninsula magmatic arc (Pirrie et al. 1997). The basin fill constitutes a regressive megasequence (Nelson 1975, Ineson et al. 1986, Crame et al. 1991). For instance, the Aptian-Turonian of the basin is characterized by submarine fan deposits, whereas the Snow Hill Island Formation of late Campanian-early Maastrichtian age reflects a shallow shelf environment based on mollusc assemblages including the ammonite Gunnarites antarcticus. The Snow Hill Island Formation unconformably underlies the Maastrichtian López de





Reconstrucción de la Cuenca Austral modificada de Lawver et al. (2009). La conexión durante el Campaniano y Maastrichtiano se muestra como un istmo entre la península Antártica y Patagonia.



Fig. 2: Geographical location of sections studied here. Top: Antarctic localities; Below: Patagonian localities. Riccardi & Rolleri 1980, Russo et al. 1980, Náñez & Malumian 2008.

La posición geográfica de las localidades estudiadas. Arriba: localidades antárticas; Abajo: localidades patagónicas. Riccardi & Rolleri 1980, Russo et al. 1980, Náñez & Malumian 2008 2011.

beneath the Paleopacific margin (Fig. 2). The magmatic arc, as well as accretional complexes reflecting forearc and back-arc conditions, preserves a variety of paleoenvironments, many of which contain fossil plants (Poole & Cantrill 2006). Plant-bearing units include the Half Three Point Formation (Shen 1994) of Late Campanian or Campanian-Maastrichtian age (Cao 1992), a lacustrine deposit reflecting a subtropical humid climatic interval (Shen 1994). Campanian-Maastrichtian plants are



Fig. 4: Most parsimonious tree generated by PAE of taxa from Patagonia and the Antarctic Peninsula during the Campanian-Maastrichtian. (L: 292, CI: 51, RI: 54). Black dots represent synapomorphy and white dots homoplasy.

Árbol más parsimonioso generado por el PAE para taxa de Patagonia y la Península Antártica durante el lapso Campaniano Maastrichtiano. (L: 292, CI: 51, RI: 54). Puntos negros representan sinapomorfías y los blancos homoplasia.

Bertodano Formation, which is restricted to the northern tip of Snow Hill Island, to Seymour Island, and to a small exposure on Vega Island (Pirrie et al. 1997). This sequence thus represents one of the most complete Upper Cretaceous sections in the Southern hemisphere, with a wide record of paleoenvironments and diverse biota.

Here we suggest that biogeographic bridges connected Patagonia and the Antarctic Peninsula during the last interval of the Late Cretaceous (Fig. 2), generating one or more ancestral biota. The geographic continuity of Patagonia and the Antarctic Peninsula, currently disjointed by the Drake Passage, may partly explain the vicariant pattern and areas of endemism, but weather patterns differing between the western and eastern side of the isthmus may also have played in important role.

METHODS

The biogeographic analysis presented here is based on fossil plant associations from Antarctic localities at Snow Hill Island, James Ross Island, Seymour (Marambio) Island, Skua Bay (King George Island), Half Three Point (King George Island), Price Point (King George Island) and Zamek Hill (King George Island), as well as from Patagonian localities at Rocallosa Point (Riesco Island), Guido Hill, Las Chinas, Dorotea Hill in Chile, and and Cazador Hill and La Irene in Argentina (Fig. 2). Las Chinas is a new locality not documented before. Six localities were studied during field campaigns from 2008 to 2011 (Las Chinas, Cerro Guido, Half Three Point, Skua Bay, Price Point and Cerro Dorotea). Distributional data of fossils and localities were obtained from the review of published articles, books and field campaigns (See Appendix). With this information at hand, a georeferenced record database was performed. A geographic distribution map of each taxon was obtained using ArcView GIS 3.2. Altogether, 4044 records were used. A total of 364 taxa were registered, 71 of which correspond to leaf imprints and 293 to palynomorphs.













Fig. 5: Diagram of consensus areas (1-28) obtained by AE. The grid in each locality represents an area of 0.25° x 0.25° . The diagram shows localities considered here and areas obtained by PAE relationship, black points correspond to localities and gray dots represent the area considered in the consensus.

Diagrama de Áreas de consenso (1-28) obtenido por AE. La grilla en cada localidad representa un área de 0.25° x 0.25°. El esquema final muestra las localidades consideradas aquí y relación de áreas obtenidas por PAE, los puntos negros corresponden a la coordenada de la localidad considerada y los grises representan el área considerada en el consenso.

Biogeographical analysis

The floral diversity and relationships among each locality were analysed using the Parsimony Analysis of Endemicity (PAE) and the Analysis of Endemicity (AE). PAE comprises locations, optimizing the correlation between distributional patterns of taxa, using shared taxa among areas according to the most parsimonious solution (Morrone 1994, Posadas 1996). Rosen (1988) coded the presence or absence of taxa in an area as (1) or (0), respectively. This method is followed here. Our dataset includes 364 taxa of 13 areas (12 localities + 1 hypothetical area to root the tree) (Appendix). Data were analyzed with NONA 2.0 (Goloboff 1993) and WinClada (Nixon 1999) using a heuristic search (multiple TBR + TBR). The software was allowed to retain a maximum of 10000 trees with 100 replicates of random addition sequence and an initial 100 trees in each replication. Only informative characters were considered. If two or more resulting cladograms were equally parsimonious, a strict consensus cladogram was generated. The areas

of endemism identified and the possible relationships between the localities analyzed by PAE were compared with the result of AE. The AE was realized by the method of Szumik et al. (2002) and Szumik & Goloboff (2004). Basically, the method evaluates the consistency of the distribution range of species to a predefined area. The optimality criterion was implemented in NDM/VNDM programs (Goloboff 2005), using default parameters: sets of areas were saved with two or more endemic species (score >2), while sets of <0.90 worst fit were excluded. Optimal sets were chosen when the number of different endemic species was >40 %. Search for endemism was conducted using different proportions of radius size. The best score for endemicity areas was used (fill: X = 90, Y = 90; to assume X = 50, Y = 50). Consensus areas were obtained using 30 % of similarity in species, compared to other areas in the consensus. A flexible consensus is used when at least 50 % of endemic species are in common.

TABLE 1

Areas of consensus for the analysis of flora obtained using, grids of 0.25° x 0.25°. For each area the following parameters are indicated: AI, including individual areas and endemic taxa present.

Áreas de consenso para el análisis de flora obtenidas usando grillas de 0.25° x 0.25°. Para cada área se indica: AI, áreas individuales incluidas y los taxa endémicos presentes.

AC	AI	N° Taxa
0	0	0, 5, 6, 8, 16, 30, 31, 32, 33, 34, 39, 41, 55, 66, 69, 76, 87, 92, 93, 94, 95, 99, 100, 101, 104, 105, 116, 117, 118, 125, 127, 135, 137, 138, 139, 142, 144, 145, 146, 153, 154, 158, 159, 162, 167, 168, 169, 207, 208, 240, 257, 260, 261, 262, 263, 264, 265, 266, 272, 282, 295, 316, 318, 337, 349, 361
1	1	2, 10, 119, 126, 218, 281
2	2	3, 4, 27, 35, 36, 42, 43, 45, 52, 53, 58, 59, 65, 74, 76, 81, 85, 90, 91, 112, 114, 120, 124, 128, 132, 136, 149, 150, 155, 157, 164, 165, 174, 179, 180, 181, 184, 189, 192, 196, 210, 213, 219, 239, 242, 244, 249, 251, 252, 275, 280, 284, 285, 288, 289, 290, 298, 300, 309, 310, 311, 321, 329, 330, 341, 359, 363
3	3	7, 24, 37, 64, 83, 107, 109, 121, 122, 131, 204, 276, 294, 334, 340, 345, 348, 355
4	4, 25, 26	9, 22, 23, 29, 62, 63, 82, 152, 278, 320, 333, 360
5	5	11, 13, 102, 108, 166, 194, 201, 222, 233, 235, 236, 237, 243, 248, 315
6	6	12, 56, 57, 357
7	7	1, 17, 19, 38, 47, 48, 49, 51, 67, 111, 115, 143, 151, 171, 175, 176, 177, 193, 199, 211, 215, 216, 259, 269, 273, 291, 292, 322, 323, 324, 331, 335
8	8	26, 88, 134, 173, 186, 228, 275, 283, 305, 339, 352
9	9	28, 89, 96, 178, 190, 195, 198, 209, 221, 224, 225, 226, 231, 277, 312, 313, 354
10	10	21, 70, 187, 307, 351
11	11	86, 214, 286
12	12, 15	97, 98, 205, 206, 220, 325

AC	AI	N° Taxa
13	13	111, 113, 129, 130, 147, 188, 238, 297, 302, 306, 314, 318
14	14	156, 165, 241
15	16	253, 303, 308
16	17	44, 46, 79, 197, 299
17	18	202, 245, 246, 293
18	19, 20, 21	103, 223, 227, 232, 254
19	22	14, 327, 358
20	23	15, 160, 161
21	24, 27	20, 78, 171, 185, 203, 256, 271

RESULTS

Both the PAE and AE showed results consistent among them (Figs. 4 and 5, Table 1). The heuristic search results in a single most parsimonious tree (Length [L] 292, Consistency Index [CI] 51 and Retention Index [RI] 54; [Fig. 4]). The cladogram is divided in two main branches: one cluster grouping to Patagonia and King George Island localities in one branch, and Patagonian and James Ross Basin localities in the second. Some elements are exclusive for the Las Chinas and Cerro Guido outcrops, among them S. sehuensis, Cinnamonum, Taeniopteris, Menispermites, P. innopinatus and other Laurophyllum taxa. This is an expected result because of the geographical proximity and stratigraphic affinities between both regions. The clade IB clustered all King George Island localities which share six synapomorphic species of the following genera: Dicotylophyllum, Monimiophyllum, Phyllites and Sterculia. A conspicuous difference exists between the two main branches of Clade I: Clade IA includes the Patagonian localities Las Chinas and Cerro Guido, and Clade IB contains the King George Island outcrops. This latter (Clade IB) contains several taxa related to Nothofagaceae, among them leaves of Nothofagus cretense and pollen of Nothofagidites. Nothofagaceae are absent in Clade IA. The AE analysis generated 33 endemicity areas (Fig. 5, Table 1). The consensus of these areas provided 29 ACs (Fig. 5, Table 1, Appendix). The links between Antarctic and Patagonian localities are supported by several EA (AC 6 to 12, 14, 17, 19, 20, 21, 24 to 29, Fig. 5), even though nearby localities such as the Cerro Guido-Las Chinas complex and Dorotea-La Irene, show important differences in their fossil plant composition. The discovery of EAs for the Antarctic Peninsula and Patagonia (AC 0, 10 in Patagonia; 1 to 5, 11, 13, 15, 16, 18, 22, 23 in Antarctica; Fig. 5) is also important to note, because it represents a probable heritage of the vicariant event previous to the Campanian-Maastrichtian.

DISCUSSION

A land bridge between Patagonia and the Antarctic Peninsula is considered to be crucial for the genetic flux between the two continents of terrestrial plants It is known that CO_2 reached maximum levels during the early Late Cretaceous and that the region was exposed to westerly winds (Elliot 1988, Del Valle et al. 1992, Hathway 2000). A mountainous terrain is suggested from the proximity to the island arc and may have led to orographic rainfall, moderating temperature extremes and distributing precipitation throughout the year. These were appropriate conditions for the rapid establishment and expansion of a Valdivian type forest. Climatic conditions changed in the Early Campanian and again in the Late Maastrichtian due to the continuous subduction and aggregation of land on the western side of the Antarctic Peninsula (South Shetlands), in addition to a decrease in the global atmospheric levels of CO₂. These changing environmental conditions could explain the ring-growth pattern in fossil wood from the western part of the isthmus (Francis 1991). On the eastern side, the James Ross Basin was more protected and the changes were less accentuated. The first records of *Nothofagidites* in Patagonia and Oceania are from the Maastrichtian (Menéndez & Caccavari de Filici 1975, Romero 1978, Mcloughlin 2001), endorsing the idea of a terrestrial continuity of South America, Antarctica and Australia-New Zealand with a common biogeographic province (Case 1988).

Nothofagaceae are known to occur on the Antarctic Peninsula since the Campanian (Zastawniak & Szafer 1990, Francis 1991, Dutra 1997, Dutra & Batten 2000, Dutra 2001, Dutra 2005). The group successfully infiltrated gymnosperm-dominated forest ecosystems, with some opportunistic species of Nothofagus competing for openings in the canopy. This strategy, commonly known as "gap dynamics" (Veblen et al. 1983, Hill 1992, 1994, Veblen et al. 1996), is currently observed in modern Valdivian forests, especially in Andean forests with repeated volcanic disturbance. Species supporting Clades I and II in the present analysis may be related to this strategy, using special microclimatic conditions. From an ecological perspective, both share typical elements of the Valdivian Forests: a canopy dominated by angiosperms and subordinate presence of gymnosperms, and an understory mainly composed of Myrtaceae, Liliaceaea, and Sapotaceae, and ferns such as Blechnaceae and Dicksoniaceae. The sites located in the Tethyan margin, exposed to southern oceanic conditions, are clustered in Clade I and are dominated by angiosperms with subordinated elements of gymnosperms, shrubby ferns and angiosperms. This vegetation significantly differs from the eastern flora (Clade II), which exhibits subtropical taxa mixed with cold temperate elements. This contradictory results regarding Clade II may be explained by a difference in climatic conditions, While floral assemblages lumped in Clade II were exposed to the South Atlantic-Weddell currents, and, westerly winds and moist or/and a previous vicariant event differentially isolated Patagonian plants of Clade I from the northwestern Antarctic Peninsula (South Shetland Islands) and the northeastern Antarctic Peninsula

(James Ross Basin). Unfortunately, the subductive activity along the western border of the Antarctic Peninsula may have erased physical evidence for this hypothesis along the western border of the Magallanes Basin. Clades IA and IB share morphotypes of Sterculiaceae, neotropical trees and shrubs, which were abundant in Cretaceous Patagonian localities. Clade II clusters the Patagonian localities of Dorotea, La Irene and Cazador Hill with the James Ross Basin localities of Seymour Island, James Ross Island and Snow Hill Island. This clade is supported by a few palynomorphs, with Snow Hill Island and Dorotea sites in a basal position. Seymour Island and James Ross Island are well structured with numerous synapomorphic species of Olacaceae, Proteaceae, Bombacaceae, Podocarpaceae, Aquilafoliaceae and Casuarinaceae. Some are tropical in origin, such as Olacaceae, a Gondwana group of mangroves with a wide record during the Paleogene of South America, New Zealand and Africa (Muller 1981); they indicate megathermal and high rainfall conditions. Other taxa, such as Bombacaceae and Aquilafoliaceae were subtropical to tropical elements of the Maastrichtian-Danian (Prámparo et al. 2007). Proteaceae, as well the conifers Araucariacites, Microcarcharidites and *Dacrycarpus*, show temperate affinities. Clade IIA also contains Arecipites, a taxon with affinities to Palmae (Poole et al. 2005), Arecaceae or Liliaceae (Macphail & Cantrill 2006), even though their simple type of pollen has frequently been assigned to tree ferns such as Cyathidites and palms. Arecipites is frequently used as a climate proxy indicative of warm conditions and intolerance to long and cold freezing winters (Box 1981). Nevertheless, this interpretation may be erroneous, because other similar families such as Liliaceae, produce structurally identical types of pollen (Erdtman 1971, Skog 1988). Indeed, Palmae have been reported in the same area of Antarctica by Askin (1992), even including Monosulcites minutiscabratus (Baldoni & Barreda 1986) and Longaperites (Baldoni & Medina 1989). Modern Palmae are present in cool-temperate Austral ecosystems, among them the Chilean Iubaea chilensis, near Valparaíso, or Rhopalostylis sapida, the Nikau palm, in New Zealand and the Chatham Islands.

In both, PAE and AE analyses, nearby localities such as the Cerro Guido-Las Chinas complex and Dorotea-La Irene show important differences in their floral composition. This reinforces the idea that coeval sedimentary environments differed at short distance. Nothofagaceae are completely absent at Cerro Guido and Las Chinas and are the dominant element in the Dorotea-La Irene assemblages. This important difference may result from diverging microclimates, similar to the differences that today exist between the western and eastern side of the Patagonian Andes. It is nevertheless evident that localities to the west of the hypothetical isthmus between South America and Antarctica are linked, and that a similar link existed between sites located to the east, such as the James Ross Basin, Dorotea and La Irene. However, these biotical differences may reflect another condition: that the outcrops of the Chinas-Cerro Guido may represent the instant before the massive invasion of Nothofagus from Antarctica to Patagonia. Therefore, Dorotea and La Irene outcrops belong to the end-Maastrichtian interval. Unfortunately, the physical evidence for the western bridge is lost today due to the subduction. The mix of tropical and temperate South American-Australian Antarctic taxa in Maastrichtian localities of northern Magallanes basin is also noteworthy and this area likely represents the "birth place" for the Valdivian forest.

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APPENDIX

Data matrix used for the PAE and AE analyses. First column: taxa number (character). Second column: Scientific name of taxa. Third column: presence/absence matrix in localities EXT, Outgroup; IRE, La Irene; CHI, Las Chinas; CAZ, C^o Cazador; DOR, Dorotea; GUI, C^o Guido; SNO, Snow Hill Island; SEY, Seymour Island; JAM, James Ross Island; SKU, Skua Bay; HAL, Half Three Point; PRI, Price Point and ZAM, Zamek Hill (The letters A-M correspond to the sequence of localities above).

Matriz de datos utilizada para los análisis PAE y AE. Primera columna: el número de taxa (caracteres). Segunda columna: nombre taxa. Tercera columna: matriz de presencia/ausencia en localidades EXT, Outgroup; IRE, La Irene; CHI, Las Chinas; CAZ, C° Cazador; DOR, Dorotea; GUI, C° Guido; SNO, Snow Hill Island; SEY, Seymour Island; JAM, James Ross Island; SKU, Skua Bay; HAL, Half Three Point; PRI, Price Point and ZAM, Zamek Hill (Las letras A-M se corresponden con las localidades en el orden indicado).

N° taxa	PALINOMORPHS	А	В	С	D	Е	F	G	Η	Ι	J	Κ	L	М
0	Abiyineaepollenites microalatus Delcourt & Sprumont	0	0	0	0	0	0	0	0	0	0	1	0	0
2	Aequitriradites spinulosus Cookson & Dettmann	0	0	0	0	0	0	0	0	1	0	1	0	0
3	Ailanthipites sp. Wodehouse	0	0	0	0	0	0	0	0	1	0	0	0	0
4	Alisporites grandis (Cookson) Dettmann	0	0	0	0	0	0	0	0	1	0	0	0	0
5	Alsophilidites kerguelensis Cookson	0	0	0	0	0	0	0	0	0	0	1	0	0
6	Alsophilidites sp. Cookson	0	0	0	0	0	0	0	0	0	0	1	0	0
7	Amosopollis cruciformis Cookson & Balme	0	0	0	0	0	0	0	1	0	0	0	0	0
8	Anacardites pichileufensis Berry	0	0	0	0	0	0	0	0	0	1	1	0	0
9	Anacolosidites sectus Partridge	0	0	0	0	0	0	0	1	1	0	0	0	0
10	Appendicisporites sp. Saad & Ghazaly	0	0	0	0	0	0	0	0	1	0	1	0	0
12	Araucariacites australis Cookson	0	0	0	1	0	0	0	1	1	0	1	0	0
14	Araucariacites sp. Courtinat & Jenny	0	0	1	1	0	0	0	1	1	0	1	1	0
15	Arecipites minutiscabratus (McIntyre) Milne	0	1	0	1	0	0	0	1	0	0	0	0	0
16	Arecipites sp. Wodehouse	0	1	1	1	0	0	0	0	1	0	0	0	0
17	Asterisporites sp. Venkatachala & Rawat	0	0	0	0	0	0	0	0	0	0	1	0	0
19	Baculatisporites comaumensis (Cookson) Potonie	0	1	0	1	1	0	0	1	1	0	0	0	0
20	Baculatisporites kachaikensis Llorens & Archangelsky	0	0	1	0	0	0	0	0	0	0	0	0	0
21	Baculatisporites sp. Pflug & Thomson	0	1	0	0	1	0	0	1	1	0	1	1	0

N° taxa	PALINOMORPHS	А	В	С	D	Е	F	G	Н	Ι	J	Κ	L	М
22	Baculatisporites turbioensis Archangelsky	0	0	0	0	1	0	0	0	1	0	0	0	0
23	Beaupreaidites elegansiformis Cookson	0	0	0	0	0	0	0	1	1	0	0	0	0
24	Beaupreaidites sp. Cookson ex R. Potonié	0	0	0	0	0	0	0	1	1	0	0	0	0
25	Beaupreaidites verrucosus Cookson	0	0	0	0	0	0	0	1	0	0	0	0	0
27	Biretisporites sp. cf. potoniaei Delcourt & Sprumont	0	0	1	1	0	0	0	0	1	0	1	0	0
26	Biretisporites spectabilis Dettmann	0	0	0	1	0	0	0	0	0	0	0	0	0
28	Biryisporites sp. Delcourt & Sprumont	0	0	0	0	0	0	0	0	1	0	0	0	0
30	Bombacacidites bombaxoides Couper	0	0	0	0	0	0	0	1	1	0	0	0	0
31	Brachysporisporites antarcticus Song & Cao	0	0	0	0	0	0	0	0	0	0	1	0	0
32	Brachysporisporites grandus Song & Cao	0	0	0	0	0	0	0	0	0	0	1	0	0
33	Brachysporisporites longovatus Song & Cao	0	0	0	0	0	0	0	0	0	0	1	0	0
34	Brachysporisporites ovoidus Song & Cao	0	0	0	0	0	0	0	0	0	0	1	0	0
35	Brachysporisporites sp. Lange & Smith	0	0	0	0	0	0	0	0	0	0	1	0	0
36	Brassospora sp. Hill and Read	0	0	0	0	0	0	0	0	1	0	0	0	0
37	Camarazonosporites ambigens (Fradkina) Playford	0	0	0	0	0	0	0	0	1	0	0	0	0
38	Camarazonosporites ohaiensis (Couper)	0	0	0	0	0	0	0	1	0	0	0	0	0
42	Ceratosporites equalis Cookson & Dettmann	0	1	0	0	0	0	0	1	1	0	0	0	0
43	Cibotiumspora sp. Jersey & Raine	0	0	0	0	0	0	0	0	0	0	1	0	0
44	Cicatricosisporites australiensis (Cookson) Potonié	0	1	0	0	0	0	0	0	1	0	0	0	0
45	Cicatricosisporites hughesii Dettmann	0	0	0	0	0	0	0	0	1	0	0	0	0
46	Cicatricosisporites sp. Potonié & Gellyich	0	1	0	0	0	0	1	0	1	0	0	0	0
48	Cingulatisporites scabratus Thomson	0	0	0	0	0	0	0	0	1	0	0	0	0
47	Cingutriletes australis Pierce	0	0	0	0	0	0	0	0	1	0	0	0	0
53	Classopollis sp. Danzé-Corsin & Laveine	0	0	1	0	0	0	0	0	0	0	0	0	0
55	Clavamonocolpites polygonalis Askin	0	0	0	0	0	0	0	0	1	0	0	0	0
54	Clavatipollenites hughesii Couper	0	0	0	0	0	0	0	0	1	0	0	0	0
56	Clavatipollenites sp. González-Guzmán	0	1	1	0	0	0	0	0	1	0	1	1	0
57	Clavifera jachromensis Bolchovitina	0	0	0	0	0	0	0	0	0	0	1	0	0
58	Clavifera sp. Bolchovitina	0	0	0	1	0	0	0	1	1	0	1	0	0
59	Clavifera triplex (Bolkhovitina) Bolkhovitina	0	0	0	1	0	0	0	1	1	0	1	0	0
60	Compositoipollenites tarragoensis Truswell y Owens	0	0	0	0	0	0	0	0	1	0	0	0	0
61	Contignisporites cooksoniae (Balme) Dettmann	0	0	0	0	0	0	0	0	1	0	0	0	0
64	Cranwellia sp. Srivastava	0	0	0	0	0	0	0	1	1	0	1	0	0
65	Cranwellia striata (Couper) Srivastava	0	0	0	0	0	0	0	1	1	0	0	0	0
62	Cranwellipollis palisadus (Couper)	0	0	0	0	0	0	0	1	1	0	0	0	0
63	Cranwellipollis sp. Martin y Harris	0	0	0	0	0	0	0	1	1	0	0	0	0
66	<i>Cranwellipollis subpalisadus</i> (Couper) Martin y Harris	0	0	0	0	0	0	0	1	0	0	0	0	0
67	<i>Crybelosporites striatus</i> (Cookson y Dettmann) Dettmann	0	0	0	0	0	0	0	0	1	0	0	0	0
70	Cupanieidites orthoteicus Cookson & Pike	0	0	0	0	0	0	0	1	1	0	0	0	0

N° taxa	PALINOMORPHS	A	В	С	D	Е	F	G	Н	I	I	K	L	M
71	Cupulisboronites megaporus Song & Cao	0	0	0	0	0	0	0	0	0	0	1	0	0
75	Cvatheacidites annulatus Cookson	0	0	0	1	0	0	0	0	1	0	0	0	0
72	Cvatheacidites sp. L. C. Cookson ex R. Potonié	0	0	0	1	0	0	0	0	1	0	1	1	0
73	Cyathidites australis Couper	0	0	0	1	0	0	0	0	1	0	0	0	0
74	Cyathidites concavus (Bolkhovitina) Dettmann	0	0	0	0	0	0	0	0	1	0	0	0	0
75	Cyathidites minor Couper	0	1	1	1	1	0	0	1	1	0	1	0	0
76	Cyathidites pulchellus Cao	0	0	0	0	0	0	0	0	0	0	1	0	0
78	Cyathidites sp. R. A. Couper	0	1	0	1	1	0	1	1	1	0	1	1	0
79	Cycadopites nitidus Balme	0	1	0	0	0	0	0	0	1	0	0	0	0
80	<i>Cycadopites</i> sp. Wodehouse	0	1	0	0	0	0	0	1	1	0	1	1	0
81	<i>Cyclusphaera</i> sp. W. C. Elsik	0	0	0	0	0	0	0	0	1	0	0	0	0
82	Dacrycarpites australiensis Cookson & Pike	0	0	0	0	0	0	0	1	1	0	0	0	0
83	Dacrycarpus sp. J. Arnold Arbor	0	0	0	0	0	0	0	1	0	0	0	0	0
84	Dacrydium sp. Lambert	0	0	0	0	0	0	0	1	1	0	1	0	0
85	Dacrydiumites florinii Cookson & Pike	0	0	0	0	0	0	0	0	1	0	0	0	0
86	Dacrydiumites sp. Hekel	0	0	0	0	0	0	0	1	1	0	1	1	0
87	Deltoidospora hallii Miner	0	0	0	0	0	0	0	0	0	0	1	0	0
88	Deltoidospora microlepioides (Krutzsch) Wang	0	0	0	0	0	0	0	0	0	0	1	0	0
89	Deltoidospora sp. Danzé-Corsin & Laveine	0	0	0	1	0	0	0	0	0	0	1	1	0
90	Delwynites tuberculatus Askin	0	0	0	0	0	0	0	0	1	0	0	0	0
91	Densoisporites velatus Weyland & Krieger	0	0	0	0	0	0	0	0	1	0	0	0	0
92	Dicellaesporites antarcticus Song & Cao	0	0	0	0	0	0	0	0	0	0	1	0	0
93	Dicellaesporites oblongatus Song & Cao	0	0	0	0	0	0	0	0	0	0	1	0	0
94	Dicellaesporites popovii Elsik	0	0	0	0	0	0	0	0	0	0	1	0	0
95	Dicellaesporites sp. (Elsik) Sheffy & Dilcher	0	0	0	0	0	0	0	0	0	0	1	0	0
99	Diporicellaesporites antarcticus Song & Cao	0	0	0	0	0	0	0	0	0	0	1	0	0
100	Diporicellaesporites sp. Elsik	0	0	0	0	0	0	0	0	0	0	1	0	0
101	Diporicellaesporites stenosus Song & Cao	0	0	0	0	0	0	0	0	0	0	1	0	0
104	Dyadosporites obscurus Song & Cao	0	0	0	0	0	0	0	0	0	0	1	0	0
105	Dyadosporites sp. T. van der Hammen & Clarke	0	0	0	0	0	0	0	0	0	0	1	0	0
106	Echinosporis sp. Krutzsch	0	0	0	1	0	0	0	0	0	0	1	0	0
107	Echitriporites sp. T. van der Hammen	0	0	0	0	0	0	0	1	0	0	0	0	0
110	Ephedripites notensis (Cookson) Krutzsch	0	0	0	0	0	0	0	0	1	0	0	0	0
111	Equisetosporites sp. Daugherty	0	1	0	0	0	0	0	0	0	0	0	0	0
113	Ericipites scabratus Harris	0	1	0	0	0	0	0	0	0	0	0	0	0
114	Ericipites sp. Wodehouse	0	0	0	0	0	0	0	0	1	0	0	0	0
115	<i>Exesisporites</i> sp. Elsik	0	0	1	0	0	0	0	0	0	0	0	0	0
116	Extrapunctatosporis sp. Krutzsch	0	0	0	0	0	0	0	0	0	0	1	0	0
119	Foraminisporis dailyi (Cookson & Dettmann) Dettmann	0	0	0	0	0	0	0	0	1	0	1	0	0

N° taxa	PALINOMORPHS	А	В	С	D	Е	F	G	Н	Ι	J	K	L	Μ
120	<i>Foraminisporis asymmetricus</i> (Cookson & Dettmann) Dettmann	0	0	0	0	0	0	0	0	1	0	0	0	0
121	<i>Forcipites sabulosus</i> (Dettmann & Playford) Dettmann & Jarzen	0	0	0	0	0	0	0	1	0	0	0	0	0
122	Forcipites sp. cf. longus (Stover & Evans) Dettmann & Jarzen	0	0	0	0	0	0	0	1	0	0	0	0	0
123	Forcipites sp. Dettmann & Jarzen	0	0	0	1	0	0	0	1	0	0	0	0	0
124	Foveogleicheniidites confossus (Hedlund) Norvick & Burger	0	0	0	0	0	0	0	0	1	0	0	0	0
125	Foveotriletes scrobiculatus (Ross) Potonie'	0	0	0	0	0	0	0	0	0	0	1	0	0
126	Foveotriletes sp. Puri	0	0	0	0	0	0	0	0	1	0	1	0	0
127	Fractisporonites sp. Clarke	0	0	0	0	0	0	0	0	0	0	1	0	0
128	Fuscospora sp. Hill & Read	0	0	0	0	0	0	0	0	1	0	0	0	0
129	Gabonisporites sp. Boltenhagen	0	1	0	0	0	0	0	0	0	0	0	0	0
130	Gamerroites psilasaccus Archangelsky	0	1	0	0	0	0	0	0	0	0	0	0	0
132	Gemmamonocolpites pilulus Askin	0	0	0	0	0	0	0	0	1	0	0	0	0
134	Gleicheniidites aptianus Llorens	0	0	0	1	0	0	0	0	0	0	0	0	0
135	Gleicheniidites campanianus Cao	0	0	0	0	0	0	0	0	0	0	1	0	0
136	Gleicheniidites cercinidites (Cookson) Dettmann	0	0	0	0	0	0	0	0	1	0	0	0	0
137	Gleicheniidites delcourtii Doring	0	0	0	0	0	0	0	0	0	0	1	0	0
138	Gleicheniidites fildesensis Cao	0	0	0	0	0	0	0	0	0	0	1	0	0
139	Gleicheniidites pachydermus Cao	0	0	0	0	0	0	0	0	0	0	1	0	0
140	Gleicheniidites senonicus Ross	0	1	1	1	0	0	0	1	0	0	1	0	0
141	Gleicheniidites sp. Grigoreva	0	1	1	1	0	0	0	1	1	0	1	0	0
142	Gleicheniidites trivalis Brotzen	0	0	0	0	0	0	0	0	0	0	1	0	0
143	Gleichenites sanmartini Halle emend. Herbst	0	0	1	0	0	0	0	0	0	0	0	0	0
144	Gnetaceaepollenites ellipticus Thiergart	0	0	0	0	0	0	0	0	0	0	1	0	0
145	Gnetaceaepollenites sp. Thiergart	0	0	0	0	0	0	0	0	0	0	1	0	0
146	Gothanipollis bassensis Stover & Partridge	0	0	0	0	0	0	0	0	0	0	1	0	0
147	Granulatisporites sp. Wilson	0	1	0	0	0	0	0	0	0	0	0	0	0
148	Grapnelispora evansii Stover & Partridge	0	0	0	0	0	0	1	1	0	0	0	0	0
149	Haloragacidites harrisii (Couper) Harris	0	0	0	0	0	0	0	0	1	0	0	0	0
150	Herkosporites elliotii Stover	0	0	0	0	0	0	0	0	1	0	0	0	0
152	Illexpollenites sp. Partridge	0	0	0	0	0	0	0	1	1	0	0	0	0
153	Inapertisporites obpyriformis Sheffy & Dilcher	0	0	0	0	0	0	0	0	0	0	1	0	0
154	Inapertisporites solidus Song & Cao	0	0	0	0	0	0	0	0	0	0	1	0	0
155	Inaperturopollenites laevigatus Takahashi	0	0	0	0	0	0	0	0	1	0	0	0	0
156	Inaperturopollenites sp. Pflug & Thomson	0	0	0	0	0	0	0	0	1	0	1	1	0
157	Interulobites intraverrucatus (Brenner) Phillips & Felix	0	0	0	0	0	0	0	0	1	0	0	0	0
158	Involutisporonites crassus Song & Cao	0	0	0	0	0	0	0	0	0	0	1	0	0
159	Involutisporonites sp. Clarke	0	0	0	0	0	0	0	0	0	0	1	0	0

N° taxa	PALINOMORPHS	Α	В	С	D	Е	F	G	Η	Ι	J	Κ	L	M
160	<i>Ischyosporites</i> sp. Balme	0	1	0	1	0	0	0	0	1	0	0	0	0
161	Ischyosporites volkheimeri Filatoff	0	1	0	1	0	0	0	0	1	0	0	0	0
162	Klukisporites antarcticus Cao	0	0	0	0	0	0	0	0	0	0	1	0	0
163	Klukisporites pseudoreticulatus Couper	0	0	0	0	0	0	0	0	1	0	0	0	0
164	<i>Klukisporites scaberis</i> (Cookson & Dettmann) Dettmann	0	0	0	0	0	0	0	0	1	0	0	0	0
165	Klukisporites sp. Couper	0	0	0	0	0	0	0	0	1	0	1	1	0
167	Lacrimasporonites scabratus Song & Cao	0	0	0	0	0	0	0	0	0	0	1	0	0
168	Lacrimasporonites sp. Clarke	0	0	0	0	0	0	0	0	0	0	1	0	0
169	Lacrimasporonites tenuous Song & Cao	0	0	0	0	0	0	0	0	0	0	1	0	0
170	Laevigatosporites ovatus Wilson & Webster	0	1	0	1	1	0	0	1	1	0	0	0	0
171	Laevigatosporites sp. Tschudy & Van Lonen	0	1	1	1	1	0	0	1	1	0	1	1	0
174	Laurelites dorotensis Nishida	0	0	0	0	1	0	0	0	0	0	0	0	0
175	Laurelites jamesrossii Poole & Francis	0	0	0	0	0	0	0	0	1	0	0	0	0
179	Leiotriletes sp. (Naumova) Potonié & Kremp	0	0	0	0	0	0	0	0	0	0	1	1	0
180	Leptolepidites macroverrucosus Schulz	0	0	0	0	0	0	0	0	1	0	0	0	0
181	Leptolepidites tumulosus (Doring) Srivastava	0	0	0	0	0	0	0	0	1	0	0	0	0
182	Leptolepidites verrucatus Couper	0	0	0	0	0	0	0	0	1	0	0	0	0
183	Liliacidites cf. variegatus Couper	0	1	0	0	1	0	0	0	0	0	0	0	0
184	Liliacidites kaitangataensis Couper	0	0	0	1	0	0	0	1	1	0	0	0	0
185	Liliacidites lanceolatus Stover	0	0	0	0	0	0	0	0	1	0	0	0	0
187	Liliacidites sp. cf. regularis Archangelsky	0	1	1	1	0	0	0	1	1	0	1	1	0
186	Liliacidites sp. Couper	0	0	0	1	0	0	0	0	0	0	0	0	0
188	Liliacidites variegatus Couper	0	0	0	1	0	0	0	0	1	0	0	0	0
189	Longapertites sp. Van Hoeken-Klinkenberg	0	1	0	0	0	0	0	0	0	0	0	0	0
191	Lycopodiumsporites sp. Danzé-Corsin y Laveine	0	0	0	0	0	0	0	0	0	0	1	1	0
193	<i>Lygistepollenites florinii</i> (Cookson y Pike) Stover & Evans	0	0	0	1	0	0	0	1	0	0	0	0	0
192	Lygisterpollenites balmei (Cookson) Stover & Evans l	0	0	0	0	0	0	0	0	1	0	0	0	0
196	Malvacipollis sp. Harris	0	0	0	0	0	0	0	0	0	0	1	1	0
197	Matonisporites cooksoniae Dettmann	0	0	0	0	0	0	0	0	1	0	0	0	0
198	Matonisporites sp. Couper	0	1	0	0	0	0	0	0	1	0	0	0	0
199	Meliapollis sp. Couper	0	0	0	0	0	0	0	0	0	0	1	1	0
202	Microcachryidites antarcticus Cookson	0	1	0	1	0	0	1	1	1	0	0	0	0
203	Microcachryidites sp. Cookson	0	1	0	1	0	0	1	1	1	0	1	1	0
207	Multinodisporites praecultus Chlonova	0	0	0	0	0	0	0	0	0	0	1	0	0
208	Multicellaesporites ovatus Sheffy & Dilcher	0	0	0	0	0	0	0	0	0	0	1	0	0
209	Multicellaesporites sp. (Elsik) Sheffy & Dilcher	0	0	0	0	0	0	0	0	0	0	1	1	0
210	Multinodisporites praecultus A. F. Chlonova	0	0	0	0	0	0	0	0	1	0	0	0	0
213	Myrtaceidites eugeniioides Cookson & Pike	0	0	0	0	0	0	0	0	1	0	0	0	0
214	Myrtaceidites sp. Cookson & Pike	0	0	0	0	0	0	0	1	1	0	1	1	0

N° taxa	PALINOMORPHS	А	В	С	D	Е	F	G	Η	Ι	J	Κ	L	М
217	Neoraistrickia sp. Potonié	0	0	0	1	0	0	0	0	1	0	1	0	0
218	Neoraistrickia truncata (Cookson) Potonie	0	0	0	0	0	0	0	0	1	0	1	0	0
219	Nodosisporites cf. cremimurus (Srivastava) Davies	0	0	0	0	0	0	0	0	1	0	0	0	0
220	Nothofagidites brachyspinulosus (Cookson) Harris	0	0	0	0	0	0	0	0	0	0	1	0	1
221	Nothofagidites brassi Archangelsky	0	0	0	0	0	0	0	0	0	0	1	1	0
222	Nothofagidites cf. N. emarcidus (Cookson) Harris & Truswell	0	0	0	0	0	0	0	0	0	0	0	0	1
223	Nothofagidites endurus Stover & Evans	0	0	0	0	0	0	0	0	0	0	1	1	1
224	Nothofagidites falcatus (Cookson) Hekel	0	0	0	0	0	0	0	0	0	0	1	1	0
225	<i>Nothofagidites fuegiensis</i> Menéndez & Caccavari de Fílice	0	0	0	0	0	0	0	0	0	0	1	1	0
226	Nothofagidites fusca Cranwell Hekel	0	0	0	0	0	0	0	0	0	0	1	1	0
227	Nothofagidites rocaensis Romero	0	0	0	0	0	0	0	0	0	0	1	1	1
228	<i>Nothofagidites saraensis</i> Menéndez & Caccavari de Fílice	0	0	0	1	0	0	0	0	0	0	0	0	0
229	Nothofagidites senectus Dettmann & Playford	0	0	0	0	0	0	0	0	1	0	1	1	1
230	Nothofagidites sp. Pocknall	0	0	0	0	0	0	1	1	1	0	1	1	1
231	Nothofagidites visserensis Romero	0	0	0	0	0	0	0	0	0	0	1	1	0
238	Nyssapollenites cf. squamosus Dettmann	0	1	0	0	0	0	0	0	0	0	0	0	0
239	Ornamentifera sp. Bolchovitina	0	0	0	0	0	0	0	0	1	0	0	0	0
241	Osmundacidites sp. Couper	0	0	0	0	0	0	0	0	1	0	1	1	0
242	Osmundacidites wellmanii Couper	0	0	0	0	0	0	0	0	1	0	0	0	0
244	Peninsulapollis askinae Dettmann & Jarzen	0	0	0	0	0	0	0	0	1	0	0	0	0
245	Peninsulapollis gillii (Cookson) Dettmann & Jarzen	0	1	0	1	0	0	1	1	1	0	0	0	0
246	Peninsulapollis sp. Dettmann & Jarzen	0	1	0	1	0	0	1	1	1	0	0	0	0
247	Peninsulapollis truswelliae Dettmann & Jarzen	0	0	0	0	0	0	1	1	1	0	0	0	0
249	Periporopollenites sp. Pflug & Thomson	0	0	0	0	0	0	0	0	1	0	0	0	0
250	Perotriletes cf. P. pseudoreticulatus Couper	0	0	0	0	0	0	1	0	1	0	0	0	0
251	Perotriletes laceratus (Norris) Rumeau	0	0	0	0	0	0	0	0	1	0	0	0	0
252	Perotriletes linearis (Cookson & Dettmann) Evans	0	0	0	0	0	0	0	0	1	0	0	0	0
253	Perotriletes majus (Cookson & Dettmann) Evans	0	1	0	0	0	0	0	1	1	0	0	0	0
254	Phyllites sp. Brongniart	0	0	0	0	0	0	0	0	0	1	1	1	1
255	Phyllocladidites mawsonii Cookson ex Couper	0	1	0	1	0	0	0	1	1	0	0	1	0
256	Phyllocladidites sp.Cookson	0	1	0	1	0	0	0	1	1	0	1	1	0
260	Plicifera decora (Chlonova) Bolchovitina	0	0	0	0	0	0	0	0	0	0	1	0	0
261	Plicifera delicata (Bolchovitina) Bolchovitina	0	0	0	0	0	0	0	0	0	0	1	0	0
262	<i>Plicifera</i> sp. Raine	0	0	0	0	0	0	0	0	0	0	1	0	0
263	Plicifera trialatus Cao	0	0	0	0	0	0	0	0	0	0	1	0	0
264	Pluricellaesporites antarcticus Song & Cao	0	0	0	0	0	0	0	0	0	0	1	0	0
265	Pluricellaesporites ocellatus Song & Cao	0	0	0	0	0	0	0	0	0	0	1	0	0
266	Pluricellaesporites sp. T. van der Hammen	0	0	0	0	0	0	0	0	0	0	1	0	0

N° taxa	PALINOMORPHS	А	В	С	D	Е	F	G	Н	Ι	J	Κ	L	М
267	Podocarpidites elegans Romero	0	1	0	1	0	0	0	0	0	0	0	0	0
268	Podocarpidites ellipticus Cookson	0	1	0	1	0	0	0	0	1	0	1	0	0
269	Podocarpidites marwickii Couper	0	0	1	0	0	0	0	0	0	0	0	0	0
270	Podocarpidites microreticuloidatus Cookson	0	0	0	1	0	0	0	0	0	0	0	0	0
271	Podocarpidites sp. Cookson	0	1	1	1	0	0	0	1	1	0	1	1	0
275	Podosporites microsaccatus Couper	0	0	0	0	0	0	0	0	1	0	0	0	0
276	Podosporites sp. Rao	0	0	0	0	0	0	0	1	0	0	0	0	0
277	Podozamites pinnatus Cantrill	0	0	0	0	0	0	0	0	0	0	1	1	0
278	Polycolpites langstonii Stover	0	0	0	0	0	0	0	1	1	0	0	0	0
279	Polycolpites sp. Couper & Harris	0	0	0	0	0	0	1	1	1	0	0	0	0
280	Polypodiaceoisporites elegans Archangelsky & Gamerro	0	0	0	0	0	0	0	0	1	0	0	0	0
281	Polypodiidites speciosus (Harris) Archangelsky	0	0	0	1	0	0	0	0	0	0	0	0	0
282	Polypodiisporites favus (Potonie) Potonie	0	0	0	0	0	0	0	0	0	0	1	0	0
283	Polypodiisporites sp. Pocknall	0	0	0	0	0	0	0	0	1	0	1	0	0
284	Propylipollis annularis (Cookson) Martin & Harris	0	0	0	0	0	0	0	0	1	0	0	0	0
285	Propylipollis concretus (Harris) Martin & Harris	0	0	0	0	0	0	0	0	1	0	0	0	0
286	Propylipollis sp. Martin & Harris	0	0	0	0	0	0	0	1	1	0	1	1	0
287	Proteacidites sp. Cookson	0	1	0	0	0	0	0	1	1	0	1	1	0
288	Proteacidites stipplatus Partridge	0	0	0	0	0	0	0	0	1	0	0	0	0
289	Proteacidites subscabratus Couper	0	0	0	0	0	0	0	0	1	0	0	0	0
290	Proteacidites truncatus Cookson	0	0	0	0	0	0	0	0	1	0	0	0	0
293	<i>Psilatricolporites</i> sp. T. van der Hammen ex T. van der Hammen & T. A. Wymstra	0	1	1	1	0	0	1	1	1	0	0	0	0
295	Reduviasporonites sp. Wilson	0	0	0	0	0	0	0	0	0	0	1	0	0
296	Reticuloidosporites cf. tenellis Krutzsch	0	0	1	1	0	0	0	0	1	0	0	0	0
297	Retidiporites camachoi Archangelsky	0	1	0	0	0	0	0	0	0	0	0	0	0
298	<i>Retistephanocolporites</i> sp. T. van der Hammen & Wymstra	0	0	0	0	0	0	0	0	1	0	0	0	0
299	Retitriletes austroclavatidites Cookson	0	1	0	0	0	0	0	0	1	0	0	0	0
300	Retitriletes cf. eminulus (Dettmann) Srivastava	0	0	0	0	0	0	0	0	1	0	0	0	0
301	<i>Retitriletes</i> sp. Pierce	0	1	0	0	0	0	1	1	1	0	0	0	0
302	Rhoipites cf. minusculus Archangelsky	0	1	1	0	0	0	0	0	0	0	0	0	0
303	Rhoipites sp. cf. microreticulatus (Harris) Macphail et al.	0	1	1	0	0	0	0	1	0	0	0	0	0
304	Rhoipites sp. Wodehouse	0	0	0	0	0	0	0	1	0	0	0	0	0
305	Rousea microreticulata Archangelsky	0	0	0	1	0	0	0	0	0	0	0	0	0
306	Rousea patagonica Archangelsky	0	1	0	0	0	0	0	0	0	0	0	0	0
307	Rousea sp. Srivastava	0	0	0	1	0	0	0	0	1	0	0	0	0
308	Rouseisporites reticulatus Pocock	0	1	0	0	0	0	0	1	0	0	0	0	0
309	Rugulatisporites mallatus Stover	0	0	0	0	0	0	0	0	1	0	0	0	0

N° taxa	PALINOMORPHS	A	B	С	D	E	F	G	Н	T	I	K	L	М
310	Rugulatishovitas micraularus Partridos	0	0	0	0	0	0	0	0	1	0	0	0	0
311	Rugulatishovitas nauguansis Volkheimer	0	0	0	0	0	0	0	0	1	0	0	0	0
312	Sabotacoidaebollevites sp. Stover	0	0	0	0	0	0	0	0	0	0	1	1	0
312	Schizacalbus sp. Stover	0	0	0	0	0	0	0	0	0	0	1	1	0
214	Semibites on Srivestava	0	1	0	0	0	0	0	0	0	0	0	1	0
216	Schagnumsborites sp. Cookson	0	1	0	0	0	0	0	0	0	0	1	0	0
218	Spinignumsporties Sp. Cookson	0	1	0	0	0	0	0	0	0	0	1	0	0
310	Stablacharonites sn. Shaffy & Dilchar	0	1	0	0	0	0	0	0	0	0	1	0	0
320	Stallidiotallis annulatus Dettmann & Hedlund	0	0	0	0	0	0	0	1	1	0	0	0	0
320	Stathanacalbitas sp. T. van der Hammen	0	0	0	0	0	0	0	0	1	0	0	0	0
021	Sternisbarites antiquestarites (Wilson & Webster)	0	U	0	0	U	0	U	0	1	U	0	U	0
327	Dettmann	0	1	0	1	0	0	0	1	0	0	0	0	0
328	Stereisporites sp. Norris	0	0	0	0	0	0	0	1	0	0	1	1	0
329	Stoverisporites microverrucatus Burger	0	0	0	0	0	0	0	0	1	0	0	0	0
330	Striatriporites sp. van Hoeken-Klinkenberg	0	0	0	0	0	0	0	0	1	0	0	0	0
332	Teredolites sp. Savrda	0	0	0	0	0	0	1	0	0	0	0	0	0
333	Tetracolporites sp. Couper	0	0	0	0	0	0	0	1	1	0	0	0	0
334	Tetracolporites verrucosus Stover	0	0	0	0	0	0	0	1	0	0	0	0	0
339	Triatriopollenites lateflexus Archangelsky	0	0	0	1	0	0	0	0	0	0	0	0	0
340	Trichotomosulcites subgranulatus Couper	0	0	0	0	0	0	0	1	0	0	0	0	0
341	Tricolpites confessus Stover ex Stover & Partridge	0	0	0	0	0	0	0	0	1	0	0	0	0
342	Tricolpites reticulatus Cookson	0	0	0	1	0	0	0	1	1	0	0	0	0
343	Tricolpites simatus Stover & Partridge	0	0	0	0	0	0	0	0	1	0	0	0	0
344	Tricolpites sp. T. van der Hammen	0	0	1	1	0	0	0	1	1	0	1	1	0
345	Tricolpites striatus Couper	0	0	0	0	0	0	0	1	0	0	0	0	0
346	Tricolpites waiparaensis Stover & Evans	0	0	0	0	0	0	0	0	1	0	0	0	0
347	Tricolporites lilliei (Couper) Stover & Evans	0	0	0	0	0	0	0	0	0	0	0	1	0
348	Tricolporites pachyexinus Couper	0	0	0	0	0	0	0	1	0	0	0	0	0
349	Tricolporopollenites sp. Doyle & Robbins	0	0	0	0	0	0	0	0	0	0	1	0	0
350	Trilites parvallatus Krutzsch	0	0	0	0	0	0	0	0	1	0	0	0	0
351	Trilites sp. Mildenhall	0	0	0	1	0	0	0	0	1	0	0	0	0
352	Trilites sp. cf. fasolae Archangelsky	0	0	0	1	0	0	0	0	0	0	0	0	0
353	Trilites tuberculiformis Cookson	0	0	0	0	0	0	0	0	1	0	0	0	0
354	Triorites sp. Erdtman	0	0	0	0	0	0	0	0	0	0	1	1	0
355	Triporoletes simplex (Cookson & Dettmann) Playford	0	0	0	0	0	0	0	0	1	0	0	0	0
356	Triporopollenites sectilis Stover	0	0	0	0	0	0	0	1	0	0	0	0	0
357	Triporopollenites sp. Pflug & Thomson	0	0	0	1	0	0	0	1	1	0	1	0	0
358	Trisaccites microsaccatus Couper	0	1	1	0	1	0	0	1	0	0	0	0	0
359	Tuberculatosporites parvus Archangelsky	0	0	0	0	0	0	0	0	1	0	0	0	0
360	Tubulifloridites lilliei Couper	0	0	0	0	0	0	0	1	1	0	0	0	0
361	Undulatisporites sp. Pflug	0	0	0	0	0	0	0	0	0	0	1	0	0

N° taxa	PALINOMORPHS	Α	В	С	D	Е	F	G	Н	Ι	J	Κ	L	Μ
362	Verrucosisporites sp. Dybová & Jachowicz	0	1	1	1	0	0	0	0	0	0	1	1	0
363	Vitreisporites pallidus Reissinger	0	0	0	0	0	0	0	0	1	0	0	0	0

N° taxa	LEAF IMPRINTS	Α	В	С	D	Е	F	G	Η	Ι	J	Κ	L	Μ
1	Acmopyle antarctica Florin	0	0	0	0	0	1	0	0	0	0	0	0	0
11	Araliaephyllum sp. Fontaine	0	0	0	0	0	1	0	0	0	0	0	0	1
18	Athrotaxis sp. Don	0	0	1	0	0	0	0	0	0	0	0	0	0
29	Blechnum sp. Linneo	0	0	0	0	0	0	0	0	0	0	1	1	0
39	Carpolithes sp. Brongniart	0	0	1	0	0	0	0	0	0	0	0	0	0
40	Cassia sp. Linnaeus	0	0	0	0	0	0	0	0	0	1	1	0	0
49	Cinnamonum sp. Schaeff.	0	0	1	0	0	1	0	0	0	0	0	0	0
50	Cissites parrifolius Cockerell	0	0	1	0	0	0	0	0	0	0	0	0	0
51	Cladophlebis patagonica (Frenguelli) Herbst	0	0	1	0	0	0	0	0	0	0	0	0	0
52	Cladophlebis sp. Brongniart	0	0	1	0	0	1	0	0	0	0	1	1	1
68	<i>Culcita</i> sp. Presl	0	0	0	0	0	0	0	0	0	1	1	0	0
69	Cupania patagonica Berry	0	0	1	0	0	0	0	0	0	0	0	0	0
96	Dicksonia sp. L'Héritier	0	0	0	0	0	0	0	0	0	0	1	1	0
97	Dicotylophyllum elegans Li	0	0	0	0	0	0	0	0	0	1	1	0	1
98	Dicotylophyllum sp. Bandulska	0	0	0	0	0	0	0	0	0	1	1	0	1
102	Dryopteris seymouriensis Dusen	0	0	0	0	0	0	0	0	0	0	0	0	1
103	Dryopteris sp. Adanson	0	0	0	0	0	0	0	0	0	0	1	1	1
108	Elaeocarpus sp. Linnaeus	0	0	0	0	0	0	0	0	0	0	0	0	1
109	Ephedra notensis Linnaeus	0	0	0	0	0	0	0	1	0	0	0	0	0
111	Equisetites sp. Sternberg	0	0	1	0	0	0	0	0	0	0	0	0	0
117	Ficophyllum palustris Cantrill	0	0	0	0	0	0	0	0	0	1	1	0	0
118	Ficophyllum skuaensis Dutra	0	0	0	0	0	0	0	0	0	1	0	0	0
131	Garnbierina rudata Stover	0	0	0	0	0	0	0	1	0	0	0	0	0
133	Gleichenia sp. Smith	0	0	0	0	0	1	0	0	0	0	1	1	0
151	Hymenophyllum priscum Menéndez	0	0	0	0	0	1	0	0	0	0	0	0	0
166	Knightia andreae Dusen	0	0	0	0	0	0	0	0	0	0	0	0	1
176	Laurophyllum hickenii Mendéndez	0	0	1	0	0	0	0	0	0	0	0	0	0
177	Laurophyllum proteaefolium Berry ex Menendez	0	0	1	0	0	1	0	0	0	0	0	0	0
178	Laurophyllum sp. Kartzi Berry	0	0	1	0	0	1	0	0	0	0	0	0	0
190	Lophozonia sp. Turczaninow	0	0	0	0	0	0	0	0	1	0	0	0	0
194	Lygodium sp. Swartz	0	0	0	0	0	1	0	0	0	0	0	0	0
195	Magnoliidaephyllum birkenmajeri Zastawniak	0	0	0	0	0	0	0	0	0	0	0	0	1
199	Menispermites sp. Lesquereux	0	0	1	0	0	1	0	0	0	0	0	0	0
201	Mespilodaphne longifolia Meisn	0	0	0	0	0	0	0	0	0	0	0	0	1
204	Microcachrys sp. Hooker	0	0	0	0	0	0	0	1	0	0	0	0	0

N° taxa	LEAF IMPRINTS	А	В	С	D	Е	F	G	Η	Ι	J	Κ	L	М
205	Monimiophyllum antarcticum Zastawniak	0	0	0	0	0	0	0	0	0	1	1	0	1
206	Monimiophyllum sp. Zastawniak	0	0	0	0	0	0	0	0	0	1	1	0	1
211	Myrcia chubutensis Berry	0	0	1	0	0	0	0	0	0	0	0	0	0
212	Myrciophyllum santacruzensis (Berry) Zastawniak	0	0	1	0	0	0	0	0	0	0	0	0	1
215	Myrtoidea patagonica Passalía et al.	0	0	1	0	0	0	0	0	0	0	0	0	0
216	Nelumbo sp. Adanson	0	0	1	0	0	0	0	0	0	0	0	0	0
232	Nothofagus cretacea Zastawniak	0	0	0	0	0	0	0	0	0	0	1	1	1
233	Nothofagus glaucifolia Dutra	0	0	0	0	0	0	0	0	0	0	0	0	1
234	Nothofagus sp. Tshudy & Van Loenen	0	0	0	0	0	1	0	1	1	1	1	1	1
235	Nothofagus sp. aff. lendenfeldii (Ettingshausen) Oliver	0	0	0	0	0	0	0	0	0	0	0	0	1
236	Nothofagus sp. aff. ulmifolia (Ettingshausen) Oliver	0	0	0	0	0	0	0	0	0	0	0	0	1
237	Nothofagus zastawniakiae Dutra	0	0	0	0	0	0	0	0	0	0	0	0	1
240	Osmunda sp. Linnaeus	0	0	0	0	0	0	0	0	0	1	1	0	0
243	Pecopteris sp. Sternberg	0	0	0	0	0	0	0	0	0	0	0	0	1
248	Pentaneurum dusenii (Zastawniak) Li	0	0	0	0	0	0	0	0	0	0	0	0	1
257	<i>Phyllocladus aspleniifolius</i> (Labillardière) J. D. Hooker	0	0	0	0	0	0	0	0	0	1	1	0	0
258	Phyllocladus sp. Mirbel	0	0	1	0	0	0	0	0	0	1	1	1	0
259	Phyllopteroides leavis Cantrill & Webb	0	0	1	0	0	0	0	0	0	0	0	0	0
272	Podocarpus fildesensis Zhou	0	0	0	0	0	0	0	0	0	0	1	0	0
273	Podocarpus inopinatus Florin	0	0	1	0	0	1	0	0	0	0	0	0	0
274	Podocarpus sp. Persoon	0	0	0	0	0	1	0	1	0	1	1	1	1
291	Pseudoaraucaria valentini Lamberti	0	0	0	0	0	1	0	0	0	0	0	0	0
292	Pseudopanax sp. Vargas	0	0	1	0	0	0	0	0	0	0	0	0	0
294	Quadraplanus brossus (Stover) Stover & Partridge	0	0	0	0	0	0	0	1	0	0	0	0	0
315	Sloanea sp. Linnaeus	0	0	0	0	0	0	0	0	0	0	0	0	1
317	Sphenopteris sp. (Brongniart) Sternberg	0	0	1	0	0	0	0	0	0	0	1	0	0
322	Sterculia acuminataloba Berry	0	0	1	0	0	0	0	0	0	0	0	0	0
323	Sterculia cretaceum (Velenovsky) Berry	0	0	0	0	0	1	0	0	0	0	0	0	0
324	Sterculia sehuensis Berry	0	0	1	0	0	1	0	0	0	0	0	0	0
325	Sterculia washburnii Berry	0	0	0	0	0	0	0	0	0	1	1	0	1
326	Sterculiaephyllum australis Dutra	0	0	1	0	0	0	0	0	0	1	1	0	1
331	Taeniopteris sp. Brongniart	0	0	1	0	0	1	0	0	0	0	0	0	0
335	Thorhallenia sp. Passalia	0	0	1	0	0	0	0	0	0	0	0	0	0
336	Thyrsopteris antiqua Menendez	0	0	0	0	1	1	0	0	0	0	0	0	0
337	Thyrsopteris elegans Kunze	0	0	0	0	0	0	0	0	0	1	1	0	0
338	Thyrsopteris sp. Wilson	0	0	0	0	1	1	0	0	1	1	1	0	0

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