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Palynological Investigation and Implications on the Relationship between Modern Surface Pollen and Vegetation/Climate (Especially Precipitation) in the Riesco Island (Isla Riesco), Subantarctic Patagonia, Chile

Masaaki Okuda[1], Harufumi Nishida[2], Kazuhiko Uemura[3], Atsushi Yabe[4], Toshihiro Yamada[5] and Miguel Rancusi H.[6]

[1] Natural History Museum and Institute, Chiba
955-2 Aoba-cho, Chuo-ku, Chiba 260-8682, Japan
E-mail: okuda@chiba-muse.or.jp
[2] Faculty of Science and Engineering, Chuo University, Tokyo 112-8551, Japan
[3] Department of Geology and Paleontology, The National Science Museum, Tokyo 169-0073, Japan
[4] Fukui Prefectural Dinosaur Museum, Katsuyama, Fukui 911-8601, Japan
[5] Department of Biological Sciences, Faculty of Science, The University of Tokyo, Tokyo 113-0033, Japan
[6] Colegio Compania de Maria-Seminario, Av. Seminario, 31-Provincia, Santiago, Chile

Abstract Eight surface (soil or moss-polster) samples from a longitudinal transect in the Riesco Island, Chile are palynologically analysed to depict the relationship between modern pollen and vegetation/climate for subantarctic Patagonia. The transect traverses a steep moisture gradient and vegetation zones from evergreen rain forest to dry tussock grasslands. A humid climate with 600–1,000 mm/y of precipitation, corresponding to evergreen beech forest in the Pacific side, is palynologically expressed by dominant *Nothofagus* (*fusca*-type) with abundant *Drimys winteri*. Palynofloral diversity is not high in this precipitation level, with a few arboreal taxa (*Podocarpus/Dacrydium*, *Maytenus*, *etc.*) associating this rain forest. A semi-arid climate with 400–450 mm/y of precipitation, corresponding to the ecotone of deciduous beech forest and shrub/grass steppes, shows the coexistence of *Nothofagus*, Tubuliflorae and/or Poaceae with very changeable values. No tree pollen except *Nothofagus* occurs in this precipitation level. An arid climate with <300 mm/y of precipitation, corresponding to grass steppe in the Atlantic region, is characterised by the dominance of Poaceae with persistent *Nothofagus* pollen from western forested areas.

Key words: palynology, Patagonia, Chile, *Nothofagus*, vegetation, precipitation, surface pollen.

Subantarctic Patagonia, comprising southernmost South America, is the only massive landmass that lies between 50–55°S in latitude (Fig. 1), receiving intensive biogeographical and palaeoclimatological studies together with the northern parts of the continent. Leads or lags of climate changes between the both hemispheres especially at the beginning of the present interglaciation are being focused, which largely contributes to understanding of the Earth climate system for the predictions of future climate changes (*e.g.*, Blunier *et al.*, 1998; Thompson *et al.*, 1998; Markgraf *et al.*, 2000; Thompson, 2000; Baker, 2002; Seltzer *et al.*, 2002; Nakagawa *et al.*, 2003). In high-latitude areas of the Southern Hemisphere, the Chilean Patagonia receives the sufficient amount of rains for the development of native forest and peat bogs. A large amount of fossil pollen data from Late-Quaternary borehole cores are being accumulated for subantarctic Patagonia (Heusser and Rabassa, 1987; Heusser, 1989, 1995; Heusser *et al.*, 2000a) as well as northern Chilean Patagonia (*e.g.*, Heusser *et al.*, 1996; Moreno, 1997; Heusser *et al.*, 1999; Heusser *et al.*, 2000b; McCulloch *et al.*, 2000). These data can be converted to palaeoclimate proxy data by referring to temperature preferences of the plants whose presences were palynologically recognised in the near past. This approach becomes more reliable by relying upon surface pollen data along regional (or altitudinal) climate transects (McGlone, 1982; Bonnefille and Riollet, 1988; Druitt *et al.*, 1990; Horrocks and Ogden, 2000), because it can provide direct pollen-climate relations using recent meteorological observations.

The first-order surface pollen datasets for subantarctic Patagonia have been provided by Heusser (1989, 1995). His pioneering studies were, however, restricted to the central to eastern (coastal) areas of southern Patagonia, with an insufficient coverage for present temperature/moisture variations (see Fig. 1). In general, western mountainous regions in the southern Chilean Patagonia are hard of access. The most Chilean and Argentina habitations are limited to the rain shadows to the east of the massive Andean chain, and the Pacific side with >600 mm/y of precipitation is sparsely populated with few car roads. The mountain range of Andean Cordillera (Cordillera de los Andes) is very rainy with glacier caps, being protected as nature reserves.

The first author organises the present palynological investigation for the Chilean Patagonia as one of the 2002 fiscal-year overseas expeditions of the Natural History Museum and Institute, Chiba. This investigation is part of the four-year research project by Chuo University aiming to reconstruct the latest Mesozoic-Cenozoic vegetation history in southern South America. In Dec. 2002 to Jan. 2003, the southeastern coast of the Riesco Island (Isla Riesco) was investigated as a moisture transect. Similarly a mountain pass on the north of Lake Deseado near the Argentine border (54° 19′ S, 68° 49′ W, 200–

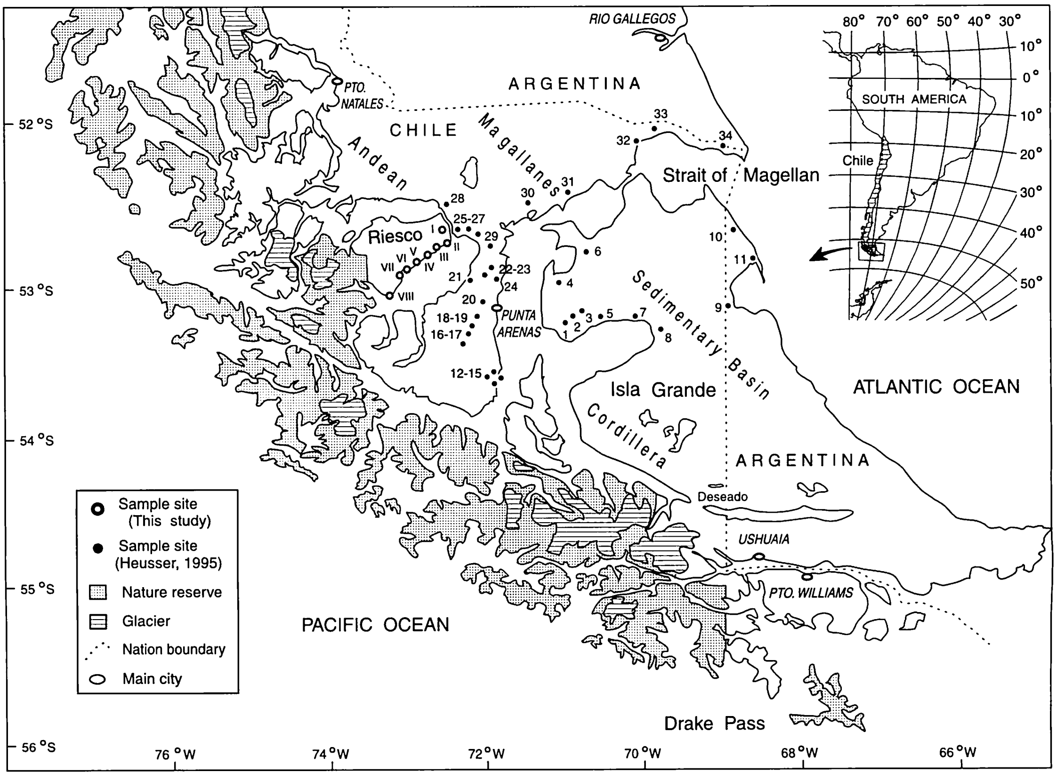

Fig. 1. Map of subantarctic Patagonia with sampling localities for this study (Ries I–VIII) and Heusser (1989, 1995).

800 m a.s.l.) was investigated as a temperature transect. In addition, we collected two borehole cores (Res-1 and Vic-1) of 5–6 m lengths near the investigated areas. In 2002–2003 the Riesco Island was connected with the mainland by a car ferry, being one of the areas of Pacific Patagonian regions that were barely inhabited allowing scientific surveys with short-term stays. The Riesco surface-pollen series is the theme of this paper, while other collected samples will appear in separate articles.

Geomorphology, Climate and Vegetation for Southern Patagonia

Southern Patagonia consists of two major geological units: the Andean Cordillera mountain range and the Magallanes sedimentary basin (see Fig. 1). The Andean Cordillera forms the Pacific and polar sides of southern Patagonia, with the altitudes of 1,000–2,500 m above sea level. Generally acidic igneous (and metamorphosed) rocks of Palaeozoic to Cretaceous ages constitute this mountain chain (Fig. 2a). The Magallanes sedimentary basin is an undulating plain extending in the Atlantic region consisting of Tertiary to Quaternary sediments (silt, sand, loess, till, glacial debris, etc.). These are frequently overlain with brown prairie soil akin to chernozem, whereas the soils of Cordillera massifs are more leached with significant podzolisation and peat formation. The highest mountains of the central/coastal Cordillera have glacier caps that probably grew to an ice sheet advancing to the Atlantic coast during Pleistocene glaciations. The Pacific coast is very broken with innumerable number of fjords, canals and islands, hidden in the persisting mist and rain (Tuhkanen *et al.*, 1990).

The climate of subantarctic Patagonia is characterised by the extreme oceanity with a SW-NE gradient resulting from its unique geographical configurations. The landmass intruding into the southern ocean is exposed to prevailing westerly winds through the year, which are generated by the circum-Atlantic low-pressure system. The NW-SE oriented Andean Cordillera chain stems the westerly winds, providing continental climate to the Magallanes sedimentary basin. More detailed climate features for subantarctic Patagonia is understood in the coastal lowlands. The Pacific and polar coasts generally enjoy mild winters under oceanic environments, with 2–4℃ of mean coldest month temperatures (Fig. 2b). By contrast, their summer temperatures do not exceed 9–10℃ in the warmest months (Fig. 2c), resulting in cool and long plant-growing seasons in the Pacific region (Fig. 2d). The prevailing winds reduce their influences to the east of the Andean chain, although the coldest month temperatures along the Strait of Magellan (Estrecho de Magallanes) are still above the freezing point. The warmest month temperature in the Atlantic side increase to *ca.* 12℃ at Rio Gallegos (Argentina). Concerning precipitation, the Pacific and polar sides receive at least 1,000–2,000 mm/y under humid westerly winds, and the precipitation amounts to 4,000–5,000 mm/y in some glaciated areas (Fig. 2e). On the contrary, a regional rain shadow exists to the east of the Andean Cordillera, with rainfalls of less than 500 mm/y. Precipitation reduces to 200–300 mm/y around the eastern mouth of Strait of Magellan. In southern Patagonia the meteorological stations with considerable observation periods are restricted to coastal areas, unfortunately so reliable climate data for inner regions are lacking. Nevertheless, as low as −2 to −4℃ of the coldest month temperatures are suggested for the interior parts of Isla Grande and the Patagonian mainland by integrating knowledges of geomorphology, macroclimate and vegetation (Tuhkanen *et al.*, 1990).

From the steep precipitation gradients, four regional vegetation zones are resulted for southern Patagonia: (1) the Magellanic moorland, (2) evergreen rain forest, (3) deciduous forest and (4) Fuego-Patagonian steppe, from southwest to northeast (Fig. 2f). The Magellanic moorland (or Tundra Magallanica) extends along the Pacific coast with fierce westerly gales and poor drainage as a consequence of very high rainfalls (2,000–5,000 mm/y). This comprises a mosaic of blanket bogs dominated by dense, low cushion plants of *Astelia*, *Bolax*. *Caltha*, *etc.* as well as rather grass-like (graminoid) bogs of Cyperaceae and Juncaginaceae. In many sheltered areas, fragmentary tree communities occur

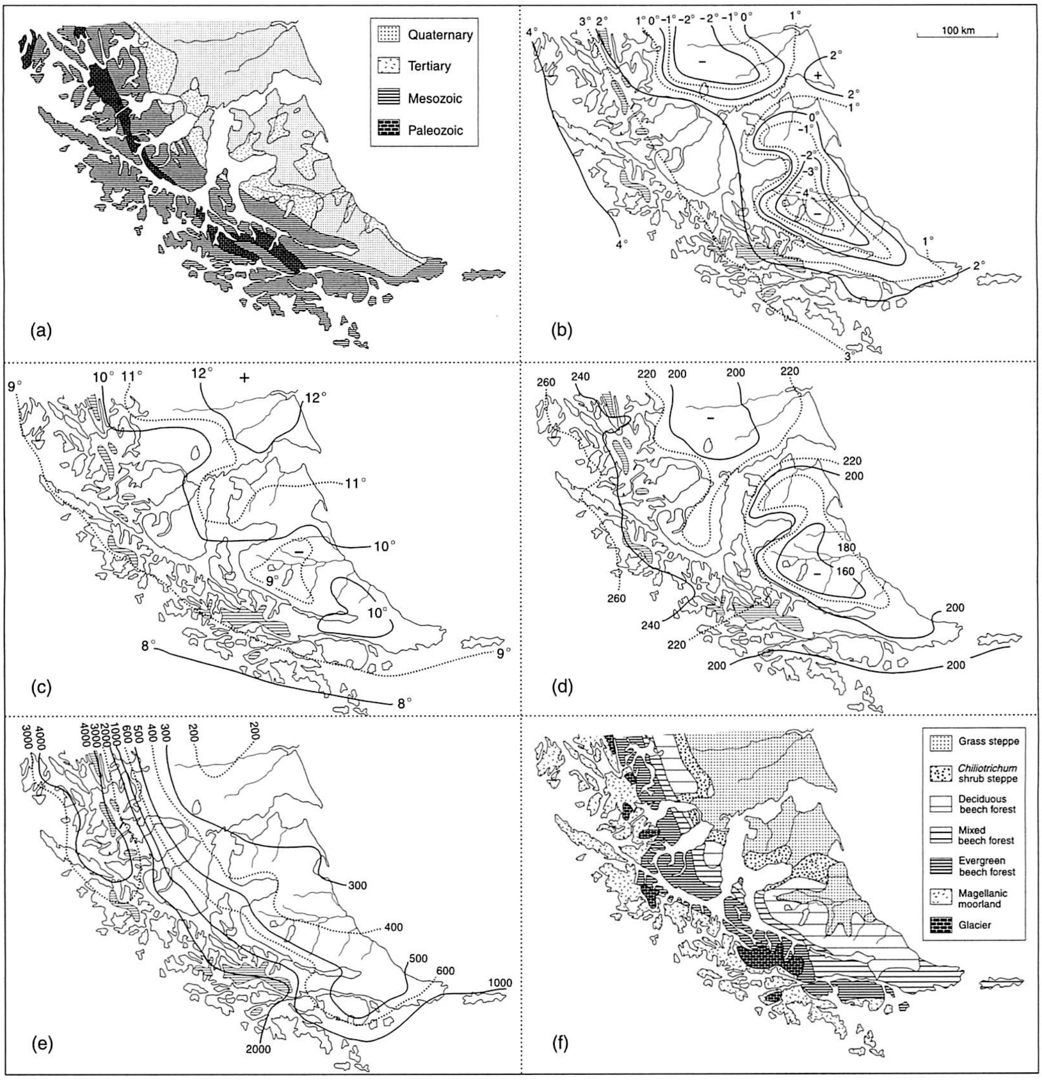

Fig. 2. Geographical properties of subantarctic Patagonia (summarised from Tuhkanen *et al.*, 1990). (a) Geological map; (b) Mean temperature for the coldest months (July–August); (c) Mean temperature for the warmest months (January–February); (d) Thermal growing season (delimitated on the basis of daily means over 5℃; (e) Annual precipitation in mm; (f) Regional vegetation types.

consisting of *Nothofagus betuloides*, *Drimys winteri*, *Pilgerodendron etc.* To the east, the areas with *ca.* 800–2,000 mm/y of precipitation are dominated by dense forest of evergreen southern beech (*Nothofagus betuloides*). *Drimys winteri* is important in coastal areas forming a mosaic of *N. betuloides-Drimys* coastal forest. *Maytenus* and *Embothrium* are other important components. *Pilgerodendron* occurs when the soil becomes boggy. On the east of 800–850 mm/y of precipitation level, deciduous southern beeches (*N. pumilio* and *N. antarctica*) coincide with *N. betuloides.* This evergreen-deciduous mixed forest gives way to pure deciduous forest of *N. pumilio* where rainfalls reduce to 400–600 mm/y. *N. antarctica* is also an element of this deciduous beech forest, though it rarely exceeds 6 m in height. *Misodendrum* parasites *N. pumilio* branches. In open spaces and forest margins, *Chiliotrichum*, *Berberis*, *Fuchsia* and *Ribes* form shrub layers together with juvenile southern beeches. The last of 4 major vegetation types (the Fuego-Patagonian steppe) consists of tussock grasslands covering the rain shadows in Argentina and part of Chilean Patagonia (<*ca.* 350 mm/y in precipitation). The grassland is dominated by *Festuca gracillima* and various grass species associated with *Acaena*, *Armeria*, *Erigeron*, *Senecio*, Silene, *Taraxacum*, *Valeriana*, *etc.* In transitional zones with 350–400 mm/y in precipitation, abundant *Chiliotrichum* forms shrub stands (Moore, 1983; Tuhkanen *et al.*, 1990).

Study Area

Eight sampling sites (Ries I–VIII) were settled along the southeastern coast of the Riesco Island (Fig. 3). Their latitudinal, longitudinal and altitudinal values are summarised in Table 1. Ries I–III are under dry conditions (<450 mm/y of precipitation) located within the grass/shrub steppe zones by Tuhkanen *et al.* (1990) (see Fig. 2e–f). In the present survey we observed open landscapes with abundant tussock grasses (*Festuca*, *Stipa*, *etc.*) associated with small shrub stands of *Chiliotrichum* and *Berberis*. The only tree taxon around Ries I–III was dwarf trees of *Nothofagus antarctica* less than 1–2 m tall. Ries IV–V receive 500–600 mm/y of rainfalls belonging to deciduous/mixed beech forest by Tuhkanen *et al.* (1990). We observed tall but sparse *Nothofagus pumilio* populations around Ries IV, forming open ‘park-forest’ with dwarf *N. antarctica* and grasses in understories. Ries V adjoined a scar of wild fire and the landscape was relatively open. Ries VI–VIII receive 600–1,000 mm/y of precipitation belonging to evergreen/mixed beech forest by Tuhkanen *et al.* (1990). We found the first *Nothofagus betuloides* tree in this route between Ries V and VI. To the west Ries VI–VIII were surrounded by dense *N. betuloides* forest with no *N. pumilio* or *N. antarctica*. *Drimys winteri*, *Dacrydium fonckii*, *Maytenus*, *Pilgerodendron*, *etc.* occurred around Ries VII–VIII. *Empetrum Pernettya*, *Berberis* and *Fuchsia* were main shrubs in this evergreen forest. There were no car roads beyond Ries VII so a rubber boat was chartered to reach Ries VIII. To the west of Ries VIII, tidal currents were too violent to go further with our transportation.

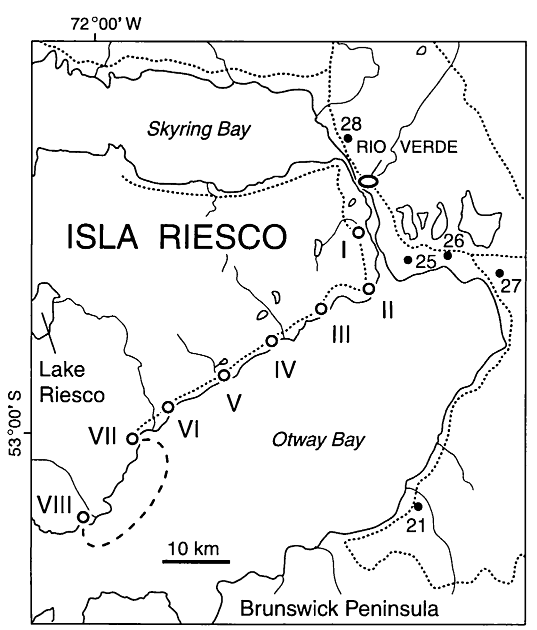

Fig. 3. Map of the eastern Riesco Island (Isla Riesco) with sampling localities (Ries I–VIII). Filled circles (nos. 21 and 25–28) indicate previous sites by Heusser (1995). A dashed line denotes the locus of our rubber boat. Dotted lines denote main roads (unpaved dirt tracks).

Table 1. Latitudinal, longitudinal and altitudinal values for the sample sites (Ries I–VIII), Riesco Island, subantarctic Patagonia, Chile.

Sample Loc. (Ries)	Latitude (S)	Longitude (W)	Altitude (a.s.l.)
I	52°45′	71°26′	<5 m
II	52°50′	71°24′	<5 m
III	52°51′	71°31′	<10 m
IV	52°54′	71°37′	<5 m
V	52°56′	71°43′	<5 m
VI	52°59′	71°51′	20 m
VII	52°02′	71°56′	<5 m
VIII	52°08′	71°02′	<5 m

Materials and Methods

Field survey and sampling for the Riesco surface-pollen series were performed in Jan. 2003. The surface samples generally consist of moss polsters from open spaces, substituted by dark-coloured surface soils when moss colonies were not common due to local conditions. In this survey we also collected native wild flowers that were in blooming seasons in order to produce modern pollen

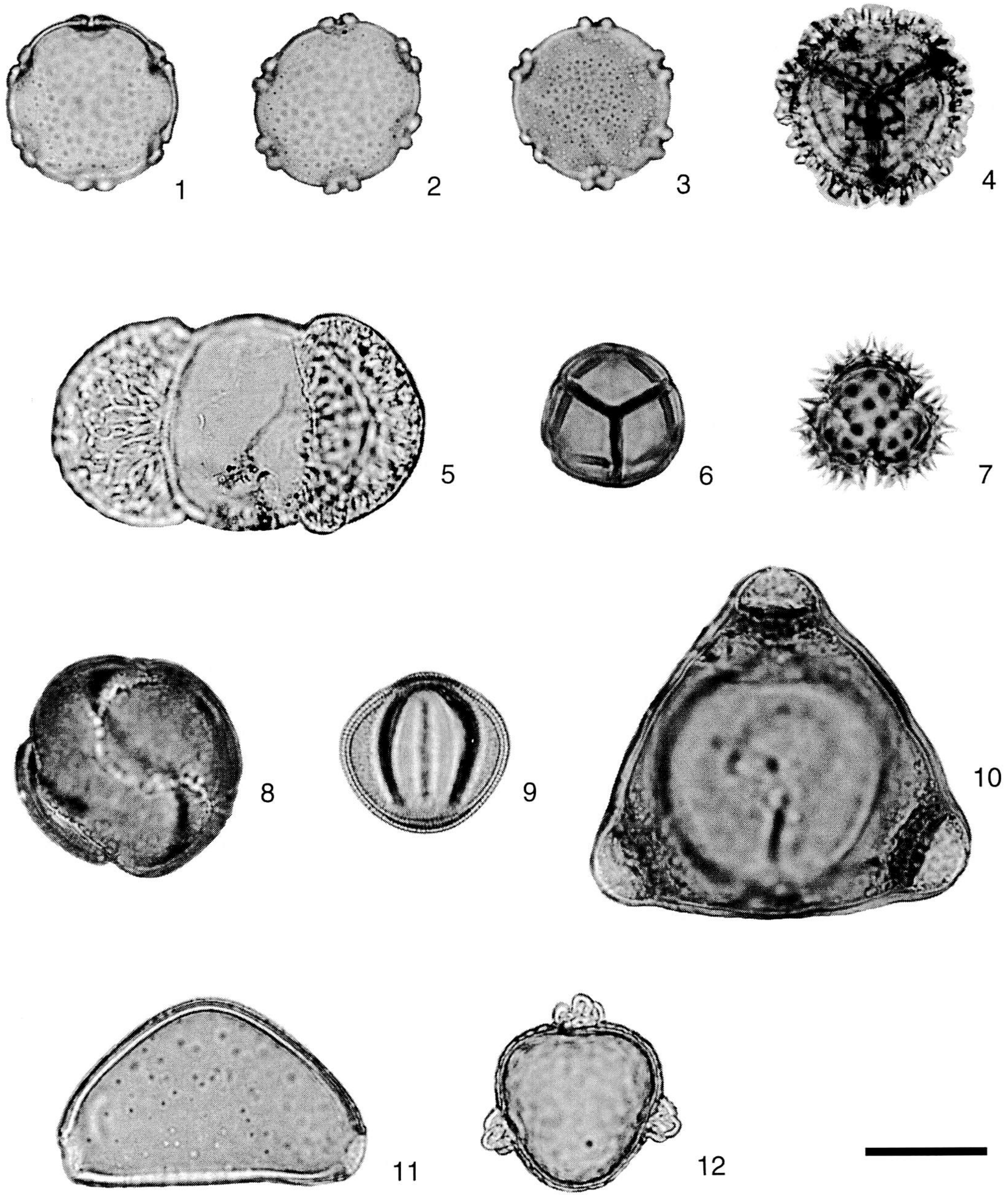

Fig. 4. Photomicrographs of major pollen types (scale: 30 μm). 1. *Nothofagus betuloides*, (Nothofagaceae) 2. *N. pumilio*, 3. *N. antarctica*, 4. *Drimys winteri* (Winteraceae), 5. *Podocarpus/Dacrydium*, (Podocarpaceae), 6. *Empetrum* (Empetraceae), 7. *Chiliotrichum* (Asteraceae subfam. Tubuliflorae), 8. *Berberis* (Berberidaceae), 9. *Gunnera* (Gunneraceae), 10. *Fuchsia* (Onagraceae), 11. *Embothrium* (Proteaceae), 12. *Acaena* (Rosaceae). Photographs of 1–3 and 6–12 consist of living pollen from wild flowers, whereas those of 4–5 consist of pollen remains from surface samples.

slides as a reference collection. Sample sizes for the surface materieals were 10–50 grams in dry weight. After sterilization the samples were brought to Japan, analysed at the pollen laboratory in the Natural History Museum and Institute, Chiba.

Pretreatment for pollen analyses followed the standard KOH-acetolysis method (Moore *et al.*, 1991). The moss and/or soil samples were boiled in 10% KOH solution and sieved by 250 μm meshes to remove remaining moss tissues and macroscopic charred fragments. Fossil pollen was extracted from heavier particles by heavy liquid flotation using saturated $ZnCl_2$ solution. Hot HF treatments were performed to remove siliceous impurities. Finally the samples were acetolysed and mounted with glycerol gelatin. Over 100–200 grains of arboreal and major non-arboreal pollen were counted for each sample, used as the pollen sum for percentage calculation. *Gunnera* pollen alone was excluded from the sum because it was probably an element of local swamp communities.

To accomplish reliable fossil pollen identification, the collected wild flowers were similarly pretreated, with extracted living pollen grains mounted and photographed (Fig. 4). *Nothofagus betuloides*, *N. pumilio* and *N. antarctica* were very similar in pollen morphology, summarised into *Nothofagus* sp. in this paper. This pollen type is the same as *Nothofagus fusca*-type (or Fuscospora) which has been termed in northern South America (and New Zealand) with more specific diversities including several *Nothofagus* pollen types such as *N. menziesii* and *N. brassii*-type (or Brassospora) (Hanks and Fairbrothers, 1976; Asakawa and Setoguchi, 2001; Okuda *et al.*, 2002). *Drimys winteri*, *Podocarpus/Dacrydium*, *Empetrum*, Tubuliflorae, *Berberis*, *Gunnera* and *Acaena* were other major pollen types. Poaceae pollen was not photographed, because this is a cosmopolitan group with no meaningful differences in pollen morphology even between Japanese and Patagonian grasses. The pollen atlas by Heusser (1971) was consulted as a supplement. The modern pollen slides were numbered mo-204 to mo-221, preserved in the Natural History Museum and Institute, Chiba.

Results and discussion

Results of pollen analysis for Ries I–VIII are shown in Figure 5. The diagram is dominated by two leading components (*Nothofagus* and Poaceae) with a significantly low palynofloral diversity. Ries I–III are dominated by Poaceae associated by Tubuliflorae and *Acaena*. *Nothofagus* shows the lowest value at Ries II (15.6%) but it is still abundant in this tussock-grass/shrub steppes. Ries IV–V, with open-forest landscape of deciduous southern beeches, show the coexistence of *Nothofagus* and Poaceae associated with shrub taxa such as *Empetrum*, *Berberis* and Tubuliflorae (probably *Chiliotrichum*). A few arboreal grains of *Drimys winteri* or *Maytenus* occur at Ries IV–V. Ries VI–VIII differ from the eastern sites by the high percentages of *Nothofagus* (>70%) and the abundance of *Drimys winteri*. Poaceae show the lowest values at Ries VII (3.9%). Minor trees (*Podocarpus/Dacrydium*, *Maytenus*, *etc.*) and shrubs (*Empetrum*, *Berberis*, *Fuchsia*, *Tubuliflorae*, *etc.*) associate this dense evergreen beech forest. *Gunnera* shows an irregular peak at Ries VIII.

To illustrate a larger-scale, more simplified pollen distribution, the three major tree, shrub and herb taxa (*Nothofagus*, *Tubuliflorae* and Poaceae, respectively) are extracted with their recalculated ratios combined with available data by Heusser (1995) (Fig. 6). This figure depicts the longitudinal palynofloral shift that almost traverses subantarc-

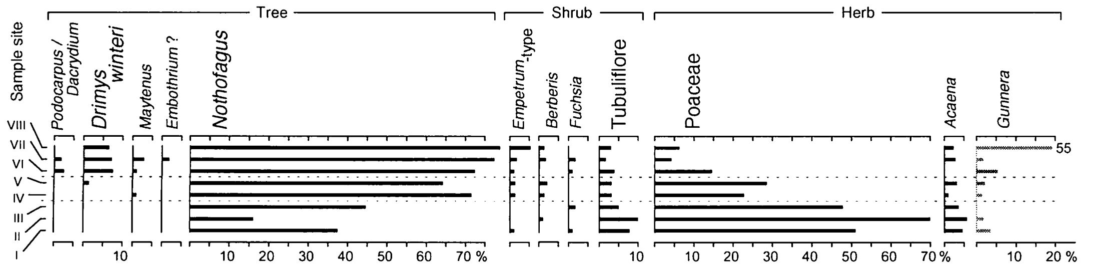

Fig. 5. Results of pollen analysis for surface (soil or moss-polster) samples (Ries I–VIII) from the Riesco Island, subantarctic Patagonia, Chile. *Gunnera* alone is extracted from the pollen sum for percentage calculation.

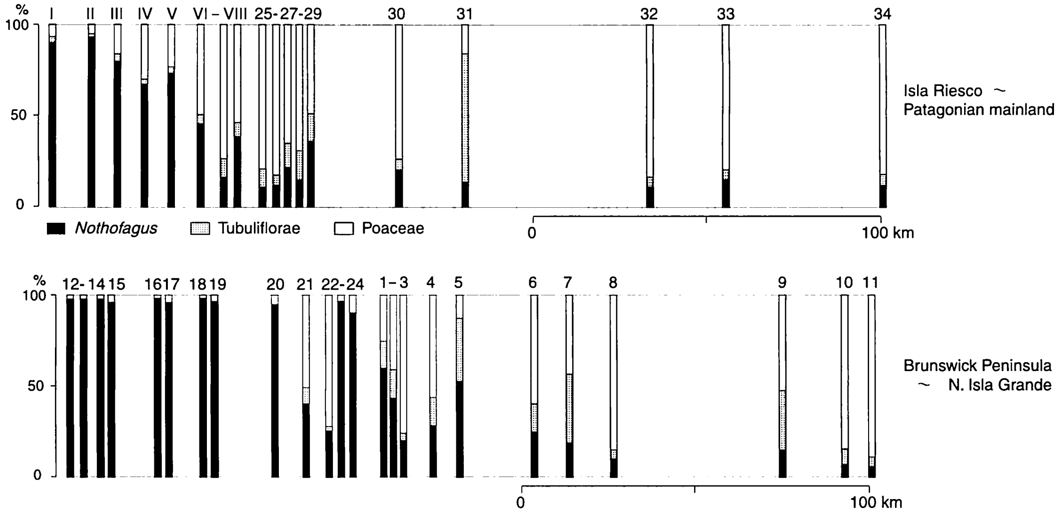

Fig. 6. Simplified surface pollen diagram consisting of three leading components for forest (*Nothofagus*), shrubland (Tubuliflorae) and herbfield (Poaceae). I–VIII denote the present data from the Riesco Island, whereas 1–34 denote previous data from eastern plains by Heusser (1995). The vertical axis means pollen percentages, while the horizontal axis means geographical distance in the longitudinal direction.

tic Patagonia along the east-west moisture/vegetation gradients. 50–99% of *Nothofagus* pollen is resulted from the evergreen beech forest of the Pacific region, whereas 70–90% of Poaceae pollen is shown in the grass steppe of the Atlantic region. Approximately 5–15% of *Nothofagus* pollen persists in every sample site apparently, even if it is in the midst of herbfield with no tree communities in the vicinity. This herbaceous palynoflora is so sparse in the pollen density that it is influenced by exotic *Nothofagus* pollen transported from western forested areas. The *Chiliotrichum*-shrub zone is not recognised in our data probably because of the strong influence of adjacent vegetation zones. In the eastern plains, nevertheless, the shrub steppe is represented by 30–70% of Tubuliflorae pollen (Heusser, 1995).

It is not directly possible to discriminate evergreen beech forest from deciduous forest palynologically, because *Nothofagus betuloides* is very similar to *N. pumilio* and *N. antarctica* in their pollen morphology. The discrimination becomes possible by relying upon *Drimys* pollen. *Drimys winteri* is an important associate of *N. betuloides* forest whose pollen is unique under the subantarctic Patagonian flora. The values of this pollen type are 0–1% in the mixed beech forest, and the regular occurrence of *Drimys winteri* (>3–5%) can be an evidence for the existence of evergreen beech forest. In addition, *Nothofagus* appears to show higher pollen values in evergreen beech forest than in mixed/deciduous forests. This is consistent with the open 'park forest' character of deciduous beech forest that differs from evergreen forest by their population densities.

There is a difference in *Nothofagus* values between the present and Heusser's (1995) data, especially in deciduous/mixed forest zones. *Nothofagus* shows 70–80% in Ries III–V but the values exceed 95% in sites no. 12–20 in the Brunswick Peninsula. This could be due to the difference in landscape openness, as the coastal areas of Riesco Island are under tree cutting and sheep grazing while the inland areas of Brunswick Peninsula have nature reserves that can produce native pollen rain with higher densities. Nevertheless, it is also possible that the Brunswick data might be taken from the inside of *Nothofagus* forest, rather than from open spaces aiming to reflect the average regional vegetation surrounding the sample sites. Some supplementary researches may be required before the whole existing data are reconciled.

The relations between pollen assemblages and climate (especially precipitation) are as follows, based on the combination of the present and Heusser's (1995) data. A humid climate with 600–1,000 mm/y of precipitation, allowing the growth of *N. betuloides*, is expressed by 80–95% of *Nothofagus* pollen and the regular occurrence of *Drimys winteri* with >3–5% in values. Other tree associates are still rare in this precipitation level. A semi-arid climate with 400–450 mm/y of precipitation, corresponding to the ecotone of deciduous beech forest and shrub/grass steppes, shows the coexistence of *Nothofagus*, Tubuliflorae and/or Poaceae, of which the pollen ratios are very changeable between 10–90%. Arboreal pollen except *Nothofagus* is absent in this precipitation level. An arid climate with <300 mm/y of precipitation, corresponding to grass steppe near the Atlantic coast, is characterised by the dominance of Poaceae with 70–90% in pollen values. *Nothofagus* pollen occurs even if the rainfalls are insufficient for the growth of southern beech. Extra-humid Pacific coasts with 1,000–3,000 mm/y of precipitation would characteristically yield *Pilgerodendron* or *Embothrium* grains, but that areas can hardly be reached due to the lack of transportation except a private charter boat, unfortunately.

Conclusions

This paper illustrates the relations among modern pollen assemblages, vegetation and climate along an east-west regional transect for southern Patagonia, based on pollen analyses for surface soils or moss polsters collected from southeastern Riesco Island, Chile. This area is chosen because of the steep longitudinal gradients of precipitation (*ca.* 450–1,000 mm/y) and vegetation zones from evergreen rain forest to dry grasslands. A significant consequence is the characteristic occurrence of *Nothofagus* and *Drimys* pollen as a key for palynological discrimination between evergreen (*N. betuloides*) and deciduous (*N. pumilio* and *N. antarctica*) beech forests. The arid steppe (<300–400 mm/y of precipitation) near the Atlantic coast is supplemented with available data by Heusser (1989, 1995), and a nearly sufficient coverage is resulted for the subantarctic Patagonian vegetation zonation. The Riesco series is merely a part of our materials, and in the 2002–3 expedition an altitudinal (*i.e.*, temperature) transect series and borehole cores are also collected, as materials of our subsequent palynological works for Late-Quaternary palaeoclimate reconstructions. Subantarctic Patagonia is one of the southernmost vegetated areas with the climate history being significant to understand the high-latitude Southern Hemisphere climatic system, which would be one of the triggers for global climate changes and sea level rises in the next centuries.

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チリ共和国パタゴニア南部リエスコ島における表層花粉調査

—特にパタゴニアの植生・気候（降水量）と表層花粉群集の相関について—

奥田昌明[1]・西田治文[2]・植村和彦[3]
矢部　淳[4]・山田敏弘[5]・Miguel Rancusi H.[6]

[1] 千葉県立中央博物館
〒260-8682 千葉市中央区青葉町 955-2
E-mail: okuda@chiba-muse.or.jp
[2] 中央大学理工学部
〒112-8551 東京都文京区春日 1-13-27
[3] 国立科学博物館新宿分館地学研究部
〒169-0073 東京都新宿区百人町 3-23-1
[4] 福井県立恐竜博物館
〒911-8601 福井県勝山市村岡町寺尾 51-11

[5]東京大学理学部生物科学科
〒113-0033 東京都文京区本郷 7-3-1
[6]マリア・セミナリオ高等学校
チリ共和国サンチアゴ新市街 31 セミナリオ通

チリ共和国最南部フェゴ島西方のリエスコ島を中心に植生調査と土壌調査を行うと同時に，採取した表層試料（土壌あるいはセンタイ類群落）を花粉分析し，パタゴニア南部における植生・気候と表層花粉群集の相関について検討した．これは千葉県立中央博物館の平成 14 年度海外出張成果であり，中央大学の海外学術研究「南米南部における白亜紀以降の植生変遷の解明」(科研番号 14255007) に研究分担者として加わった結果である．ナンキョクブナ属の常緑種 (*Nothofagus betuloides*) による大森林が成立しているパタゴニア南部の太平洋側は，年降水量 600–1,000 mm の湿潤域に相当し，表層花粉群集では *Nothofagus* (*fusca*-type) と *Drimys winteri*（シキミモドキ科）の多産が特徴的だった．それ以外は *Podocarpus/Dacrydium*（マキ科），*Maytenus*（ニシキギ科）をわずかに産する程度で，樹木花粉群集の多様性はこの降水量域ではまだ低かった．その東側，ナンキョクブナ属の落葉種 (*N. pumilio, N. antarctica*) がキク科灌木 (*Chiliotrichum*)・イネ科草本 (*Festuca, Stipa* など) と疎林を形成する地域は，年降水量 400–450 mm の半乾燥域にあたり，表層花粉は *Nothofagus*, Tubuliflorae, Poaceae の混合群集で特徴づけられた．その混合比は大きなばらつきを示し，木本花粉は *Nothofagus* を除き完全に消滅していた．これに対し，年降水量が 300 mm に満たずイネ科による大草原（乾燥ステップ）が成立する大西洋側では，ナンキョクブナ属が全く生育していないにもかかわらず *Nothofagus* 花粉がイネ科花粉群集に一定の割合で随伴した．大西洋側の乾燥ステップは植皮率が低い上，偏西風の風下にあたるため太平洋側の森林域からくる遠距離飛来花粉の影響を強く受けていると考えられる．