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Cretaceous Floras from Snow Island (South Shetland Islands, Antarctica) and Their Biostratigraphic Significance

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Abstract - New investigations of the President Head flora from Snow Island, South Shetland Islands, and the discovery of 16 new palaeobotanical localities are presented. Its preliminar systematic composition has been investigated through palynology, palaeoxylology and plant megarfossils (leaves, stems, cones, etc.) while a new age, Valanginian-Hauterivian is proposed. Palaeoecological inferences are also discussed. This rich and diverse flora is a key-point for Antarctic Mesozoic palaeobotany.

Keywords: *fossil wood, palynology, palaeobotany, Cretaceous, Antarctica*

INTRODUCTION

The South Shetland Archipelago is one of the most important areas for palaeobotanical research in Gondwana. In this region, there is evidence of Mesozoic and Cenozoic vegetation. The Mesozoic palaeobotanical record starts with a Late Triassic flora at Williams Point on Livingston Island, the age of which is characterized by several species of *Dicroidium* and other typical genera as *Linguifolium* (Orlando, 1967, 1968; Lacey and Lucas, 1981; Barnerji et al., 1987; Barale et al., 1994, 1995). However, on the same headland, there are also Upper Cretaceous sediments with angiosperm fossil woods and dicotyledon leaf impressions characteristic of a Cretaceous age (Lemoigne & Torres, 1988; Torres & Lemoigne, 1989; Rees & Smellie, 1989; Chapman & Smellie, 1992; Philippe et. al., 1993). Other Cretaceous flora, from both Early and Late Cretaceous, are known in different places (see review in Philippe et al., 1995). For the Cenozoic, the Tertiary flora of King George Island is one of the richest in number of species (Torres, 1985, 1990; Birkenmajer & Zastawniak, 1989). The presence of Jurassic flora is questionable (Kelly, 1995; Philippe et al., 1995). The area of South Shetland has a strong palaeobiogeographical interest. Indeed, it served as a land bridge, assuming an important role in continental biota dispersion (Hill & Scriven, 1995).

The Morton Strait area of the South Shetland Archipelago is of particular interest for its volcano-sedimentary strata yielding fossil plants, interbedded with marine strata that contain elements for accurate dating (Smellie et al., 1980; Smellie et al., 1984; Smellie & Thomson, 1985; Thomson, 1992; Crame et al., 1993; Duane, 1994). Volcanic event strata also contribute to accurate dating (Pankhurst et al., 1979; Santanach et al., 1992). It is one of the few areas for the Gondwana region with accurate dates of continental deposits.

In January 1995, during a field trip organized by the Instituto Antártico Chileno (Torres et al., 1995), we were able to reinvestigate the classical locality for fossil plants on President Head, Snow Island, previously discovered by Araya and Hervé (1965, 1966). Later Fuenzalida et al. (1972), Elliot and Askin (1980) and Askin (1983) studied this classic outcrop. Our investigation allowed us to make new geological observations and to collect numerous new samples for palynological studies. This new material included fossil woods and plant impressions. Moreover, careful prospecting of the President Head area led us to the discovery of new fossiliferous localities. These new elements make the President Head area a key-point for the palaeobotany of Antarctica. The President Head flora is a rich and varied Gondwanan one. This flora, which was previously thought to be Middle Jurassic or Neocomian in age, (Fuenzalida et al. 1972) belongs to the Early Cretaceous period. The President Head flora is well dated and is important for comparative dating of the numerous Antarctic Mesozoic floras for which currently the age is not accurately known.

FIELD DATA AND GEOLOGICAL SETTING

President Head (62°44'S, 61°12'W) is the easternmost headland of Snow Island (Fig.1). The palaeobotanical site is located on the northern side of the headland. In addition, in this locality sixteen other new outcrops, yielding fossil plants, have been found (Fig. 1). Two of them, however, site F and Hall Peninsula, are not located exactly on President Head. At site F (Fig. 1), fossil plants were found among a small moraine patch. Approximately three kilometers to the south are Hall Peninsula and a low-lying unnamed promontory. In the marine terraces of Hall Peninsula (site N), fossil wood frequently occurs, usually as angular boulders. These reach 50 cm in length and

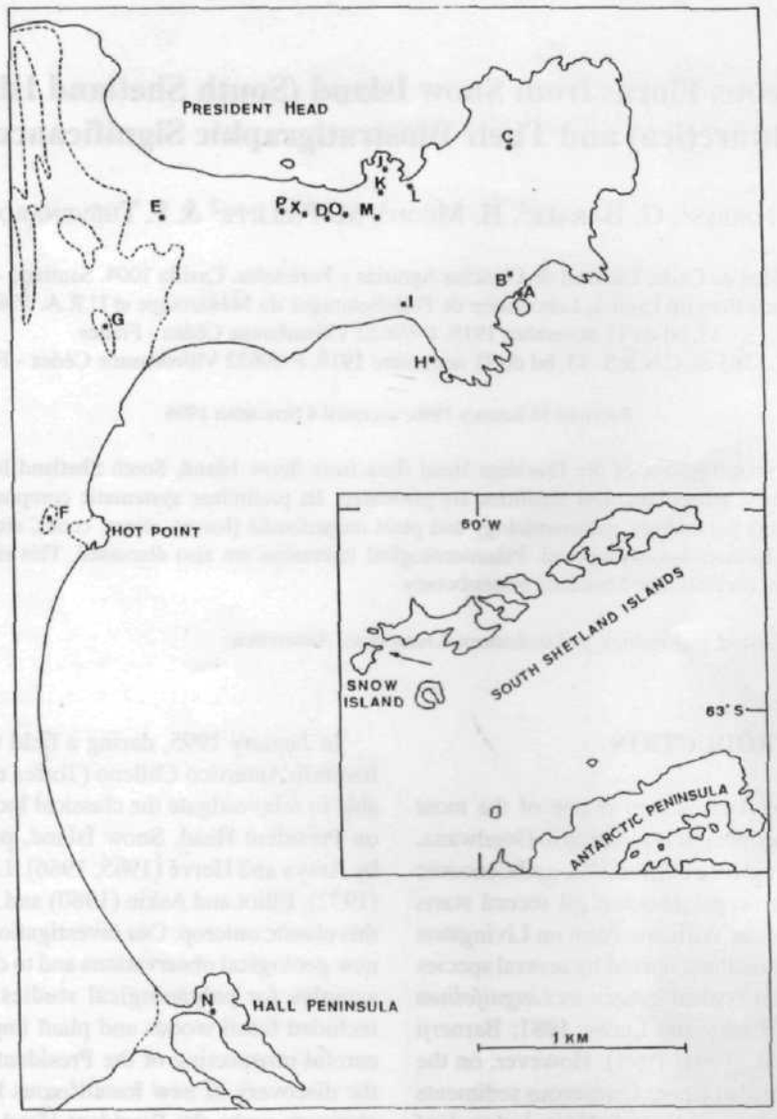

Fig.1 - President Head and Hall Peninsula, Snow Island, South Shetland Archipelago, Antarctic Peninsula.

30 cm in diameter. Fossil wood has not been found in the adjacent moraines. A volcanic agglomerate has been observed, cropping out just a little below the low-tide level, just in front of site N. All the numerous fossil wood specimens show the same type of fossilization and probably come from this agglomerate, although none of these were actually found *in situ*. The 15 other outcrops are scattered throughout President Head. Their palaeobotanical content is variable, sometimes containing only one species, sometimes as many as 17 species.

During our 1995 expedition to Snow Island, due to exceptional climatic conditions, it was possible to follow the volcano-sedimentary sequence from the lowest part of a narrow gorge (site P) up to the classical outcrop (sites D and O). There is apparently no unconformity along the sequence, despite a change from marine-dominated sediments towards volcanic-dominated sediments in the upper part of site P. In the lowest part of the gorge, dark mudstones crop out, with iron-stained levels, interbedded with fine greenish sandstones. Cone-in-cone calcite layers also occur, along with rounded mudstone concretions that include coarse sandstone laminae (Fig. 2). This lithology is strongly reminiscent of the basal Sealer Hill Member of the Chester Cone Formation on Byers Peninsula (Crame et al., 1993). The lithology is also identical to the Chester Cone Formation locality found on President Head (site E), 500 meters west of the above-mentioned narrow gorge (Thomson, 1992). In the basal mudstones of site P we found a wood species which we also encountered in site E (*Araucarioxylon* sp.).

Unlike those on Byers Peninsula, the basal mudstones of site P abruptly pass up into a dark volcanic agglomerate containing a dark matrix as well as contrasting, pale, angular, millimetre-scale volcanic elements. Going upward, the matrix becomes paler and the grain size decreases. The upper levels of these volcanic agglomerates are interbedded with green-grey shales, tuffaceous sandstones and mudstone intercalations that yield fossil plants. No equivalent unit to the undifferentiated upper Chester Cone Formation has been observed. It is noteworthy that the entire section gently dips to the East, just as on Byers Peninsula. The base of the Sealer Hill Member in Byers Peninsula has been assigned by dinoflagellate cysts and spores to the early Valanginian

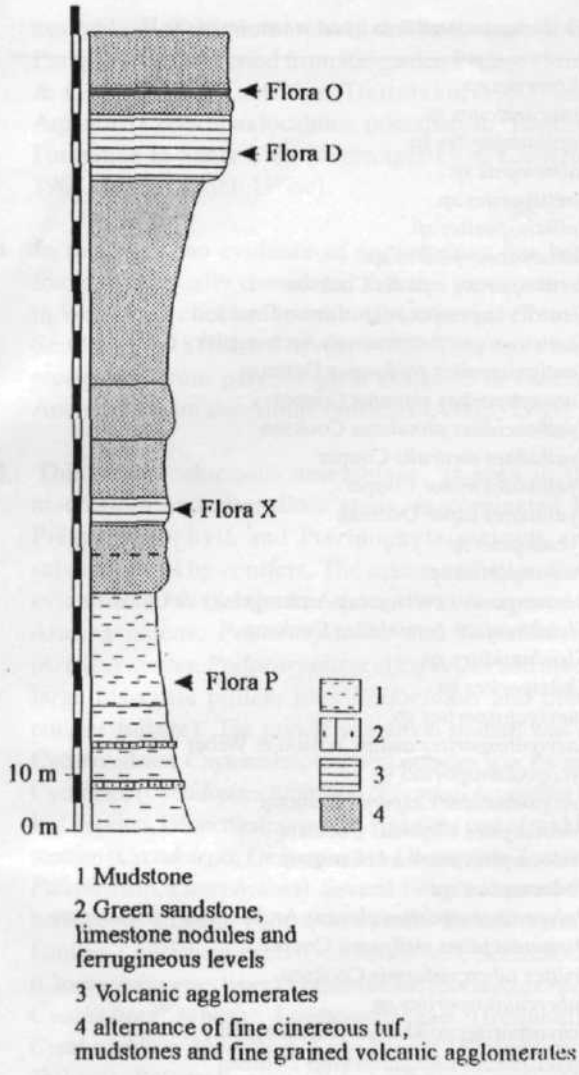

Fig. 2 - Lithological column in President Head, between sites O and P. 1, mudstones.2, intercalations of sandstones, ferrugineous levels and limestone concretions. 3, greenish to greyish shales, tuffaceous sandstones and mudstones intercalations. 4, fine to coarse volcanic agglomerates.

(Crame et al., 1993), but its upper part may have been formed as recently as the early Albian period (Duane, 1994). The volcanic rocks inserted in the sedimentary series of the area have been dated as Early Cretaceous age, between 102 and 120 million years old (Santanach et al., 1992).

The quality of the preservation and the occurrence of *in situ* roots, fern rhizomes, Bennettitalean stems, and numerous unsorted remains in the President Head flora, indicate that this flora was deposited very close to its source area. Evidence of insects and delicate plants supports the hypothesis of a freshwater environment (Cantrill, 1995).

PALAEOBOTANICAL DATA

LEAVES AND OTHER IMPRINTS

The macroflora assemblage is rich, varied, and often well-preserved. The Equisetales are represented by *Equisetum* stems and nodes. Filicales are also common and include: *Coniopteris*, *Gleichenites*, *Sphenopteris* and *Cladophlebis*. In addition, typical Pteridospermales like *Pachypteris* and *Kachchhia* are represented. Of the Cycadales, only *Nilsonia* has been found, located solely within the classical locality. The most abundant group are the Bennettitales, represented by *Otozamites*, *Cycadolepsis*, *Dictyozamites*, *Ptilophyllum* and *Zamites*. Some Bennettitalean stipes have been observed in outcrop D, as impressions reaching forty centimeters in length. There are some conifers, such as *Elatocladus* and other foliage. No evidence of Angiosperms has been found.

PALAEOXYLOLOGY

Many type of fossil wood have been found for the first time (not all *in situ*) in seven different sites on President Head (sites A, C, E, G, L, N, P). They are diverse, though there is a poor correspondence with the leaf types. They are all tracheidoxyls, but are not all related to conifers. *Sahnioxylon* could possibly be a Bennettitallean wood, however it may also belong to another group. The *Protopodocarpoxylon* we encountered may also not be a conifer, as its wood structure is quite peculiar.

Only significant anatomical details are described here; full descriptions and taxonomy will be published elsewhere. Sample numbers with 3 digits are in MP collection at Lyon-1 University (France) whereas other samples are in TT collection at Universidad de Chile, Facultad de Ciencias Agrarias y Forestales, Santiago (Chile).

Araucarioxylon arayai Torres et al. (1982)
Sample - A 1

Secondary wood with distinct growth rings. Uniseriate rays, locally biseriate. Resinous tracheids are abundant. Tracheid radial wall pits are uniseriate and biseriate alternate. Cross-field pits cupressoid. This typical araucarian wood was described from Cerro Negro (Torres et al., 1982) on Byers Peninsula on Livingston Island. There are no significant anatomical differences between this form and the wood found on President Head. In Cerro Negro, the fossil wood was included in tuff and ignimbritic levels, located in the upper part of a continental sequence, whose lower strata interfingered with Valanginian ammoniferous marine sediments. K-Ar ages are 107 +/- 10 Ma (Pankhurst et al., 1979).

Araucarioxylon sp. A
Samples - 584, 588, 589, 591, 604, 606, 607, 609, 613

Another common araucarian wood is distinguished by its radial alternate biseriate and mostly uniseriate pitting and cross-field with fewer pits (usually 2 to 5). This species is widely distributed on President Head and Hall Peninsula.

Brachyoxylon sp. B
Samples - Phall 5, 505

Araucarioid cross-fields and radial pitting of mixed type characterize this wood. This is the first mention of this genus for Antarctica.

Circoporoxylon sp. C
Samples - Phall 2, C tronco in situ C1, 585, 610, 611

Radial pitting is abietinean with few araucarioid pits. There are some Sanio's rims. One circopore occupies each

early wood cross-field and a cupressoid oculipore each late wood cross-field.

Protocircoporoxylon sp. D
Samples - 595, 596, 602

Although quite similar to the *Circoporoxylon*, this wood has a mixed type of radial pitting, with dominance of the araucarioid type. On President Head, this species was found in sites N and E, thought we had previously found it in a Valanginian locality on Byers Peninsula (site 7 in Covacevich, 1976).

Protopodocarpoxylon sp. E
Samples - A 3, A 7, 600, 603, 612, 650

Because of its podocarpoid cross-fields and mixed type radial pitting, this wood is assigned to the form-genus *Protopodocarpoxylon*. However, the pits in cross-fields are quite variable, just as the radial pitting is. This variability is sometimes encountered by extant *Podocarpaceae*.

Sahnioxylon sp. F
Samples - A 4 and A 10

This fossil wood exhibits secondary xylem with marked growth rings. The growth rings are divided into a dark latewood zone and a pale earlywood zone. The rays are homogeneous, mainly uniseriate, 1 to 30 cells in height. Tracheids have scalariform type pitting and 1-3 seriate areolate pits. Cross-fields in the latewood are with 1 or 2 pits, whereas 6 to 10 pits exist in the earlywood. This wood is particulary interesting, and is very similar to *Sahnioxylon rajmahalense* (Bose & Sah, 1954) found in the Rajmahal Hills (India, Lower Cretaceous age). The genus is also known in New Caledonia (Upper Triassic and Lower Jurassic, Salard, 1968 ; Vozenin-Serra & Salard-Cheboldaeff, 1992) and from Livingston Island of South Shetlands (Turonian-Santonian; Lemoigne & Torres, 1988; Torres & Lemoigne, 1989; Philippe et al., 1993).

PALYNOLOGY

Preliminary palynological investigation of two samples shows a rich terrestrial flora (Tab. 1) with an abundance and diversity of cryptogam spores (70%). The majority of fern spores can be assigned to *Cyathidites-type* (53%). The conifer palynomorphs are dominated by bisaccate pollen of podocarpaceous affinity (10%). Nonsaccate pollen of the *Araucariaceae* type (2%) also occurs. Other saccate and monosulcate pollens with pteridosperm affinities are frequent (16%). No dinoflagellate cyst species were found in these samples.

Tab. 1 - Sporomorph flora found in samples of site D.

Alisporites sp.
Araucariacites sp.
Baculatisporites sp.
Balmeiopsis sp.
Biretisporites sp.
Callialasporites sp.
Camarozonosporites sp.
Ceratosporites equalis Cookson
Cicatricosisporites australiensis Cookson
Cicatricosisporites ticoensis Archangelsky & Gamerro
Contignisporites cooksonae Dettman
Concavisporites sinuatus Couper
Cyatheacidites annulatus Cookson
Cyathidites australis Couper
Cyathidites minor Couper
Cyathidites asper Dettman
Cycadopites sp.
Dictyosporites sp.
Densoisporites corrugatus Archangelsky & Gamerro
Gleichiniidites cercinidites Cookson
Gleichiniidites sp.
Klukisporites sp.
Laevigatosporites sp.
Laevigatosporites ovatus Wilson & Weber
Lycopodiumsporites sp.
Lycopodiacidites asperus Dettman
Podocarpites ellipticus Cookson
Podocarpites marwicki Cookson
Podocarpites sp.
Polypodiaceosporites elegans Archangelsky & Gamerro
Osmundacidites wellnamii Couper
Trilites tuberculiformis Cookson
Tuberculatosporites sp.
Schyosporites volkheimeri Archangelsky
Stereisporites antiquasporites Dettman

DISCUSSION

The palaeobotanical results in President Head Flora allow many inferences about age and palaeoecology:

1. According to their palaeobotanical contents, the localities are probably of the same age. The fossil plants show a similarity with Upper Jurassic - Lower Cretaceous floras found on Livingston Island (Hernandez & Azcarate, 1971), in Hope Bay (Halle, 1913 ; Gee, 1989, Birkenmajer, 1993), Antarctic Peninsula (Jefferson, 1981; Baldoni, 1978, 1981, 1986; Baldoni & Medina, 1989; Gee, 1992) and even in India (Bose et al., 1990).

2. By the palaeoxylological study, three types of wood (*Araucarioxylon arayai* Torres et al., 1982, *Araucarioxylon* sp. and *Protocircoporoxylon* sp.) have been recognized which were already known in outcrops of Cretaceous (Valanginian) age on Byers Peninsula (Philippe et al., 1995). *Brachyoxylon* is discribed for the first time from Antarctica. *Sahnioxylon* Bose & Sah, a genus of phytogeographical significance, is found on the South Shetland Islands for the second time. It is also noteworthy that wood from President Head does not resemble any of the woods previously described from the Upper Cretaceous period of West Antarctica, like *Microcachryoxylon gothani* (Torres et al., 1994) or the wood from Williams Point on Livingston Island (Torres & Lemoigne, 1989; Chapman & Smellie, 1992; Torres, 1993).

3. Palynology points to an early Cretaceous age, and is consistent with a Valanginian-Hauterivian age. The

assemblage of palynomorphs is similar to those of the Early Cretaceous period from Kerguelen Plateau (Mohr & Gee, 1992), Australia (Dettmann, 1963) and Argentina Cretaceous localities, principaly the Baquero Formation in Santa Cruz (Archangelsky & Gamerro, 1965, 1966a, 1966b,1966c).

4. In this study no evidence of angiosperms has been found. It is usually considered that this group arrived in West Antarctica around the Albian period (Rees & Smellie, 1989 ; Hill & Scriven, 1995). They have been recognized from palynological evidence in western Antarctica from the Albian onwards (Askin, 1983).

5. This subautochtonous assemblage, as seen in the macroflora and microflora study, is dominated by Prespermatophyta and Pteridophyta remains and subdominated by conifers. The macro and microflora evidence shows that the tree stratum was composed of *Araucariaceae*, *Podocarpaceae* and *Taxodiaceae* (*Araucariacites*, *Podocarpidites*, *Alisporites* and much large bisaccate pollen, plus *Elatocladus* and other conifer foliage). The middle vegetation stratum was of Cycadeoidales, Caytoniales, Corytospermales species and Cycadales (*Cycadopites* types and *Nilsonia*). According to leaf imprints, Bennettitales were an important part of middle stratum (*Cycadolepis*, *Dictyozamites*, *Otozamites*, *Zamites*, *Ptilophyllum*, *Pterophyllum*). Several Filicales formed the herbaceous stratum. Fern spores found include several families : Gleicheniaceae (*Gleicheniidites*), Schizeaceae (*Cicatricosisporites* types), Osmundaceae (*Baculatisporites*, *Cyathidites* types), Lophosoriaceae (frequently *Cyatheacidites annulatus*), Lygodiaceae (*Klukisporites*, *Trilites*), Polypodiaceae (*Tuberculatosporites*). The macroflora include *Coniopteris*, *Gleichenites*, *Sphenopteris* and *Cladophlebis*.

CONCLUSION

Field results show that volcano-sedimentary rocks are more widely distributed on President Head than was previously supposed. The floras studied were rich and diverse, terrestrial, and probably growing around fresh-water lakes in a volcanic area. The Snow Island flora is an important contribution to the knowledge of Mesozoic palaeobotany. From our palaeobotanical, palynological and paleoxylological data, an Early Cretaceous age (Valanginian ?) is suggested for the sedimentary rocks of President Head.

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