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Reappraisal of the Triassic flora from Williams Point, Livingston Island (South Shetland Islands, Antarctica) : systematical, biostratigraphical and paleogeographical implications

GEORGES BARALE[1] , MARC PHILIPPE [1],TERESA TORRES[2] and FREDERIC THEVENARD [1].

ABSTRACT

The more extensive assemblage of fossil plants remains from the Northern part of Williams Point (Livingston Island, South Shetland Islands, Antarctica) is presented. Two different floras were found in the stratigraphical section. Flora 1 consists in six forms: Dictyophyllum, Cladophlebis, Scoresbya, Sagenopteris, Sphenobaiera, Pagiophyllum. *Flora 2 is more diversified with* Linguifolium steinmannii, *many forms of* Dicroidium *type, also a new species* Cladophlebis williamsensis *is recognized. The systematic composition indicates an Upper Triassic age. The autochthony of plants fossils is asserted and permit to infer and to revise the paleogeographical conditions for this region at the end of the Triassic.*

Key words: Triassic megaflora, new species, paleogeography, stratigraphy, Livingston Island, Antarctica.

Nuevos estudios sobre la flora triásica de Punta Williams, isla Livingston (Shetland del Sur, Antártica): Inferencias sistemáticas, bioestratigráficas y paleogeográficas

GEORGES BARALE [1] , MARC PHILIPPE [1],TERESA TORRES [2] y FREDERIC THEVENARD [1].

RESUMEN

Se da a conocer el conjunto más extenso de impresiones de plantas fósiles, recolectadas en dos niveles diferentes, en el Noreste de Punta Williams, isla Livingston, archipiélago de las Shetland del Sur. El nivel inferior denominado Flora 1, contiene formas afines a Dictyophyllum, Cladophlebis, Scoresbya, Sagenopteris, Sphenobaiera, Pagiophyllum. *El nivel superior denominado Flora 2 contiene numerosos taxa entre los cuales destacan una nueva especie* Cladophlebis williamsensis, *varios tipos de* Dicroidium *y* Linguifolium steinmannii. *La composición de la macroflora indica una edad Triásica Superior, para estos niveles. La autoctonía de las plantas permite inferir algunas consideraciones paleogeográficas para fines del Triásico, en esta región de la Antártica.*

Palabras claves: Megaflora triásica, nueva especie, paleogeografía, estratigrafía, isla Livingston, Antártica.

[1] Laboratory of Mesozoic and URA 11 of CNRS, Claude Bernard University, 43, Bd. of 11 November 1918, 69622 Villeurbanne Cedex, France.

[2] Laboratorio de Paleobotánica, Facultad de Ciencias Agrarias y Forestales, Universidad de Chile, Casilla 1004, Santiago, Chile.

INTRODUCTION

Williams Point, Livingston Island, South Shetland, has long been known for its particularly rich paleobotanical localities (Orlando, 1968). Until now, six outcrops yielding fossil plants have been located (A,B,C,D,E,F in Fig. 1) and studied (Orlando, 1968; Lacey and Lucas, 1981 ; Lemoigne, 1987; Banerji and Lemoigne, 1987; Lemoigne and Torres, 1988;Torres and Lemoigne, 1989; Rees and Smellie, 1989; Chapman and Smellie, 1992; Philippe *et al.*, 1993 ; Barale *et al.*, 1994). All the studies about the flora of one of these localities, A (= Loc. A, Lacey and Lucas, 1981), were in agreement about a Triassic age, until Rees and Smellie (1989), (Locality P.,1823) claiming angiosperm findings proposed a Cretaceous age. Most of the angiosperm leaves were in fact found in other localities. So, fossil woods of angiosperm types were found by Lemoigne and Torres (1988), Torres and Lemoigne (1989), and Chapman and Smellie (1992). In the locality A yielding only questionable fragments and an unidentified form (form «F») limited to this outcrop.

During a scientific expedition, organized by the Instituto Antártico Chileno (INACH) in January 1993, new material was collected at Locality A. *In situ* fossil plants were found for the first time. This new collection is one the most extensive assemblage for this locality and casts a whole new light on the deposit, its age, its paleoecologic and its paleogeographic significance.

After a systematic description of the fossils, we comment on these points and the implications of the age for the reconstruction of this part of Gondwana. Livingston Island is part of the South Shetland Archipelago, and it is located in the North West tip of the Antarctic Peninsula. Williams Point (62° 28' S., 60°09' W.) placed in its northeastermost part, is the type locality for the so-called Williams Point Beds (Hobbs, 1968; Smellie *et al.* 1984). This terrestrial sedimentary sequence crops out extensively there (Fig.1), and is intruded by numerous sills and vents. These make the understanding of the stratigraphy quite difficult. The six known fossil plant localities are all separated by the Late Cretaceous intrusions (Rees and Smellie, 1989).

Locality A (= Loc. A, Lacey and Lucas, 1981 ; = P. 101, Orlando, 1968 and P. 1823 by Rees and Smellie, 1989) consists of a dome, approximatively 100 m in diameter and 10 m in thickness, of greyish to whitish sandstones or mudstones. Contrary to what has been previously stated, material at

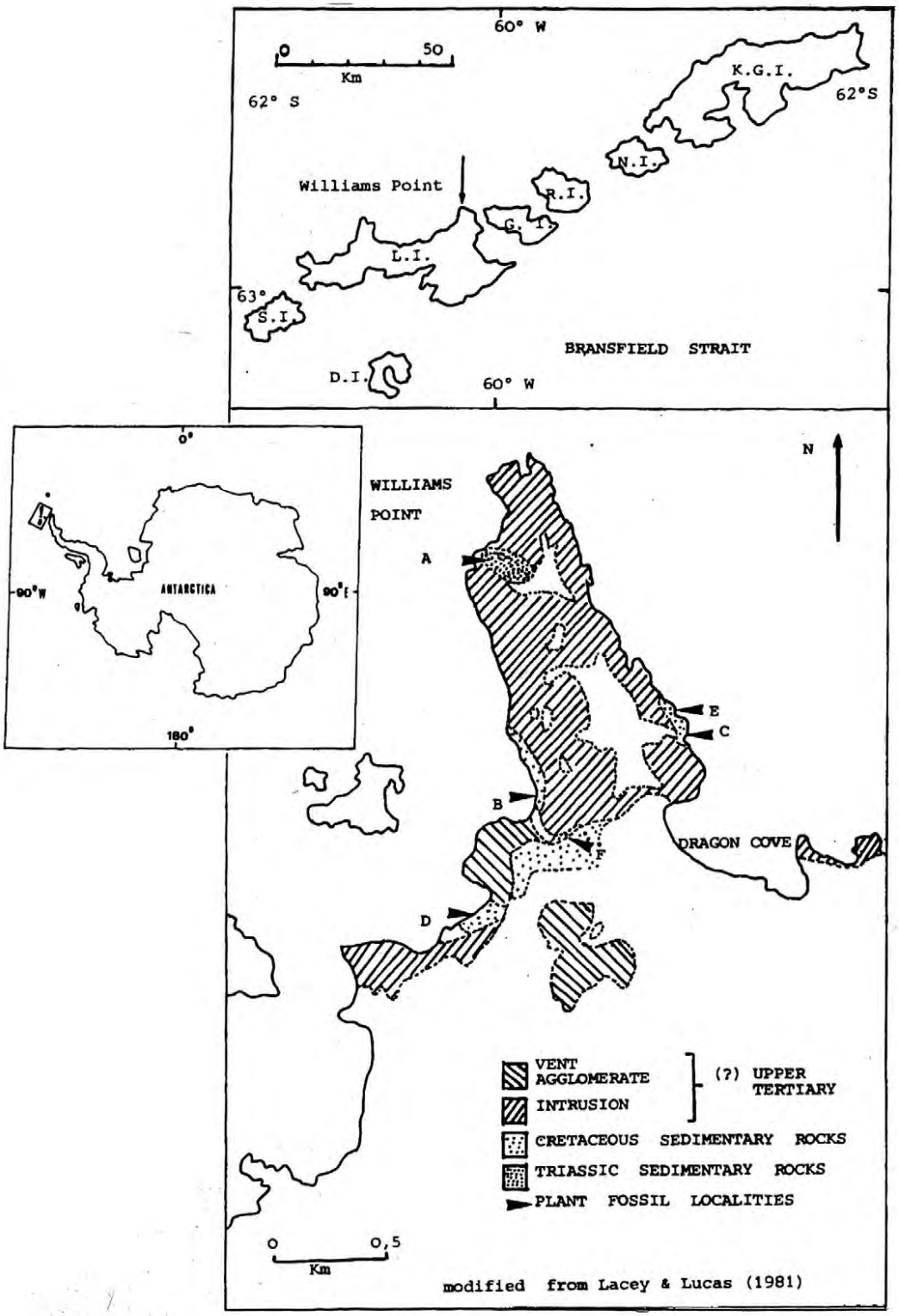


Fig. 1 - Position of the South Shetland Archipelago, in the North West head of the Antarctic Peninsula.
1Map showing the location of Livingston Island (L.I.) in the South Shetland Islands and fossiliferous sites of Williams Point (arrows). KGI. : King George Island ; (N.I) Nelson Island ;(R.I) Robert Island ;(G.I) Greenwich Island ; (S.I) Snow Island ; (D.I) Deception Island.

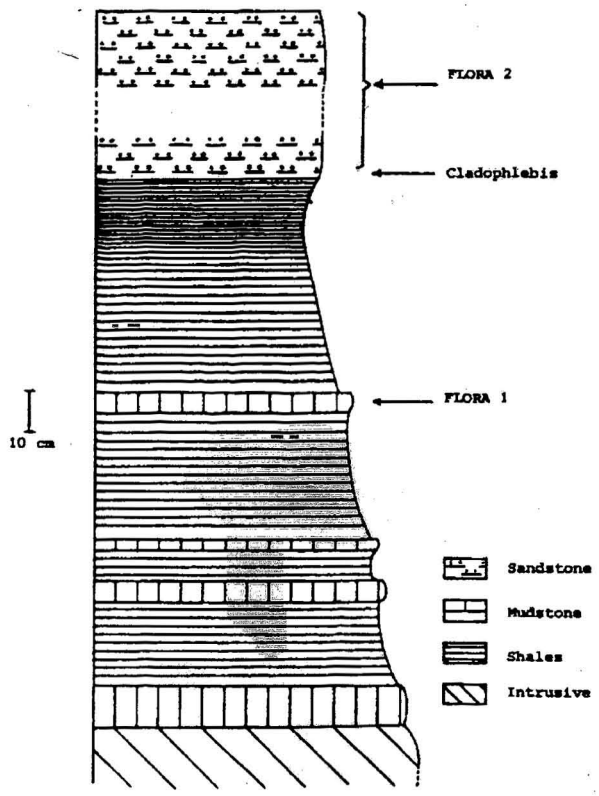


Fig. 2. Schematic lithostratigraphic column of locality A, Williams Point, Livingston Island.

Locality A is abundant and, sometimes, in a well preserved state. However, this material is almost always lacking a preserved cuticle. In fact most previous collections were made from samples gathered at the surface, which were frost-shattered and poorly preserved. Good snow-melting conditions allowed to dig extensively through the western border of Locality A, and to get a more accurate image of the stratigraphy preserved in this outcrop.

A lithostratigraphic column has been drawn (Fig. 2) and fossil flora sampled at different levels. For the first time material has been collected *in situ*. This allows us to identify two floristic units, instead of one as in previous works. The first flora is observed in greyish sandstones (Flora N° 1), whereas the second flora comes from the upper whitish mudstones or sandstones (Flora N° 2).

Large and complete imprints, certain reaching up to 20 cm, have been collected along with numerous, but more fragmentary remains. Indeed, plant remains are diversified in nature: small and medium-sized pieces of wood, nude twigs, leafy twigs, isolated leaves and fronds, frond fragments and even cones. All this material lacks a preserved cuticle but venation can, most of the time, be seen clearly . Roots were also observed in one of the levels, together with dichotomizing rootlets. This taphonomy clearly indicates a hypoautochthonous (Gastaldo, 1989) terrestrial deposit. The systematic studies are based in Anderson and Anderson (1983) for the *Dicroidium*.

SYSTEMATIC DESCRIPTION

Division PTERIDOPHYTA
Order Equisetales
Family Equisetaceae
Genus *Neocalamites* Halle, 1908
Type species : *Neocalamites hoerensis* (Schimper) Halle, 1908
Neocalamites sp.

Description

Three specimens preserved in volume, about 2.5 cm broad and 3-4 cm long. On each piece longitudinal ridges and grooves are present, and one nodal region with a twig scar has been observed. Longitudinal ridges and grooves seem to be continuous from one internodal region to the next.
Specimen N° 28

Comment

Leafy shoots were not observed but the gross morphology of stems is very close to the genus *Neocalamites* Halle. The poor preservation does not permit a specific determination.

Genus *Equisetum* Linnaeus, 1753
Type species : *Equisetum fluviatile* Linnaeus, 1753
Equisetum sp.
(pl. I, Fig. 14)

Description

The specimen consists of an articulated unbranched stem of 0.4 cm in diameter and 2.3 cm in length. The nodes are separated from each other by 0.6 cm. Nodes bear incomplete whorls of leaves.The free part of each leaf is very acuminate.
Specimen N° 9.

Comment

It is not possible to give a specific determination for this specimen. The articulate appearance of the specimen agrees with the morphology of Equisetales. The authors follow Harris' nomenclature (1961), who used the name *Equisetum* Linnaeus rather than *Equisetites* Sternberg.

Division PTERIDOPHYTA
Order Marattiales
Family Marattiaceae
Genus: *Marattia* Swartz, 1788
Type species : *Marattia anglica* (Thomas) Harris, 1967
Marattia sp.
(pl. I, Fig. 15)

Description

Two incomplete ribbon like pinnae about 1 cm broad and 3-3.5 cm long have been observed. The main vein is slightly raised. Lateral veins over most of their course are simple, straight and at an angle of 80-85°to the midrib. Along the veins there are synangia, which cover about a third of the lamina's width.
Specimen N° 19.

Comment

The specimens are incomplete and the form and size of the leaf are unknown. However, it is possible to attribute them to the genus *Marattia* Swartz. The present specimen is in someway comparable with *Marattia anglica* (Thomas) Harris from the Middle Jurassic flora of Yorkshire, but it is too fragmentary for an accurate determination.

Order Filicales
Family Dipteridaceae
Genus *Dictyophyllum* Lindley and Hutton, 1834
Type species : *Dictyophyllum rugosum* Lindley and Hutton emend. Harris, 1961
Dictyophyllum sp.
(pl. I, Fig. 2)

Description

Segments of fronds 5-6 cm long to 3-4 cm wide. The margins are undulated or slightly lobed. Each lobe or segment bears a midrib with primary lateral veins emerging at an angle of 40°-60°. The secondary veins form rather irregular polygonal meshes and the smaller veins are poorly marked.
Specimen N° 1b.

Comment

This sterile material can be assigned to the genus *Dictyophyllum* Lindley and Hutton. It is somewhat similar to *Dictyophyllum* sp. from Loc. A and figured by Banerji and Lemoigne (1987, pl. I, Fig. 5, text- Fig. 3A) and also to *Dictyophyllum tenuifolium* Stipanicic and Menéndez, figured by Bonetti and Herbst (1964, pl. 1, Fig. 1) from the Upper Triassic of Paso Flores, Neuquén, Argentina. Orlando (1968, Fig. 7a) figured and identified a small fragment of frond from the same locality A, which is very close to our specimen.

Family Dipteridaceae ?
Genus *Scoresbya* Harris, 1932
Type species : *Scoresbya dentata* Harris, 1932
Scoresbya dentata Harris
(pl. I, Fig. 1)
1968, Dipteridaceae, Orlando, p.10 Fig.7a.

Description

An incomplete leaf, 5 cm long and 3.2 cm broad, composed of two segments, both of unequal size. The margins of segments are coarsely dentate. At the base of the leaf there is a main vein which dichotomizes on each segment. The lateral veins are poorly preserved, branching dichotomously and anastomosing to form a network with elongated meshes.
Specimen N° 1 a.

Comment

According to its typical features (dichotomously divided lamina with venation and dentate margins) this leaf can be assigned to the genus *Scoresbya* Harris. The specimen figured (pl. 1, Fig. 1) is very close to those of *Scoresbya dentata* Harris illustrated by Harris (1932, pl. 2, Fig. 7, text- Fig. 22) from the Liassic of Greenland and by Krausel and Schaarschmidt (1968, pl. 26, Fig. 4) from the Liassic of Germany. The present specimen does not show the pseudo-marginal vein and for this reason it is different from *Scoresbya dichotoma* (Shirley) Herbst, figured by Banerji and Lemoigne (1987) from the same locality A. All the observed characteristics allow the specimen to be attributed to *Scoresbya dentata* Harris. The small fragment of a lamina of a frond described by Orlando (1968) is very close to the specimen here presented.

Family Osmundaceae ?
Genus *Cladophlebis* Brongniart, 1849
Type species : *Cladophlebis albertsii* (Dunker) Brongniart, 1849
Cladophlebis sp. A

Description

A fragmentary pinnate frond of 8 cm length has been observed with a main rachis of 0.3 cm breadth. The pinnae are alternate and separated by 2 cm intervals. The pinna is fragmentary, bearing opposite pinnules of about 1-1.5 cm long to 0.45-0.5 cm broad near the base.

Pinnules are falcate, attached to the rachis by a broad base, gradually becoming smaller and narrower towards the distal end ; the apex is acute. The pinnule base is expanded both acroscopically and basiscopically. The midvein is prominent and present in the pinnule apex. The lateral veins are subopposite arising at intervals of up to 1 mm, at angles approximately 45-50° and dichotomizing only once at a point one-third or less of its length. The margins of some pinnules are slightly denticulate.
Specimen N° 29.

Comment

The sterile material described above is attributed to the Mesozoic fern *Cladophlebis* Brongniart .The pinnule shape is very similar to *Cladophlebis antarctica* Halle from the Latte Jurassic- Early Cretaceous of Hope Bay, Antarctica (Halle, 1913; Gee, 1989). However the typical frond of *Cladophlebis antarctica* is characterized by its opposite secondary pinnae. These secondary pinnae are also very long , over 21 cm in length (Gee, 1989). This specimen from Williams Point Loc. A definitely does not show these characteristics.

Cladophlebis sp. B
(pl. I, Fig. 3)

Description

One slightly falcate pinnule, 1.2 cm in width and 3.5 cm in length has been observed. The apex is not visible. The pinnule is attached to the rachis by all of its base. A midvein is marked, which secondary veins are not preserved.
Specimen N° 2.

Comment

This pinnule may be assigned to the genus *Cladophlebis* Brongniart. There are superficial similarities between this specimen and some pinnules of *Cladophlebis aktashensis* Turutanova Ketova (1930) described from the Middle Jurassic of South-East Asia and West Europe.

Cladophlebis williamsensis sp. nov.
(pl. I, Fig. 5, 6, 7), text- Fig. 3A,3B
1987 *Cladophlebis* sp., Banerji and Lemoigne, p. 473, pl. 1, Fig. 6-8; text- Fig. 3 D.

Holotype : specimen N° 10, Instituto Antártico Chileno Collection, Santiago de Chile.
Paratypes : specimens N° 11 - 12 and 28, Instituto Antártico Chileno Collection, Santiago de Chile.
Type locality : Locality A, Punta Williams, Livingston Island, South Shetland Islands.
Stratigraphic horizon : level with *Cladophlebis*, Flora N° 2, Upper Triassic.
Etymology : from Punta Williams.

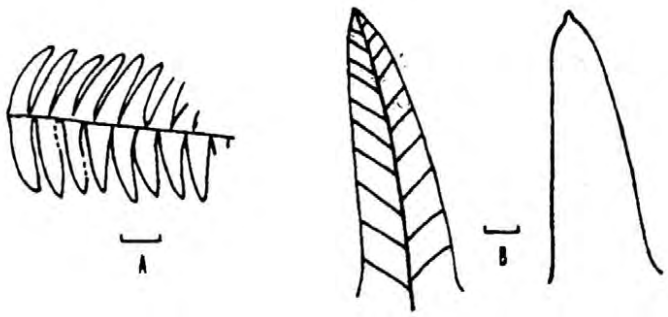


Fig. 3. *Cladophlebis williamsensis* nov. sp. A - Part of a pinna (scale = 5 mm). Specimen: N° 28; 3B - Two pinnules, one showing typical venation, the other an acute apex (scale = 1 mm). Specimen: N° 28.

Diagnosis

The frond is at least bipinnate and 10 cm long. Pinnae are alternate or subopposite, arising from primary axis at angles between 45° to 90° They are separated from each other at least by 2 cm. Pinnae are 8 cm long, bearing alternate pinnules. Pinnules are slightly falcate with an acute apex, sometimes mucronate of 0.7 1.1 cm length and 0.15 0.25 cm width. The pinnule base is expanded both acroscopically and basiscopically. The margins of pinnules are straight or slightly crenulate.

In the upper parts of pinnae, pinnules are smaller (0.5 cm long x 0.12 cm wide). Pinnule attachment to the pinna is at an angle of about 90° near the pinna base. This becomes smaller distally to about 60°. The midvein is faintly marked and lateral veins are unforked, in opposite pairs arising from midvein at smaller angles (usually between 50° to 60°). Intervals between the lateral veins are of about 0.5 mm.

Comment

The described material is attributed to the genus *Cladophlebis* Brongniart. In general appearance the specimens are close to *Cladophlebis antarctica* Nathorst described by Halle (1913). This species is easily recognized by its opposite secondary pinnae; the linear shape of the pinnules; the dentate to lobed pinnule margins; the intervals of about 1 mm between lateral veins, and veins dichotomizing only once at a point one-third or less of its length.

Cladophlebis williamsensis is different from *C. antarctica* especially in relation to secondary venation which is never forked here. The other species of *Cladophlebis* described by Halle (1913) or Gee (1989), from Antarctica, and Frenguelli (1947) from Argentina, are morphologically different to this specimen.

Herbst (1971, pl.1) made a revision of the Argentinian species of the genus *Cladophlebis*. Typical morphological characteristics and venation of pinnules of each species are figured. All species have dichotomizing secondary veins, which is different from the specimens here studied. In a Triassic flora from the Cacheuta Formation (Argentina), Jain and Delevoryas (1967) describe five species of *Cladophlebis*, but the venation of these appears different, always with lateral veins, once to twice normally forked.

Family Asterothecaceae?
Genus *Asterotheca* Presl, 1845
Type species : *Asterotheca sternbergii* (Goeppert) Presl, in Corda, 1845
Asterotheca crassa Orlando
(pl. I, Fig. 4)

Description

The frond is at least bipinnate and about 8 cm long bearing 2-4 cm long opposite pinnae. Pinnae are constituted of alternate to opposite pinnules with parallel margins and a rounded apex (0.2-0.3 cm long and 0.12-0.15 cm broad). Primary rachis are 3 mm broad, bearing numerous short trichomes. Each pinnule has a midvein that gradually tapers towards the distal end. Lateral veins are dichotomously forked near the base, but simple near the apex, forming an angle of 45°-50° with the main vein. The pinnule is always of the same size along the pinna except for the 3 or 4 apicals. The secondary rachis are straight or flexuosus.
Specimen N° 3.

Comment

The material is similar to that figured by Orlando (1968) from the same locality, attributed to *Asterotheca crassa* Orlando.

Family Dicksoniaceae
Genus *Coniopteris* Brongniart emend. Harris, 1961
Type species : *Coniopteris murrayana* (Brongniart) Brongniart emend. Harris, 1961
Coniopteris sp.
(text- Fig. 4)

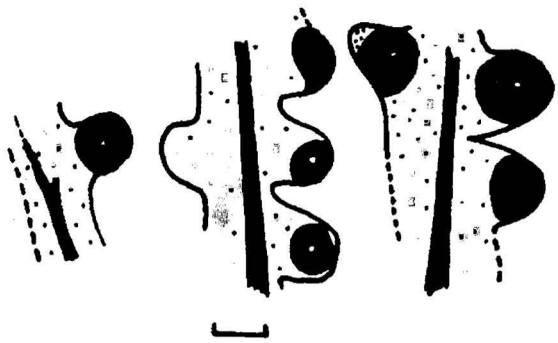


Fig. 4. *Coniopteris* sp. Specimen: N° 29. Pinnule lobes of a fragmentary specimen (scale = 1 mm)

Description

Three fragments of pinnae of only about 0.5 cm long . The pinnules seem to be opposite, about 0.15 cm long to 0.15 cm broad and rounded in outline. The apex is characterized by the presence of a sorus of approximately 1 mm in diameter. There is a dark central dot which probably corresponds to the attachment of each sporangium.
Specimen N° 29.

Comment

The affinities of these specimens are doubtful due to their small size. However they may be attributed to the genus *Coniopteris* Brongniart emend. Harris because of their fertile pinnules.

Some relationship can be established with *Coniopteris meridionalis* Gee (1989, pl. I, Fig. 10-12) but because of their small size these specimens remain without a specific determination.

Division PRESPERMATOPHYTA
Order Umkomasiales
Family Umkomasiaceae
Genus *Dicroidium* Gothan, 1912
Type species : *Dicroidium odontopteroides* (Morris) Gothan, 1912
Dicroidium odontopteroides forma odontopteroides Anderson and Anderson
(pl. II, Fig. 1 and 5)

Description

The figures 1 and 5 of plate II show fragmentary specimens characterized by pinnae of at least 10 cm long. The pinnules, 2.3-3 cm long. x 0.8-1.3 cm broad, are opposite. The margins of pinnules are parrallel, slightly undulated and decurrent to the rachis. The apex is rounded. The venation is clearly marked with a midvein and secondary veins which are simple or bifurcate once near the margins.
Specimens N° 13a-13c.

Comment

The disposition of the two fragmentary pinnae seems to demonstrate that their rachis are resulting from the same main axis in accordance with the genus *Dicroidium* Gothan. Anderson and Anderson (1983) give many figures of the genus showing different species. The material comes close to *Dicroidium odontopteroides* forma *odontopteroides* as figured by Anderson and Anderson (1983, pl. 32).

Dicroidium dubium subsp. *dubium* Anderson and Anderson
(pl. II, Fig. 7 and 12)

Description

It is a bipinnate frond of about 5 cm long and 3.5 cm broad. The pinnae are linear to lanceolate with a relatively acute apex. The pinnules near the end of pinna are triangular in form but are more elongated towards the base with more curved margins. The base of pinnules are more often widened in the apex of the pinna and more contracted near the opposite end. One midvein with acute secondary simple or dichotomising veins.
Specimens: N° 16 -20.

Comment

The figured material (pl. II Fig. 12) shows the typical rachis dichotomy characteristic of the genus *Dicroidium*. The specimens are morphologically very close to D. *superbum* forma *townrowi* (Retallack) Anderson and Anderson but the veins are different. They are identical to the figured specimens of *Dicroidium dubium* subsp. *dubium* Anderson and Anderson (1983).

Dicroidium cf. crassinervis forma *obtusifolium* (Johnston) Anderson and Anderson
(pl. II, Fig. 11)

Description

The frond is about 5.3 cm long. The primary rachis are divided with an acute angle (25°). The pinnate frond bears small pinnules (0.1 cm long to 0.1 cm broad at the base). The general form of the pinnules is square to bluntly triangular. The venation is not preserved.
Specimen: N° 24.

Comment

This material belongs to the genus *Dicroidium.* It is very similar to *Dicroidium* sp. figured by Banerji and Lemoigne (1987, pl. 2, Fig. 2-3). Within the species of *Dicroidium* described by Anderson and Anderson (1983) there is some similarity in general morphology with *Dicroidium crassinervis* forma *obtusifolium.* However due to the absence of venation in the present material, the specific identification remains uncertain.

Dicroidium odontopteroides subsp. *orbiculoides* Anderson and Anderson
(pl. II, Fig. 10 et 17)

Description

It is a frond of 2.6 cm length with a main rachis divided by a dichotomy forming an angle of 30°. The pinnule is positioned along rachis of small size, 0.2 cm length and 0.2 cm breadth at the base, in the opposite position with parallel margins and a rounded apex. The venation is not clearly visible.
Specimens N° 21-27.

Comment

The material with typically forked rachis has been assigned to *Dicroidium.* Morphologically it is identical to many specimens figured as *D. odontopteroides* subsp. *orbiculoides* by Anderson & Anderson (1983, pl. 42). The size and form of the pinnules allow the attribution of this material to this species despite the lack of venation.

Dicroidium cf. *elongatum* (Carruthers) Archangelsky
(pl. II, Fig. 8-9)
1968, *Xilopteris* cf. *elongata* Carruthers, Orlando,p.10,fig.7b.

Description

A bipinnate frond of about 12 cm length and 4-5 cm breadth. The pinnae are attached at an angle of 30°-40° and are alternate. Pinnules arise alternately at angles of 10°-15° They are linear in shape and

about 2-3 cm long and 0.1-0.2 cm broad. The margins taper gradually into an acute apex. Each pinnule is always with a single median vein extending until the apex.
Specimens N° 22-23.

Comment

The described material is similar to *Xylopteris* cf. *elongata* (Carruthers) Frenguelli figured by Banerji and Lemoigne (1987) and by Orlando(1968; p.10, Fig 7b) from the same locality. Some authors (Archangelsky 1968; Anderson and Anderson, 1983) have proposed to put in synonimy *Xylopteris* and *Dicroidium* on the basis of epidermal features, but Baldoni (1980) preserves this difference. The lack of a cuticle makes the choice impossible.

The material is close to *Dicroidium elongatum* forma *remotipinnulum* Anderson and Anderson 1983, but this species has short pinnules. The length of the pinnules is more similar to that of the forma *D.elongatum* but the latter is not bipinnate.

Dicroidium (?) sp.
(pl. II, Fig. 6)

Description

A fragmentary specimen corresponding to the distal part of a pinna. The pinnule has a broad base, parallel margins and an acute apex. The venation is of odontopteroid type.
Specimen: N° 17.

Comment

Because of the absence of a rachis it is impossible to attribute confidently this specimen to the genus *Dicroidium*. However it resembles some material of *Dicroidium odontopteroides* subsp. *lineatum* figured by Anderson and Anderson (1983).

Order Incertae Sedis
Family Incertae Sedis
Genus *Linguifolium* Arber emend. Retallack, 1980
Type species : *Linguifolium lilleanum* Arber, 1913
Linguifolium steinmannii (Solms-Laubach) Frenguelli
(pl. II, Fig. 2-3-4.)

Description

The pinnules are isolated and of 7.5 to 9 cm in length. The margins of the distal part of the pinnules are slightly lobed. The widest part of each pinnule is situated at approximately 4/5 the distance

from the pinnule base to apex. The pinnule is about 1 cm broad at the base, progressively widening to 1.5-2 cm . A midvein is present and well marked with numerous secondary veins forming an angle of 45° These secondary veins are simple or are more rarely divided by 1 or 2 dichotomies.
Specimens: N° 13b, 14 - 15.

Comment

The figure 3 of plate II shows an isolated pinnule of large size which is identical in morphology to specimens of *Linguifolium* Arber emend. Retallack. Retallack (1980) described many species of *Linguifolium* from New Zealand. The collected specimens at Williams Point are similar to *Linguifolium steinmannii* (Solms-Laubach) Frenguelli in relation to the width of the pinnule.

Order Caytoniales
Family Caytoniaceae
Genus *Sagenopteris* Presl *emend.* Harris, 1964
Type species : *Sagenopteris nilssoniana* (Brongniart) Ward, 1900
Sagenopteris sp.
(pl. I, Fig. 8-9-10-11)

Description

Numerous fragmentary leaflets. The leaflet length ranges from 3 to 4 cm, with a maximum width at the middle between base and apex of 1 cm commonly. The leaflet apices are typically acute, margins are entire or slightly undulating gradually tapering towards base. The midrib is distinct, secondary veins are hardly perceptible but if they are present they fork and anastomose irregularly at varying distances from the midrib, forming elongated meshes.

In figure 11 plate I two leaflets can be observed, they converge to the same point, the whole structure probably corresponds to a compound, palmate leaf.
Specimens: N° 4-5-6-7.

Comment

This material can be attributed to the genus *Sagenopteris.* It is similar to the specimens figured by Banerji and Lemoigne (1987, pl. 2, fig. 6-11) from the same locality and from B in Rees and Smellie (1989). However it is different from the specimens found by Rees (1993 c) from the Early Jurassic of Hope Bay and Botany Bay (Antarctic Peninsula). Without the epidermal structure it is impossible to give specific determination. This same leaflet was found in Flora 1 and Flora 2. This type of material has been attributed to Angiosperm (form B) by Rees and Smellie (1989).

Genus *Caytonia* Thomas *emend.* Harris, 1964
Type species : *Caytonia sewardi* Thomas, 1925
Caytonia sp.
(pl. II, Fig. 13-14)
1968 *Coniopteris distans* Orlando, p. 8, Fig. 5, 6a, b.

Description

Megasporophylls of at least 4.5 cm long bearing seed-containing sacs laterally in nearly opposite pairs. The fruits are rounded, up to 4 mm wide and the pedicel is broadened above. The length of the aperture of fruit is unknown.
Specimens: N° 18 - 19.

Comment

The megasporophylls are very much comparable to those described by Harris (1964) from the Bajocian-Bathonian of Yorkshire and attributed to the genus *Caytonia*. The present material is similar to *Coniopteris distans* described and figured by Orlando (1968) from the same locality. Banerji and Lemoigne (1987) have described numerous isolated fruits from the same beds. However, due to the absence of a cuticle, these specimens remain without specific determination.

Order Ginkgoales
Family Ginkgoaceae
Genus *Sphenobaiera* Florin emend. Harris, 1974
Type species : *Sphenobaiera spectabilis* (Nathorst) Florin, 1936
Sphenobaiera sp.
(pl. I, Fig. 12-13)

Description

Leaflet oblanceolate or slightly bilobed up to 2.5 cm long (1.3-2.5cm) without a distinct petiole. The lamina is about 0.7 cm wide (0.5-1.2 cm). The veins are inconspicuous and parallel. These are about 20 per cm which branch proximally and converge slightly near apex. This apex is rounded. Resin bodies are absent.
Specimens : N°8a-8b.

Comment

The leaflets are typical of the genus *Sphenobaiera* Florin emend. Harris (1964). The specimens are quite common in the Flora N°1 but absent in flora N°2. Somewhat similar leaflets are seen in *Sphenobaiera sp.* described by Banerji and Lemoigne (1987) from the same locality. Some specimens

described by Jain and Delevoryas (1967, pl. 96, fig. 4-5) as *Sphenobaiera argentina* (Kurtz) Frenguelli, show some similarity with the present material. The undivided lamina of some specimens comes closest to *Sphenobaiera gyron* Harris from the Bajocian/Bathonian of Yorkshire. However, the Yorkshire species has a longer leaf and its epidermal structure is known.

Division SPERMATOPHYTA
Order Coniferales
Family Incertae Sedis
Genus *Elatocladus* Halle emend. Harris, 1969
Type species : *Elatocladus heterophylla* Halle, 1913
Elatocladus sp.
(pl. II, Fig. 15)

Description

The main axis is straight and up to 3 mm wide. Lateral axes are distant, often subopposite and branching in one plane at an angle of 25°-30°

The leaves are spirally arranged pointing radially, typically about 3 mm x 0.9 mm. The base of the leaf is constricted; the upper part is linear-lanceolate and dorsoventrally flattened. The apex is commonly rounded and sometimes slightly acuminate. A midvein is present on each lamina.
Specimen: N° 26.

Comment

This material belongs to the genus *Elatocladus* Halle emend. Harris. Gee (1989) described three species of *Elatocladus* from the Lower Jurassic flora of Hope Bay: *Elatocladus heterophylla* Halle, *Elatocladus confertus* (Oldham and Morris) Halle, *Elatocladus jabalpurensis* (Feistmantel) Halle. The present material differs from that of the Hope Bay species with short leaves, that generally do not spread horizontally. It is described here without specific determination.

Genus *Pagiophyllum* Heer emend. Harris, 1979
Type species : *Pagiophyllum cirinicum* (Saporta) Heer emend. Barale, 1970
Pagiophyllum sp. A
(pl. II, Fig. 16)

Description

The axis is of about 1-2 cm length. It is simple or with one or two dichotomies. The axes are in alternate position spreading apparently in one plane.

The leaves are arranged spirally in a simple helix with parastichies 1+2. Leaves are crescent-shaped in transverse section. The adaxial surface of leaf is concave and the abaxial is convex with a broad base. Leaves are about 1-2 mm long and 0.5-1.4 mm broad at the base. A cone has been observed (5x3 mm), consisting of an axis bearing sporophylls of peltate form without pollen-sacs.
Specimen: N° 25.

Comment

These specimens are very much comparable to *Pagiophyllum* sp. described by Lacey and Lucas (1981, fig. 4) and Banerji and Lemoigne (1987, pl. 3, Fig. 8-9, text-Fig. 6 C, D). The leaves do not contain organic matter or show cuticular details. One cone (pl. II, Fig. 16) has been observed (4 x 3.5 mm) but without pollen.

The affinities of the material within the conifers are difficult to discern. Heterophylly was observed on the same axis between short leaves (1 x 0.5 mm) and larger ones (2 x 1 mm).

Pagiophyllum sp. B

Description

The leaves are arranged spirally, elongated ovate in shape and typically measuring 3-3.5 x 1.2-1.5 mm. Their general form is rhomboidal with an acute apex marked by the tip of a distinct median keel.
Specimen: N° 31.

Comment

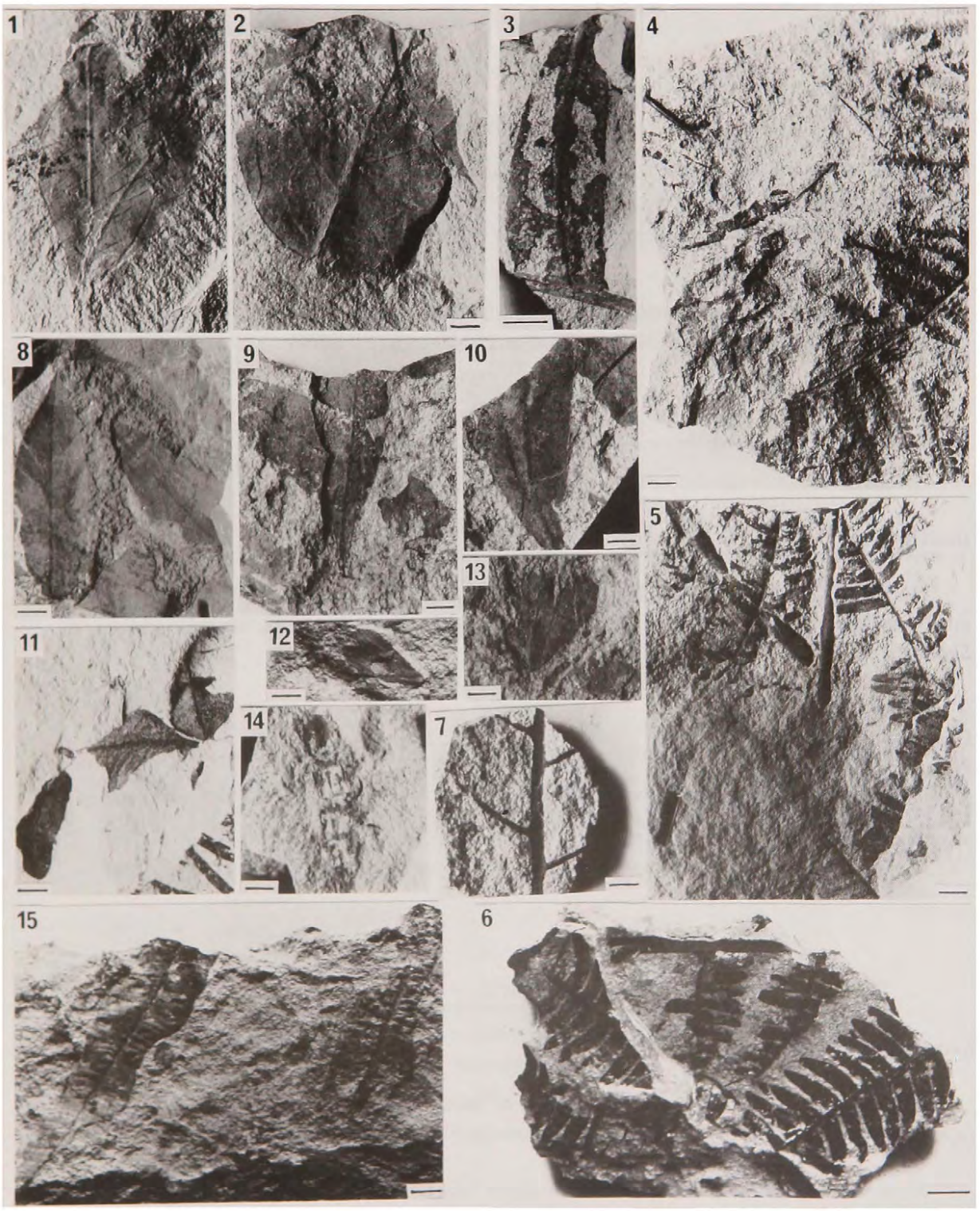
Pagiophyllum sp. B differs from *Pagiophyllum* sp. A in having elongated to ovate adpressed leaves. *Pagiophyllum* sp. B is identical to *Pagiophyllum* sp. B described by Banerji and Lemoigne (1987, pl. 3, Fig. 10 ; texte-Fig. 6 E).

DISCUSSION

Systematic Composition

The results of flora identification are presented in Table 1 in comparison with previous works from this same locality. Six taxa have been determinated in Flora N° 1 and eighteen in Flora N° 2.

Flora N° 1, with few taxa, is the only flora in which "Angiosperm-like leaves" can be seen. It is most likely this flora from which Rees and Smellie (1989) described putative Angiosperm leaves. These are the specimens which correspond to their form F and the fragments possibly belonging to their forms B and D.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The scale represents 5 mm.

Fig. 1 - *Scoresbya dentata* Harris Specimen N°1Leaf showing dichotomizing midvein

Fig. 2 - *Dictyophyllum* sp.Leaf base slightly lobed with midvein and primary lateral veins.

Fig. 3 - *Cladophlebis* sp. B.Specimen N° 2Isolated pinnule with a midvein

Fg. 4 - *Asterotheca crassa* Orlando. Specimen N°3 Bipinnate frond

Fig. 5-6 - *Cladophlebis williamsensis* sp. nov. Fragmentary bipinnate fronds. Parâtype : Specimen N°12 (Fig. 5) - Holotype: specimen N°10 (Fig. 6).

Fig. 7 - *Cladophlebis williamsensis* sp. nov.Main rachis showing the position of secondary rachis. Paratype : Specimen N° 42

Fig. 8 - *Sagenopteris* sp. Specimen: N°4 Isolated leaflet with an acute apex

Fig. 9-10 - *Sagenopteris* sp. Specimens:N° 5-6 Base of leaflets with a well marked midvein

Fig. 11 - *Sagenopteris* sp. Specimen: N°7 Two base of leaflets in connection

Fig. 12-13 - *Sphenobaiera* sp. Specimens: N° 8a,8b. Isolated leaf with a lobed apex

Fig. 14 - *Equisetum* sp. Specimen: N° 9 Articulated axis

Fig. 15 - *Marattia* sp. Specimen: N° 19 Two isolated pinnae ; note on the lower surface of lamina the position of synangia


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The value of the scale is 5 mm.

Fig. 1 *Dicroidium odontopteroides* forma *odontopteroides* Anderson and Anderson.Specimen: N° 13a Two isolated pinnae belonging probably to the same frond.

Fig. 2 - *Linguifolium steinmannii* (Solms-Laubach) Frenguelli. Distal part of a lobed pinnule. Specimen :N°13b

Fig. 3 - *Linguifolium steinmannii* (Solms-Laubach) Frenguelli. Proximal part of a pinnule showing the midvein. Specimen :N°14

Fig. 4 - *Linguifolium steinmannii* (Solms-Laubach) Frenguelli. Middle part of a pinnule with sinuous margins.Specimen: N°15

Fig. 5 - *Dicroidium odontopteroides* forma *odontopteroides* Anderson and Anderson. Specimen: n° 13c Primary and secondary venation of pinnules.

Fig. 6 - *Dicroidium* (?) sp. Specimen: N° 17 Fragmentary pinna with pinnules showing odontopteroid venation.

Fig. 7 *Dicroidium dubium* subsp. *dubium* Anderson and Anderson. Distal part of a frond showing opposite pinna. Specimen: N° 16

Fig. 8-9 - *Dicroidium* cf. *elongatum* (Carruthers) Archangelsky. Fragmentary pinnae with elongated pinnules. Specimens: N° 22-23

Fig. 10 *Dicroidium odontopteroides* subsp. *orbiculoides* Anderson and Anderson. Specimen: N° 21 Frond with a dichotomizing rachis.

Fig. 11 *Dicroidium* cf. *crassinervis* forma *obtusifolium* (Johnston) Anderson and Anderson. Specimen: N° 24 Typical frond with slender pinnules.

Fig. 12 - *Dicroidium dubium* subsp. *dubium* Anderson and Anderson. Distal part of a frond after main rachis. Specimen: N° 20

Fig. 13-14 - *Caytonia* sp. Specimens: N° 18-19 Fertile pinna with ovules (or seeds) in alternate position.

Fig. 15 - *Elatocladus* sp. Specimen: N° 26 Ramifying leafy shoots.

Fig. 16- *Pagiophyllum* sp. A. Specimen: N° 25 Different leafy axes ; note a shoot fragment with a small cone.

Fig 17- *Dicroidium odontopteroides* sub sp. *orbiculoides* Anderson and Anderson. Specimen:N° 27 Frond showing the dichotomy of main rachis.

Table 1.

Paleobotanical studies of locality A at Williams Point, Livingston Island (South Shetland Islands, Antarctica).
Asterisks refer to taxa collected in flora N° 1

	Orlando (1968)	Lacey & Lucas (1981)	Banerji & Lemoigne (1987)	Rees & Smellie (1989)	Present study
PTERIDOPHYTA					
Equisetales		*Equisetites* sp.	*Neocalamites* sp.	*Equisetites* sp.	*Equisetum* sp. *Neocalamites* sp.
Filicales	*Asterotheca crassa* *Osmundaceae rachis* *Coniopteris distans dichotoma* Dipteridaceae fronds	cf. *Asterotheca crassa* *Coniopteris distans*	*Marattiopsis* sp. *Dictyophyllum* sp. *Scoresbya* *Cladophlebis* sp.	«*Brevipteris elongat*»Marattia sp. *Asplenites* sp. *Klukia* sp. *Cladophlebis* sp. «*Bifida dichotom*» «*Bifida longiphyl*» *Coniopteris* sp.	**Dictyophyllum* sp. **Cladophlebis* sp. A *Cladophlebis* sp. B *Cladophlebis williamsii* *Asterotheca crassa* **Scoresbya dentata*
PRESPERMATOPHYTA					
Umkomasiales	*Thinnfeldia* sp. *Xylopteris* cf. *elongata*	*Dicroidium* cf. *lancifolium* *Dicroidium* cf. *spinifolium*	*Dicroidium* sp. *Xylopteris* cf. *elongata*		*Dicroidium* cf. *crassinervis* forma *obtusifolium* *D. dubium* subsp. *dubium* *D.* cf. elongatum *D.* odontopteroides subsp. *orbiculoides* *D. odontopteroides* forma *odontopteroides* *Dicroidium* (?) . sp.
Cycadales		Dorotophyllum tension woodsi	Taeniopteris sp.	Taeniopteris sp.	
Caytoniales			*Sagenopteris* sp. *Caytonia* sp.		**Sagenopteris* sp. *Sagenopteris* sp. *Caytonia* sp.
Ginkgoales		*Ginkgoites* sp.	*Sphenobaiera* sp.		**Sphenobaiera* sp.
SPERMATOPHYTA					
Coniferales		*Pagiophyllum* sp.	*Pagiophyllum* sp A *Pagiophyllum* sp. B *Elatocladus* sp. A *Elatocladus* sp. B		*Pagiophyllum* sp. A **Pagiophyllum* sp. B *Elatocladus* sp.
Angiosperms				Forms B,D,F	
INCERTAE SEDIS		*Hexagonocaulon minutum* *Thallites* sp. A *Thallites* sp. B		*Linguifolium steinmannii*	

These determinations cf Rees and Smellie (1989) call for some remarks:

-»Form B» : the leaf is lanceolate to narrow - elliptical, simple, microphyllous up to 7,1 cm long and 2,2 cm wide. The margin is entire. There is venation with one midvein. In locality A it was possible to collect some leaves with such anastomosing secondary veins. This type of material belongs to the genus *Sagenopteris.*

-»Form D» : the leaf is narrow to widely elliptical and simple. The margin is not very well preserved. It has one midvein and two lateral veins which are not attached at exactly the same level. The material of this type collected in locality A is always poorly preserved and «form D» represents poorly preserved material of the genus *Scoresbya*. However, it is noted that the other specimens assigned to «form D» from locality P.1801, figured by Rees and Smellie (1989, Fig. 2d), are indeed Angiosperm leaves.

-»Form F» : leaf trilobate, simple, with a midvein in each lobe. This form, found only at locality A, may well be *Dictyophyllum* or *Geoppertella* fragmentary fronds.

Flora N° 2 is more diversified in systematic composition, without Angiosperm - like forms. It is found within sandstones. The lower beds are characterized by numerous *Cladophlebis,* whereas in the upper beds, *Dicroidium* fronds are dominant.

Age of the two floras

Orlando (1968), Lacey and Lucas (1981), Banerji and Lemoigne (1987) all attributed a Lower, Middle or Upper Triassic age to locality A.

Rees and Smellie (1989) demonstrate that the taxa identified by earlier works in locality A are similar to known Jurassic and Cretaceous Gondwana genera or else too fragmentary to allow definitive identification. It should be however granted that many of the fossils described in previous studies (Orlando, 1968 ; Lacey and Lucas 1981 ; Banerji and Lemoigne, 1987) were fragmentary and poorly preserved compared to the better preserved material collected in 1993. Using a combination of radiometric measurements and paleontological data (assumed presence of Angiosperm leaves), Rees and Smellie (1989) suggest an Albian-Cenomanian age for all the flora from the northern part of Livingston Island and, especially, locality A studied here.

However, here it is demonstrated that in the locality A leaves of Angiosperms are in fact absent. So the result of taxonomic analysis must be considered in relation to stratigraphy. Within Flora N° 2, some fossils have a stratigraphical value : for example several typical *Dicroidium* fronds with evidence of the equal frond dichotomy which is characteristic of this Triassic genus were collected.

The first discovery in locality A of *Linguifolium steinmannii* (Solms - Laubach) Frenguelli is stratigraphically significant : this species is known only from Ladinian to Rhetian in Gondwana (Retallack, 1980). *Dicroidium, Asterotheca* and *Linguifolium* are found in Flora N° 2, along with some other fossils (cf. table) which do not have high stratigraphical value but may be present in the Triassic.

Dicroidium odontopteroides forma *odontopteroides* and subsp. *orbiculoides*, *Dicroidium dubium* subsp. *dubium*, *Dicroidium* cf. *crassinervis* forma *obtusifolium* were observed for the first time in Williams Point. In conclusion it may be considered that flora N° 2 is Upper Triassic in age.

In the Flora N° 1 few taxa have a stratigraphical value, especially as specific determination was impossible. However, two taxa, *Sagenopteris* sp. and *Pagiophyllum* sp. B are in common with flora N° 2, dated as Upper Triassic.

The occurence of *Scoresbya dentata*, known from Upper Triassic and Lower Jurassic strata, confirms equally that flora N°1 is contemporaneous to flora N° 2.

Comparisons with other floras :

The flora from Hope Bay (Antarctic Peninsula) is one of the largest and taxonomically most diverse Jurassic plant assemblage.

It has been described by Halle (1913) but revised by Gee (1989) and Rees (1993 b, 1993 c). The age of this flora is now considered after Rees (1993 a) as Lower Jurassic and the discovery of new fossiliferous locality (Botany Bay) has modified the fossil flora list. However Morel *et al.* (1994) in their discussions about the flora of Botany Bay and Hope Bay consider the formation to be Jurassic. Nevertheless, they admit the necessity to study more palaeobotanical material to specify the age. The Hope Bay and Botany Bay floras are of the same age and include Sphenophytes, ferns, pteridosperms, Caytoniales, Cycadophytes and conifers - (32 species in Botany Bay, 36 species in Hope Bay). Six genera are in common with the flora described here : three Pteridophytes (Equisetites, *Cladophlebis* and *Coniopteris*), one Prespermatophyte *(Sagenopteris*), two conifers (*Pagiophyllum* and *Elatocladus*). The presence in the flora described by Halle (1913) of the Antarctic Peninsula of numerous pinnae of Bennettitales (*Otozamites, Zamites, Weltrichia, Cycadolepis, Williamsonia*) gives an evidence of a younger age.

Orlando (1968) thought that some badly preserved remains collected by Hobbs at P.111 and P.112 in Byers Peninsula, Livingston Island, belonged to the same flora as in the locality A of Williams Point. These deposits have recently been dated as Kimmeridgian to Barremian (Crame *et al.* 1993). From eastern Antarctica, Townrow (1967) described a Triassic flora with some *Dicroidium* species. Evidence of Late Triassic plants in East Antarctica is also given by Webb and Fielding (1993) who describe a flora dominated by *Dicroidium zuberi*, associated with a species of *Pteruchus*, fragmentary cycadophyte leaves, conifer foliage of the voltziacean type and a single specimen of *Dicroidium crassinervis* forma *stelznerianum.* Cantril *et. al.* (1995) describe two *Dicroidium* and a new species *Pagiophyllum papillatus* from the Prince Charles Mountains of Late Triassic age.

Among the numerous fossil floras of Argentina, the one described by Ganuza *et. al.*(1992) from the Triassic of the Paso Flores Formation, Neuquen Province, Argentina shows some similarities with the flora of Williams Point, especially the numerical importance an diversity of *Dicroidium* fronds and the presence of the genus *Linguifolium.* Also, another Mid-Triassic flora from the Cacheuta Formation in Argentina, has some genera in common with Locality A, especially the Pteridosperms (Jain and Delevoryas, 1967).

Morel (1994) described a rich flora in Cerro Cacheuta (Mendoza province, Argentina) with 65 taxa belonging to Bryophytes, Lycophytes, Sphenophytes, Ginkgophytes and Coniferophytes. Early to Late Upper Triassic age is proposed for this flora.. Eight taxa are in common with the Williams Point flora: *Neocalamites*, *Cladophlebis*, *Asterotheca*, *Sphenobaiera*, *Dicroidium odontopteroides* forma *odontopteroides*. *Linguifolium steinmannii*, *Sagenopteris* and *Elatocladus*. But some genera are unknown

in Locality A: *Zuberia*, *Johnstonia*, *Lepidopteris*, *Nilsonia*, *Feruglia*, *Heidiphyllum*, *Cycadocarpidium*, *Telemachus*, *Cordaicarpus* and *Yabeiella*.

Morel (1994) drew up a list of all the Triassic floras of Argentina and the main floras of the same age in Gondwana. He proposes a table with the common taxa on each floras. Six taxa are more represented than the others: *Neocalamites carrerei, Cladophlebis mendozaensis, Zuberia zuberi, Xylopteris argentina, Xylopteris elongata v. rigida, Yabeiella mareyesiaca.* These species are not present in the flora of Locality A.

In their synopsis of the Gondwana (Karoo Basin) Triassic Molteno Formation Floras, Anderson and Anderson (1983) indicated the presence of *Dicroidium*, *Heidiphyllum*, *Neocalamites* and *Baiera.* These genera are dominant in that flora. Two of their genera, *Heidiphyllum* and *Baiera*, are still unknown in Locality A.

The megaplant assemblages described by Retallack (1979) from the Middle Triassic deposits of Canterbury New Zealand are situated at the same paleo-latitude that the Williams Point deposits.The list of fossils is quite similar, with a parallel abundance of *Linguifolium* and *Dicroidium.* This association is typical of a cool temperate to subantarctic climate. This is suggested by the presence of deciduous plants (*Linguifolium)*, prominent seasonal growth rings in fossil logs and marine shellfish (Retallack, 1979).

Paleogeography

There is strong evidence of an emerged landmass near the Williams Point as early as the Upper Triassic. Indications of hypoautochthony in this locality for the fossil material include numerous fern rachis of about 15 cm long and many ramifying leafy twigs of conifers, some bearing cones, as well as levels with *in-situ* roots. The presence in the same beds of isolated cones and small leafy twigs may be explained by an unselective transport. A level with roots and rootlets, sometimes with dichotomy, has been found (Barale *et. al.* 1994), justifying the closeness of a paleosol.

Rees (1993 a) suggests an Early Jurassic age for the Hope Bay and Botany Bay plant - assemblages of Antarctic Peninsula, whereas according to Birkenmajer (1993) the possible age of these may stretch from Upper Triassic to Lower Cretaceous. An Early Jurassic age for Hope Bay and Botany Bay flora (Rees, 1993 a) would coincide with the Early - Middle Jurassic peak of magmatic activity previously recognized on the East coast of central and southern Graham Land (Pankhurst 1982, Holdsworth and Nell. 1992). The beds of Hope Bay and Botany Bay may represent the deposition on an emergent Early Jurassic arc. However the present study shows that these flora are not the oldest known for the northern region of the Antarctic Peninsula. This study shows that continental sediments were deposited during the Upper Triassic at Williams Point and that a land mass existed at that time.

In Livingston Island the Miers Bluff Formation has revealed the presence of poorly preserved plant material (Schopf, 1973). Willan et al. (1994) indicate a probable Early Triassic age for this formation. Covacevich (1994) has discovered trace fossils in Miers Bluff Formation and suggests a Paleozoic age. These results support the evidence of an emerged landmass during this time. It seems necessary to revise both the model proposed by Farquharson (1983, 1984), which suggested a landmass that was emerged since the Early Cretaceous, and that proposed by Rees (1993 a) with emersion during Early Jurassic times.

CONCLUSIONS

1. Two different autochthonous floras are described of Locality A from Williams Point, Livingston Island.

2. The Flora N° 1 is taxonomically poor ,but contemporaneous and near to diversified Flora N° 2. Angiosperms are absent.

3. The presumed age is Upper Triassic regarding the presence of *Scoresbia*, *Dicroidium*, and *Linguifolium*.

4. A new species *Cladophllebis williamsensis* Baral *et al.*, 1995 is described in the Flora N° 2.

5. This study shows that continental sediments were deposited during the Upper Triassic at Williams Point and that a land mass existed at that time.

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