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PLANT REMAINS OF THE DUFAYEL ISLAND GROUP (EARLY TERTIARY?), KING GEORGE ISLAND, SOUTH SHETLAND ISLANDS (WEST ANTARCTICA) *

Szczątki roślinne z utworów grupy Dufayel Island (wczesny trzeciorzęd?) na Wyspie King George, Szetlandy Południowe (Antarktyka Zachodnia)

ABSTRACT. Remains of fossil plants preserved as leaf impressions collected at Dufayel Island (Gdynia Point site), Admiralty Bay, King George Island (South Shetland Islands, West Antarctica) have been described and illustrated. The fossil plants derive from tuffs of the Dalmor Bank Formation belonging to the upper part of the Dufayel Island Group. Basaltic andesite lava capping these tuffs yielded a K-Ar date of 51.9±1.5 Ma, while altered andesite lavas underlying the plant-bearing beds — of 56.8±1.2 Ma. This may suggest an Early Eocene or Early Eocene — Late Paleocene age of the plant fossil assemblage in case these lavas have not been reheated at a later date. In the latter case, a late Cretaceous age is equally possible.

The fossil plant assemblage, consisting predominantly of angiosperm leaf impressions, is characterized by the presence of *Nothofagus* sp., *Myrtaceae*, and various remains of laurophyllous plants. They are accompanied by leaf remains of: aff. *Cochlospermum*, ?*Dodonea*, *Leguminosites*, ?*Sterculia*, *Tetracera patagonica* Berry, as well as by monocotyledonous and probably pteridophyte remains. No gymnosperm remains have been found. The taphocoenosis examined belongs to the so-called „palaeoflora mixta" type as described by Romero (1978) from South America and West Antarctica, in which besides more termophilous plants simultaenously occurs a cool temperate (subantarctic) element.

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I. GEOLOGICAL PART
(by K. Birkenmajer)

INTRODUCTION

The fossil plant collection here described comes from the Dufayel Island Group, Dalmor Bank Formation (as defined by Birkenmajer 1980a, d), exposed at its type locality Gdynia Point, Dufayel Island (Admiralty Bay, King George Island), in the South Shetland Islands, West Antarctica (Figs 1, 2). The plant-bearing beds at Dufayel Island have been discovered by Bibby (1961) and their floral content briefly discussed by Barton (1964). Barton has also commented on the state of preservation of these leaf remains as being devoid of organic matter and generally poorly preserved. The age of these plant-bearing beds was accepted to be Eocene by Adie (1964), and early Tertiary (?Eocene — Oligocene) by Barton (1964), however a late Cretaceous age based on mineralization phenomena has also been considered

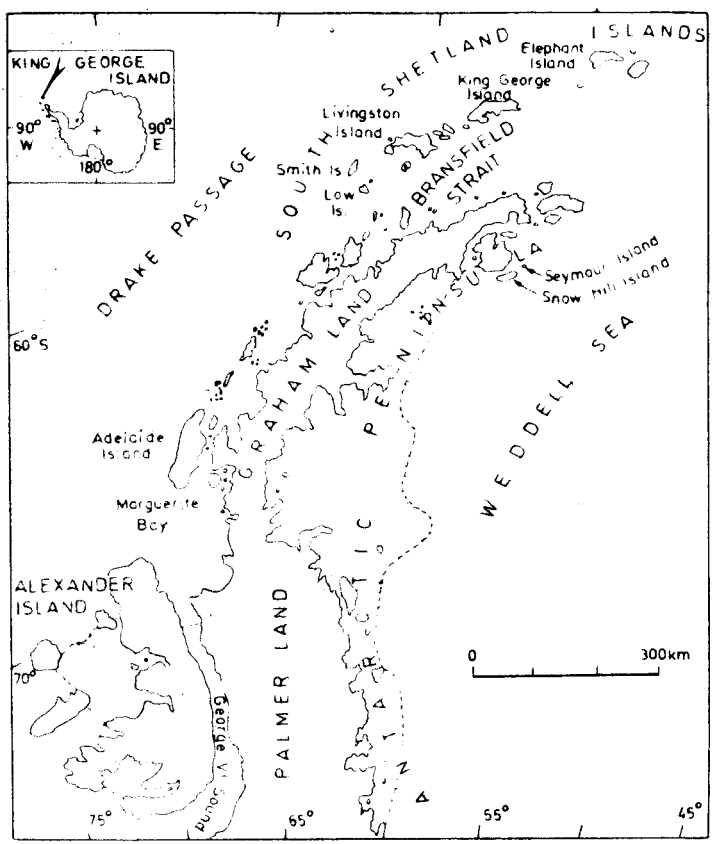

Fig. 1. Key maps to show position of the discussed fossil plant localities in the Antarctic Peninsula sector, and in Antarctica (inset)

by Barton (1965). Birkenmajer (1980a, d) accepted an early Tertiary (Eocene) age of the flora and the enclosing sediment, and that age has been supported by radiometric K-Ar dating ot overlying and underlying lavas (Birkenmajer et al. 1983a, b).

Thanks to detailed geological investigations and fossil sampling in King George Island, nearly 20 fossil plant sites have been recognized (Fig. 2). A part of these sites (Fig. 2: *1—3*) refer to rocks pre-dating Tertiary volcanic-sedimentary complexes

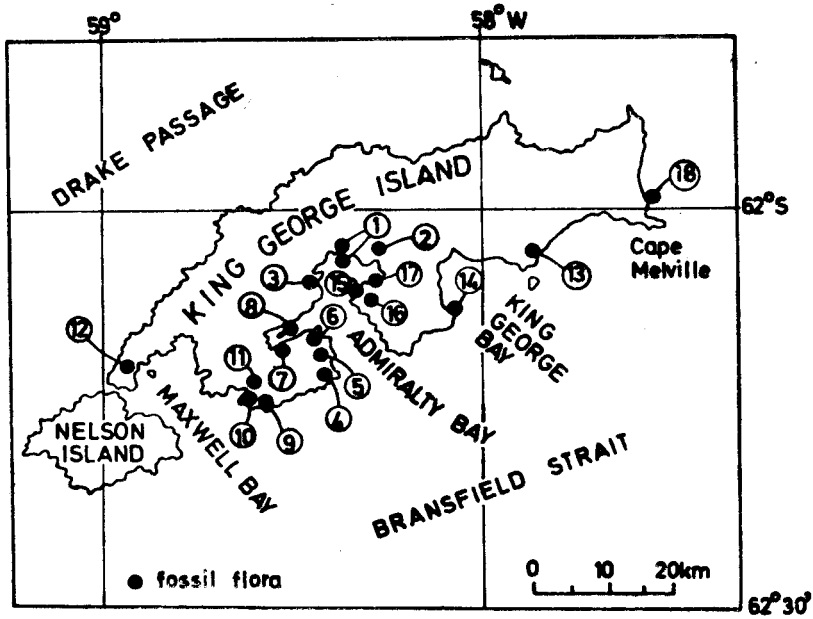

Fig. 2. Localities map of Late Mesozoic and Tertiary floras in King George Island, South Shetland Islands. Rock complexes older than Late Cretaceous: 1 — Keller Peninsula; 2 — Precious Peaks; 3 — Admiralen Peak. Late Cretaceous — Tertiary complexes: 4 — Paradise Cove (Late Cretaceous, 5 — Zamek (Late Cretaceous); 6 — Petrified Forest Creek and vicinity (?Paleocene and Eocene); 7 — Cytadela, Ezcurra Inlet (Eocene); 8 — Dufayel Island (Paleocene-Eocene or Late Cretaceous); 9 — Stranger Point (?Eocene); 10 — Potter Peninsula (?Eocene); 11 — Potter Cove (?Late Cretaceous); 12 — Fildes Peninsula (?Eocene-Paleocene); 13 — Three Sisters Point (Late Cretaceous); 14 — Lions Rump (Palaeogene or Late Cretaceous); 15 — Point Hennequin, Dragon Glacier (Late Oligocene); 16 — Point Hennequin, Mount Wawel (Late Oligocene); 17 — Point Hennequin, Wanda Glacier (Late Oligocene); 18 — Wrona Buttress, Destruction Bay (Early Miocene)

possibly of late Mesozoic age; another group (Fig. 2: *4, 5, 14*) corresponds to rocks originally attributed to Tertiary but recently revised to be late Cretaceous in age — based on the results of radiometric dating; the remaining sites (Fig. 2: *6—12, 15—18*) are represented by rocks of Tertiary age, ranging from Paleocene-Eocene (sites 6—12) through Oligocene (sites 15—17) to early Miocene (site 18), as confirmed by radiometric dating (Fig. 3).

The descriptions of particular sites have been presented in numerous papers, particularly by Bibby (1961), Barton (1961, 1964, 1965), Orlando (1963, 1964),

Birkenmajer (1980a-c, 1981a-c, 1982a-c, 1984), Błaszyk and Gaździcki (1980), Stuchlik (1981), Zastawniak (1981), Gaździcki and Wrona (1982), Paulo and Tokarski (1982), and Zastawniak et al. (1985). Additional information is contained in preliminary results presented by the Brazilian geologists and palaeontologists: Czajkowsky and Rösler (1984), Gonzaga (1984) and Torres et al. (1984).

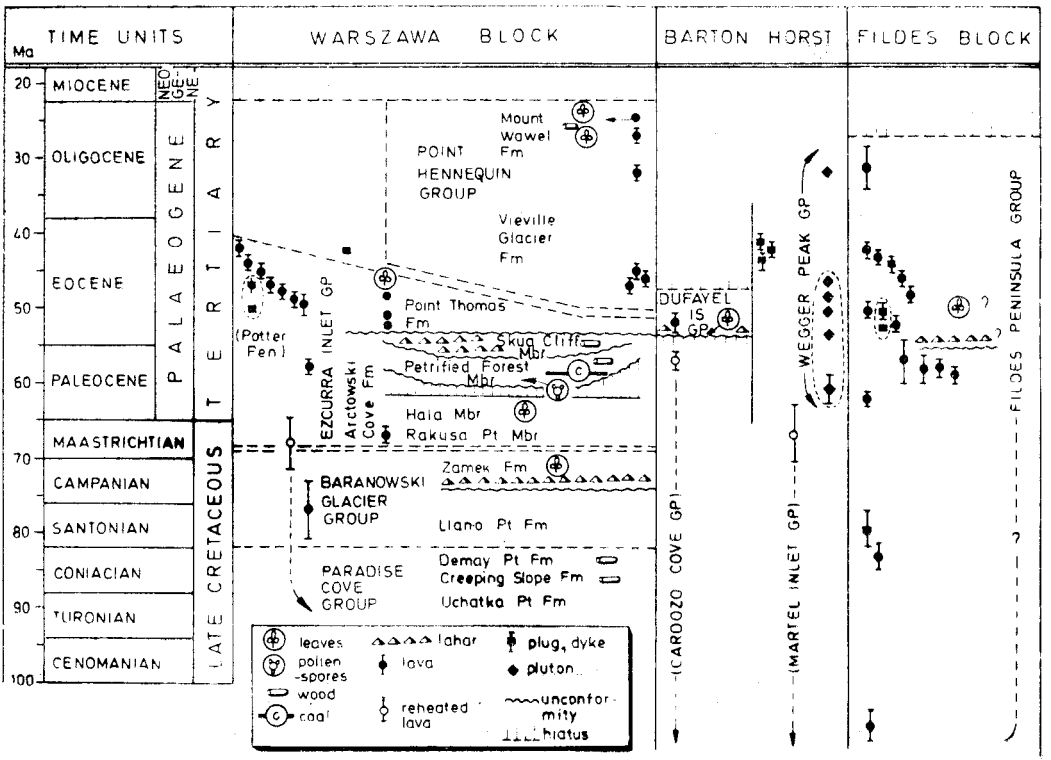

Fig. 3. Stratigraphic position of fossil floras in the Cretaceous — Palaeogene lithostratigraphic standard. Radiometric dates from Watts (1982), Birkenmajer et al. (1983a, b) and Pankhurst and Smellie (1983)

Three groups of sites in King George Island rich in fossil plant remains, already elaborated in considerable detail, should be mentioned:

1) Sites at Fildes Peninsula south-west of the Chilean Presidente Frei — Teniente Marsh Station (described in literature as Mount Flora or "vicinity of Ardley Peninsula, resp. Island"). They belong to the Fildes Peninsula Group of early Tertiary (Eocene or Paleocene) age (Fig. 2: *12*). The fossil flora has been described in particular by Orlando (1963, 1964) and, more recently, by Czajkowsky and Rösler (1984) and Torres et al. (1984);

2) Site near Arctowski Station (Poland), Admiralty Bay, known as Petrified Forest Creek. The fossil flora (sporomorph *Nothofagus-Pteridophyta* assemblage) occurs in the Ezcurra Inlet Group (probably Paleocene — see Fig. 2: *6*; Fig. 3). It has been elaborated in detail by Stuchlik (1981);

3) Sites (rock exposures and moraine sites) near Point Hennequin (Dragon Glacier, Mount Wawel) at Admiralty Bay. Rich plant remains (*Nothofagus-Podocarpaceae* assemblage) occur in the upper part of the Point Hennequin Group (Late Oligocene — see Fig. 2: *15—17*; Fig. 3). They have been elaborated partly by Barton (1964) and in more detail by Zastawniak (1981; Zastawniak et al. 1985).

The Dufayel Island site (Fig. 2: *8*) here described in detail (see Part II of this paper) becomes the fourth important palaeofloral site of King George Island.

SITE DESCRIPTION

The fossil plant site at Dufayel Island is located near its eastern termination called Gdynia Point, in a cliff section more than 100 m high (Fig. 4). The detailed description of volcaniclastic strata which occur between andesitic (at the base) and basaltic andesite lavas (at the top) is given elsewhere (Birkenmajer 1980a, pp. 23—24, Figs 6A, 7A) and will not be repeated here. The leaf fragments occur in alternating bands of mainly green, but also purple, shale and tuff-shale 4 m thick, at the base of the Dalmor Bank Formation, just above edgewise conglomerate belonging to the Gdynia Point Formation, at about 60 m above the sea.

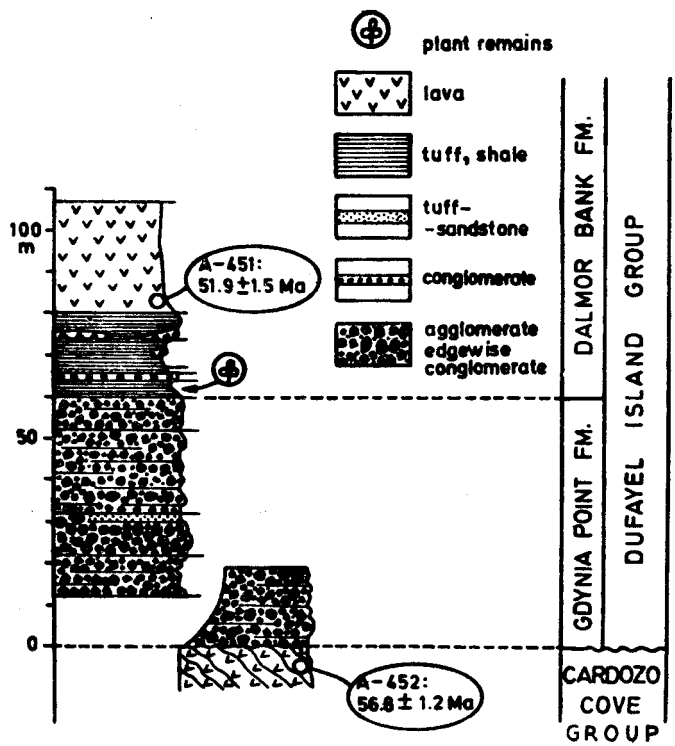

Fig. 4. Position of plant-bearing beds in lithostratigraphic column of the Dufayel Island Group at Dufayel Island (after Birkenmajer 1980a; radiometric K-Ar dates after Birkenmajer et al. 1983a, b)

AGE OF THE DUFAYEL ISLAND GROUP PLANT-BEARING BEDS

An early Tertiary age of the Dufayel Island Group palaeoflora was suggested by Barton (1964) and Adie (1964), and the Eocene age was considered the most probable.

Radiometric K-Ar dating of basaltic andesite lava capping the plant-bearing sediments gave 51.9 ± 1.5 Ma, and of the underlying folded and considerably altered (metasomatic) andesite lavas — 56.8±1.2 Ma (Birkenmajer et al. 1983a, b) — Fig. 4. The seradiometric age brackets would indicate an early Tertiary (Paleocene — Eocene) age of the plant beds, provided the lavas had not been reheated during post-Eocene thermal events. The older date, from the lavas at the base of the section, below angular unconformity, refers to the supposedly late Mesozoic Cardozo Cove Group. Its K-Ar age (Paleocene-Eocene) should be considered with caution as argon loss by Tertiary reheating is here very probable (*op. cit.*), and late Cretaceous stratigraphic age of the basal lavas cannot be ruled out. The plant-bearing beds of the Dufayel Island Group may thus represent either the base of early Tertiary or the top of late Cretaceous.

II. PALAEOBOTANICAL PART
(by E. Zastawniak)

DESCRIPTION OF FOSSIL PLANT MATERIAL

The fossil plant material here described has been collected during two Polish Scientific Antarctic Expeditions to King George Island, by Birkenmajer (in 1977/78 and 1980/81) and by Gaździcki and Wrona (in 1980/81). It consists of 49 rock fragments showing 72 imprints of leaf fragments, some possibly representing parts of compound leaves. The imprints are devoid of organic matter and generally very indistinctly visible, differing from the bright-green tuffaceous matrix of the rock by slightly darker hue. Traces of nervation in form of parts of midvein with several lateral veins, are visible on some specimens. The shapes of complete leaves, leaf margins, and the highest order vein are in most cases hardly recognizable [1]. Outlines of leaves from the Dufayel Island Group shown in Figs. 5—7 clearly demonstrate their fragmentary character of preservation.

The collection of leaves here described is housed in the Palaeobotany Department of the Institute of Botany of the Polish Academy of Sciences under the Numbers

[1] According to Barton (1964, p. 603), „Plant remains occur in green-coloured medium- and coarse-grained laminated tuffaceous flagstones. The commonest fossils take the form of detached leaf impressions; they are aligned subparallel to the bedding and along the bedding planes. Fine leaf detail is often obscured by the minor irregularities which partly project through the relatively smooth surface layers of the fossils. All original organic material has been removed".

173/2—11 and 173/383—420. The leaf outlines were traced on transparent plastic paper with the use of the Carl Zeiss Jena stereo-microscope SM-XX. The terminology of leaf description used here follows that of Hickey (1973).

REMARKS ON TAXONS OF FOSSIL LEAVES

In the present state of knowledge of the Antarctic fossil floras, it was possible to determine the leaf fragments from the Dufayel Island Group with only small degree of accuracy. Lack of impressions of whole leaves makes it difficult or even impossible to detailly characterize particular forms, and to attribute them to proper fossil taxons. Analogous leaf forms have already been distinguished in the Tertiary strata of West Antarctica: at Seymour Island (Dusén 1908); at Fildes Peninsula, King George Island ("vicinity of Ardley Island vel Peninsula" — Orlando 1963, 1964), moreover in South America: Chubut and Río Negro Provinces, Argentina (Berry 1925a, b, 1938); Coronel in Chile (Engelhardt 1891), and others.

No gymnosperms have been found in the investigated material. Almost all plant remains represent angiosperms, only two specimens may belong to pheridophytes. The angiosperms are represented mainly by various dicotyledonous genera, except for a fragment of parallel-veined monocotyledonous leaf.

Leaf fragments characteristic for *Nothofagus* section *Calucechinus* (Hombr. et Jacq.) Krasser are shown in Fig. 5: *1*, *4*, *7*, *15a*. They display predominantly simple craspedodromous venation, obtuse leaf base and probably toothed margins. The midvein is massive or stout, provided with outer secondary veins. The angle of divergence of secondaries is acute (30—43°). To this genus may also belong: a small leaf with petiole preserved, with massive midvein (Fig. 5: *5*; Pl. II, 4); another leaf fragment (Fig. 5: *8*); possibly also three other fragments with curved secondary veins in apical part of the leaves (Fig. 5: *6*, *10*, *11*).

Some fragments of larger leaves, with craspedodromous venation, with secondary veins straight and subparallel, more or less regularly loosely speced, are shown in Fig. 5: *9*, *13*, *15b*. They may also belong to the genus *Nothofagus*. However a possibility cannot be excluded that some of them could belong to another fossil taxon — *Tetracera patagonica* Berry [2] as the specimen on Fig. 6: *8*. Leaf remains of this genus have been reported from the Tertiary of South America (Engelhardt 1891; Berry 1925a, b) and from Fildes Peninsula, King George Island ("vicinity of Ardley Island vel Peninsula" — Orlando 1963, 1964).

Two other specimens are shown in Fig. 6: *11*, *12*. Only one of them represents a more complete leaf about 5.5 cm long and 1.2 cm broad, of narrow elliptic shape, with cuneate leaf base and entire margin; venation pinnate, primary vein moderate,

[2] The genus *Tetracera* belongs to the family *Dilleniaceae* which includes 18 genera of trees, shrubs and climbers. The family *Dilleniaceae* is almost pantropical, with the main distribution centre in Asia and Australasia. It is also frequent in tropical America (Brazil), but infrequent in Africa where it is represented only by some species of the genus *Tetracera* (Gilg 1895; Heywood 1978).

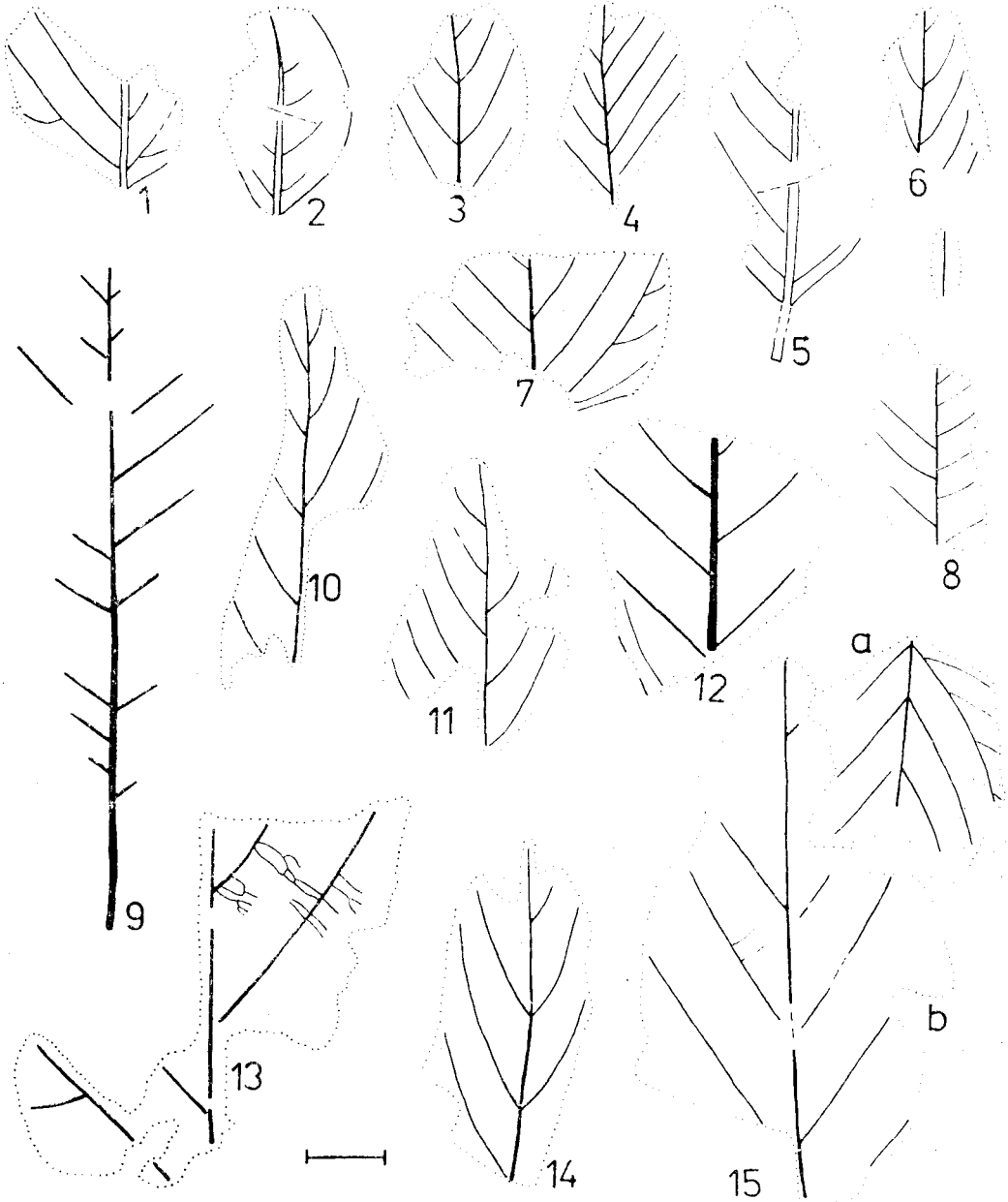

Fig. 5. Leaf impressions from the Dufayel Island Group (Dalmor Bank Formation), Admiralty Bay, King George Island; coll. K. Birkenmajer 1977/78 (specimens Nos 173/3—5, 10) and A. Gaździcki & R. Wrona 1980/81. Bar = 1 cm. 1 — specimen No 173/4, *Nothofagus* sp. aff. *N. alessandri* Espinosa; 2 — specimen No 173/3, *Dicotylophyllum* sp.; 3 — specimen No 173/408, *Nothofagus* sp.; 4 — specimen No 173/400, *Nothofagus* sp., see Pl. I, 8; 5 — specimen No 173/5, *Nothofagus* sp., see Pl. II, 4; 6 — specimen No 173/10, *Nothofagus* sp.; 7 — specimen No 173/414, *Nothofagus* sp., see Pl. I, a; 8 — specimen No 173/406, *Nothofagus* sp.; 9 — specimen No 173/414, *Tetracera patagonica* Berry or *Nothofagus* sp.; 10 — specimen No 173/414, *Nothofagus* sp., see Pl. I, 1b; 11 — specimen No 173/415+415a, *Nothofagus* sp. (drawing from both twin impressions); 12 — specimen No 173/399, *Dicotylophyllum* sp., see Pl. I, 6; 13 — specimen No 173/387, *Tetracera patagonica* Berry or *Nothofagus* sp.; 14 — specimen No 173/414, *Dicotylophyllum* sp., see Pl. I, 1, c; 15 — specimen No 173/393: a — *Nothofagus* sp., b — *Tetracera patagonica* Berry or *Nothofagus*, see Pl. I, 5

straight; secondary veins moderate, of straight course, forming an intramarginal vein closely paralleling leaf margin; angle of divergence of secondaries 48—65°, upper secondary veins more obtuse than lower ones; some simple intersecondary veins are visible; tertiary veins of ramified pattern — they run approximately at right angles to midvein. Such a type of venation is characteristic of leaves of the family *Myrtaceae*. The fossil remains of this family, known from several Tertiary localities of South America, have been attributed chiefly to the genus *Myrcia* (Engelhardt 1891; Berry 1923, 1928; Hollick & Berry 1924). To the same genus, according to Berry (1928), belongs also the upper part of leaf reported from Seymour Island by Dusén (1908, Pl. II, Fig. 10) as *Phyllites* sp. 16.

The presence of *Myrtaceae* in the Tertiary of Antarctica has also been confirmed by Cranwell (1959), based on palynological analysis of sediments from Seymour Island.

The family *Myrtaceae* of to-day is mostly tropical and subtropical, with the main centre of distribution in America and Australia. In Australia, *Myrtaceae* are the most important woody plants known since Paleocene (Martin 1982).

Two specimens of small leaflets (?) shown in Fig. 6: *13*, and Fig. 7: *12*, belong to *Leguminosites*. This fossil genus has also been reported by Dusén (1908, Pl. II, Figs. 1, 2; Pl. III, Fig. 16) from the Seymour Island Tertiary strata.

The leaf imprint shown in Fig. 6: *7* may be compared with the recent leaves of *Nothofagus* from the subsection *Bipartitae* Steen., which are entire and have camptodromous venation. The species of this subsection occur to-day in tropical climatic conditions of New Caledonia and New Guinea (van Steenis 1953; Dawson 1966).

In the examined material, there are also numerous plant remains of laurophyllous type, represented by entire leaves with pinnate, camptodromous venation (Fig. 6: *1*, *2*, *4*, *6*, *7*, *9*, *14*, *17*; Fig. 7: *8*, *9*; Pl. I, 3; Pl. II, 6). Scanty morphological leaf features do not allow to determine these fragments with precision. Some of them could belong to the family *Lauraceae* which is represented by petrified wood in the Tertiary strata of Seymour Island (Gothan 1908). From the same strata, Dusén (1908) described a laurophyllous plant remain as *Lauriphyllum nordenskjoeldii*.

Two specimens (Fig. 6: *15*, *16*; Pl. II, 1) resemble the fossil leaves distinguished by Hollick and Berry (1924) and Berry (1939) as *Dodonea* (*Sapindaceae*). These are elongate leaves with numerous, delicate, more or less straight secondary veins diverging from midvein at wide angle.

Another leaf impression (Fig. 6: *5*) with characteristic loops of secondary veins and massive primary vein resembles leaf remains attributed by Berry (1926) to the family *Verbenaceae*.

Two lobed leaf fragments with massive veins are shown in Fig. 7. The first one (Fig. 7: *1*) with actinodromous venation is similar to leaves of the genus *Cochlospermum* of the family *Cochlospermaceae* (cf. Berry 1938). The second one (Fig. 7: *2*) shows the venation within the lobes similar to that of the species of the genus *Sterculia* from Paleocene-Eocene strata of Río Pichileufu, Argentina (Berry 1938). The leaf fragment determined from the Tertiary deposits of Seymour Island by

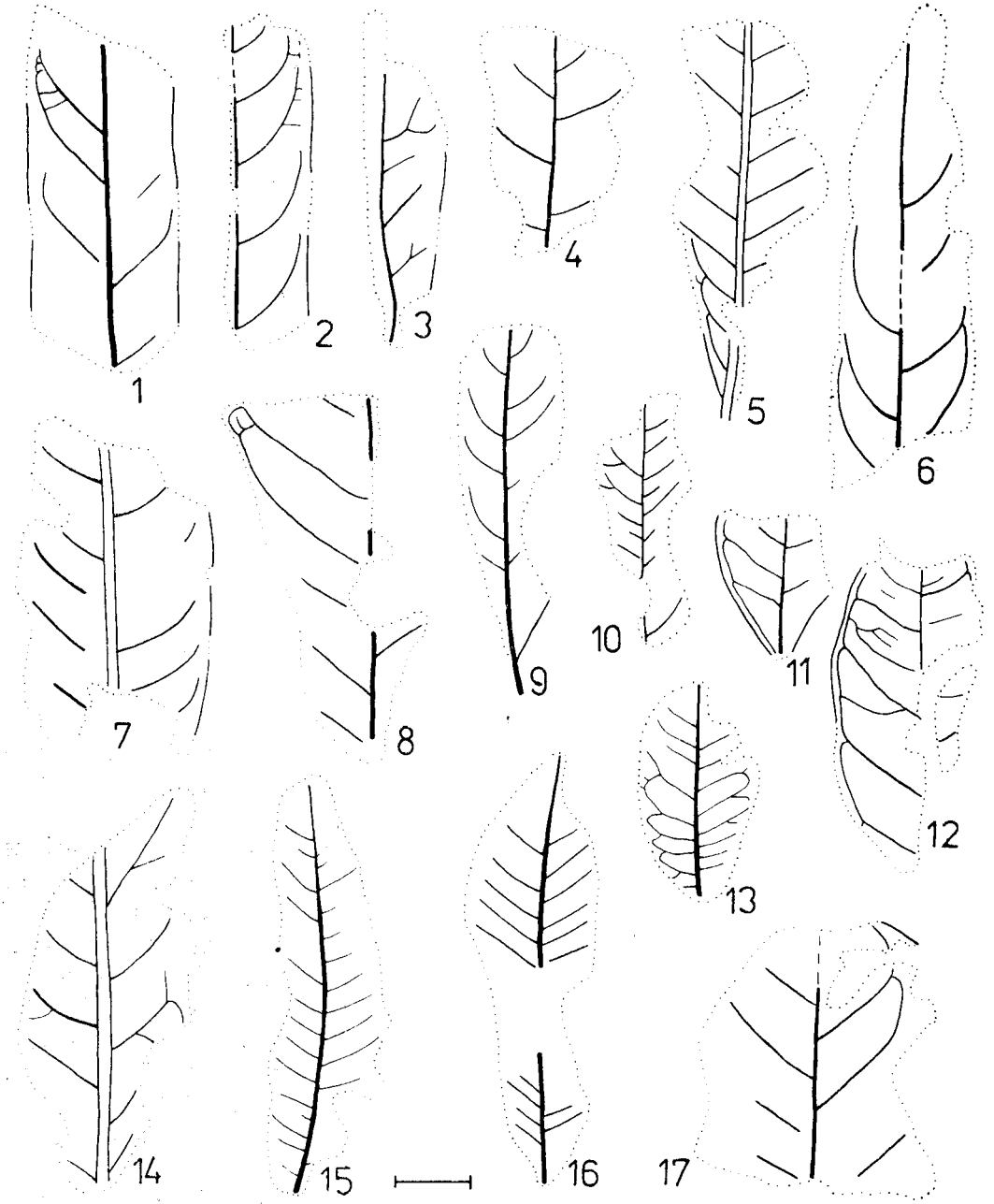

Fig. 6. Leaf impressions from the Dufayel Island Group (Dalmor Bank Formation), Admiralty Bay, King George Island; coll. K. Birkenmajer 1977/78 (specimen No 173/10) and A. Gaździcki & R. Wrona 1980/81. Bar = 1 cm. 1 — specimen No 173/392, laurophyllous impression; 2 — specimen No 173/391, laurophyllous impression; 3 — specimen No 173/406, *Phyllites* sp.; 4 — specimen No 173/397, laurophyllous impression; 5 — specimen No 173/418, *Dicotylophyllum* sp., (?*Verbenaceae*), see Pl. I, 2, a; 6 — specimen No 173/409, laurophyllous impression; 7 — specimen No 173/384, laurophyllous impression; 8 — specimen No 173/418, ?*Tetracera patagonica* Berry, see Pl. II, 2, b; 9 — specimen No 173/394, laurophyllous impression, see Pl. I, 3; 10 — specimen No 173/406, *Phyllites* sp.; 11 — specimen No 173/387, *Myrtaceae*; 12 — specimen No 173/387, *Myrtaceae*, see Pl. I, 4; 13 — specimen No 173/413, *Leguminosites*; 14 — specimen No 173/10, laurophyllous impression; 15 — specimen No 173/415, ?*Dodonea*, see Pl. II, 1; 16 — specimen No 173/415a, ?*Dodonea*; 17 — specimen No 173/417, laurophyllous impression

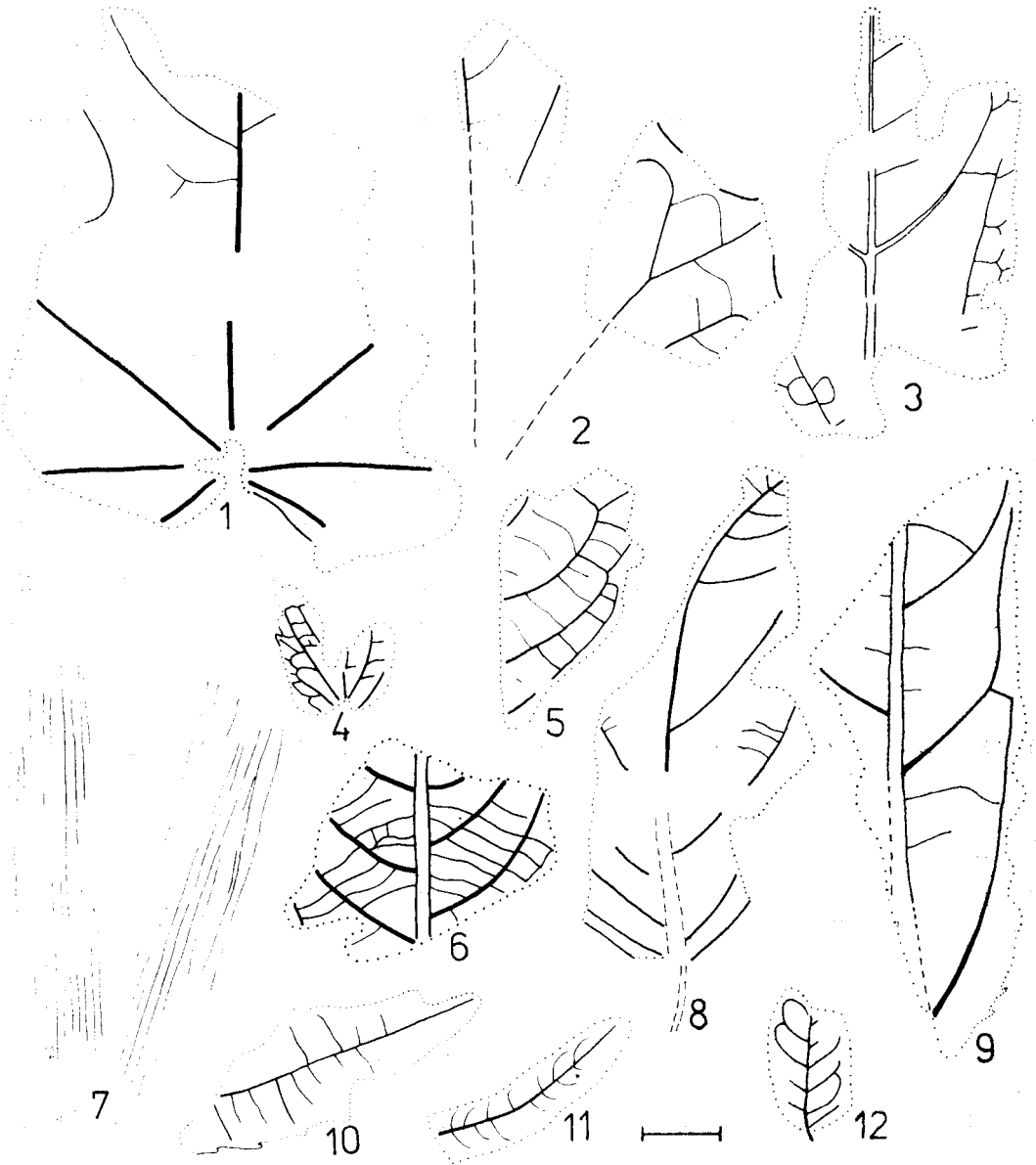

Fig. 7. Leaf impressions from the Dufayel Island Group (Dalmor Bank Formation), Admiralty Bay, King George Island, coll. K. Birkenmajer 1977/78 (specimen No 173/8) and A. Gaździcki & R. Wrona 1980/81. Bar = 1 cm. 1 — specimen No 173/389, aff. *Cochlospermum*, see Pl. II, 3; 2 — specimen No 173/399, ?*Sterculia*, comp. *Phyllites* sp. (9) in Dusén (1908, Pl. 2, fig. 17); 3 — specimen No 173/8, *Dicotylophyllum* sp.; 4 — specimen No 173/388, *Dicotylophyllum* sp., see Pl. I, 7; 5 — specimen No 173/402, *Dicotylophyllum* sp.; 6 — specimen No 173/410, *Dicotylophyllum* sp., see Pl. II, 5; 7 — specimen No 173/395, monocotyledonous remains, see Pl. II, 7; 8 — specimen No 173/398, laurophyllous impression; 9 — specimen No 173/385, laurophyllous impression, see Pl. II, 2; comp. *Lauriphyllum nordenskjeoldii* Dus. (Dusén 1908, Pl. 2, fig. 9); 10 — specimen No 173/385, part of frond?; 11 — specimen No 173/416, part of frond?; 12 — specimen No 173/419, *Leguminosites*

Dusén (1908, Pl. II, Fig. 17) as *Phyllites* sp. 9, seems to be an apical part of leaf lobe of the same fossil plant. Occurrence of trilobed dicotyledonous leaves resembling those of *Sterculia* has also been reported by Barton (1964, Fig. 2) from the Tertiary of King George Island, however without closer localization and/or stratigraphic position given.

Fragments of a monocotyledonous plant with moderately narrow, parallel-veined leaves are shown in Fig. 7: 7 and Pl. I, 7. They do not resemble any monocotyledonous remains known so far from the Tertiary floras of West Antarctica and the southern part of South America: either *Scirpites* sp. — a stem was illustrated by Dusén (1908, Pl. II, Fig. 6) from the Tertiary strata of Seymour Island, or *Chusquea rolloti* Berry belonging to the family *Gramineae* — as described by Berry (1929) from the Tertiary of Colombia. It should be added that our form confirms the presence of monocotyledons in the palaeoflora of West Antarctica already reported by palynological investigations (Hall 1977; Stuchlik 1981). The pollen type described by Stuchlik (1981) from the Petrified Forest Member (Ezcurra Inlet Group, Early Tertiary) of Admiralty Bay (King George Island) as *Graminidites antarcticus* n. fsp. is, according to him, very similar to the *Bambusa*-type. It cannot be excluded that *Graminidites antarcticus* Stuchlik belongs to the genus *Chusquea* which grows to-day in bamboo woodland of the Valdivian Rain Forest of South America.

FOSSIL PLANT ASSEMBLAGE OF THE DUFAYEL ISLAND GROUP AS COMPARED WITH THE RECENT VEGETATION

It is very difficult to compare the fossil flora of the Dufayel Island Group with the recent vegetation due to fragmentary preservation of the former. In the author's opinion, only two recent taxons, the genus *Nothofagus* and the family *Myrtaceae*, seem to be without doubt present in the Dufayel Island collection. Systematic position of the fossil leaves ?*Dodonea*, ?*Sterculia*, *Tetracera patagonica* Berry etc., is unclear. The occurrence of the families *Cochlospermaceae*, *Dilleniaceae*, *Leguminosae*, *Sapindaceae*, *Sterculiaceae* and *Verbenaceae* cannot be proved at the present state of investigation.

The Dufayel Island palaeoflora is characterized by the presence of the genus *Nothofagus* and the family *Myrtaceae*, associated with numerous other dicotyledonous laurophyllous trees and shrubs — the components of broad-leaved forest of temperate or even warm temperate climate. The leaves of *Nothofagus* of the *Calucechinus* section indicate the presence of cool temperate element in our palaeoflora.

There are some analogies of the Dufayel Island palaeoflora to the Valdivian Rain Forest and the *Nothofagus obliqua*-and-*Nothofagus procera* Forest of the temperate forest types of West Patagonia, as characterized by Schmithüsen (1956, 1966) and Hueck (1966). According to Hueck, the Valdivian Rain Forest represents a peculiar type of evergreen rain forest which occurs in temperate climate, considered o be a relic of Tertiary vegetation. This is a very rich forest, in which neotropical t

and subantarctic elements co-exist. Numerous angiosperm genera of trees and shrubs belong mainly to the families *Aexotoxicaceae*, *Cunonioceae*, *Fagaceae*, *Lauraceae*, *Monimiaceae*, *Myrtaceae*, *Proteaceae* and *Winteraceae*. The gymnosperms are represented by *Araucaria araucana* (Molina) K. Koch and the families *Cupressaceae* and *Podocarpaceae* (Hueck *op. cit.*; Weber 1969). The climatic conditions recorded for the Valdivian Rain Forest are characterized by mean annual temperature of 10—12°C (without frost), and precipitation of 2000—4000 mm (Hueck & Seibert 1972).

The lack of gymnosperm plants in our collection makes the Dufayel Island Group fossil flora resemble also the deciduous forest of *Nothofagus obliqua*-and-*Nothofagus procera* type [3]. According to Hueck (*op. cit.*), in this type of forest two main deciduous components, *Nothofagus obliqua* and *Nothofagus procera* grow alongside evergreen *Lauraceae*. The climatic conditions recorded from the present-day temperate zone forests with *Nothofagus obliqua* and *N. procera* are as follows: mean annual temperature of 12—13°C, and precipitation of 1000—3000 mm (Hueck & Seibert 1972).

RELATION OF THE FOSSIL FLORA OF THE DUFAYEL ISLAND GROUP TO OTHER LEAF FLORAS OF WEST ANTARCTICA AND SOUTH AMERICA

Leaf remains from the Cretaceous and Tertiary of Antarctica have so-far been reported only from the western part of the continent, from the coastal zone of Antarctic Peninsula and the South Shetland Islands (King George Island in particular). The leaf flora from Seymour Island, northern Antarctic Peninsula, described by Dusén (1908) is palaeontologically best elaborated. Originally determined as Eocene, this flora has been later redefined as Paleocene-Eocene (Romero 1978), and quite recently as Paleocene (Elliot & Trautman 1982). A shoot fragment belonging to the genus *Dacrydium* (*Podocarpaceae*) has been found in Late Cretaceous strata of the nearby Snow Hill Island (Halle 1913: cf. *Sequoia fastigiata* (Sternb.), Florin 1940).

New fossil leaf sites have recently been found on Alexander Island (Thomson & Burn 1970) and Adelaide Island (Jefferson 1980) west of Antarctic Peninsula. Some drawings of poor preserved angiosperm leaves have been presented. A Paleocene-Eocene age has been suggested for the Alexander Island palaeoflora based on correlation with tuffs K-Ar-dated for 63—41 Ma (Pankhurst, in Jefferson 1980). Beech-like leaf impression from Adelaide Island were derived from the rocks so-far regarded as late Jurassic, but considered by Jefferson to be late Cretaceous or younger.

Only three out of a score or so fossil plant assemblages from the volcanic-

[3] A comparison of the *Myrtaceae-Lauraceae* forest community (Hueck 1966, p. 348) of the latter forest type with our assemblage would be of interest.

sedimentary successions of King George Island, South Shetland Islands (Fig. 2), have been described in relative detail. These are:

— The Fildes Peninsula site [4] ("vicinity of Ardley Island vel Peninsula"), Maxwell Bay, with palaeoflora described by Orlando (1963, 1964), considered by him to be of Miocene age; age corrected to Late Paleocene — Middle Eocene by Romero (1978). According to Orlando (*op. cit.*), this is a mixed-type palaeoassemblage resembling that of Seymour Island and differing in this respect from the Patagonian ones. It consists of fossil leaf taxons belonging to dicotyledonous families of different climatic requirements: *Anacardiaceae*, *Dilleniaceae*, *Fagaceae*, *Lauraceae*, *Monimiaceae*, *Myrtaceae*, *Proteaceae* and *Sterculiaceae*. They are associated with monocotyledonous remains, infrequent gymnosperms (*Fitzroya tertiaria* Berry of the family *Cupressaceae*, and *Athrotaxites*), and ferns;

— The Dragon Glacier morainic site at Admiralty Bay, with the *Nothofagus-Podocarpaceae* palaeoassemblage (Zastawniak 1981) derived from rocks of the Point Hennequin Group. It was considered to be of Lower-Middle Miocene age (Barton 1964; Orlando 1963, 1964), but has been K-Ar dated on associated andesite lavas as Late Oligocene (Birkenmajer et al. 1983b);

— The Mount Wawel site at Admiralty Bay, with the same *Nothofagus-Podocarpaceae* palaeoassemblage derived from a tuff intercalation between lavas of the Point Hennequin Group, K-Ar-dated as Late Oligocene (Birkenmajer et al. 1983b; Zastawniak et al. 1985).

Despite fragmentary knowledge of the taphocoenoses discussed, it seems that the Dufayel Island palaeoflora resembles most those of Seymour Island and Fildes Peninsula. The latter two palaeofloras differ from the Dufayel Island one in being richer in pteridophyte and gymnosperm remains, but this difference does not seem related to their stratigraphic position (see below). The age of the fossil flora of the Dufayel Island Group: Early Tertiary or Upper Cretaceous (comp. Geological Part) could be probably determined after further investigations, which are carried out in the Institute of Botany of the Polish Academy of Sciences in Cracow, of the other leaf floras collected during the Polish Scientific Antarctic Expeditions to King George Island from the localities: Zamek, Cytadela, Fildes Peninsula and Potter Cove.

The Seymour Island and Fildes Peninsula palaeofloras have been included by Romero (1978) to the "palaeoflora mixta" type. The latter had developed in Patagonia during the Paleocene. It is characterized by the presence of plant remains belonging to both subtropical and cool temperate elements. The subtropical element dominated in the "palaeoflora mixta" assemblages during the Paleocene and Early Eocene, having at that time its maximum areal distribution between latitudes 40 degrees south (Nahuel Huapi, Argentina) and about 64 degrees south (Seymour Island, Antarctic Peninsula).

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[4] The plant remains from Fildes Peninsula are recently investigated by Czajkowsky and Rösler (1984) and Torres et al. (1984).

In the Dufayel Island palaeoflora, which also belongs to the „palaeoflora mixta" type, the subtropical element seems to be represented by such fossil leaves as aff. *Cochlospermum*, ?*Dodonea*, *Leguminosites*, ?*Sterculia* and *Tetracera patagonica* Berry, moreover by entire leaves with various venation types characteristic of plants with higher climatic requirements. The cool temperate element of this palaeoflora is represented by non-entire leaves of *Nothofagus* and this remains of *Myrtaceae*.

It should be added that Romero (1978) includes to his cool temperate element of "palaeoflora mixta" also representatives of the angiosperm genera *Laurelia* (*Monimiaceae*) and *Lomatia* (*Proteaceae*), moreover the conifers *Araucaria*, *Cupressaceae* and *Podocarpaceae*.

The gymnosperm remains which are a common and differentiated group in the majority of the Tertiary palaeofloras of West Antarctica (Dusén 1908; Cranwell 1959; Orlando 1963, 1964; Zastawniak 1981; Zastawniak et al. 1985), have not been found in the Dufayel Island assemblage. This feature does not seem related to either age or climatic character of the palaeoflora discussed but may suggest the presence of various types of forest in palaeovegetation of the South Shetland Islands: 1) A coniferous-broad-leaved dicotylous mixed forest, being the most frequent and most widely distributed; 2) A broad-leaved dicotylous forest abounding in ferns (e.g., as recognized in the Early Tertiary sporomorph assemblage of the Ezcurra Inlet Group, Petrified Forest Member — see Stuchlik 1981); 3) Broad-leaved forest composed almost entirely of angiosperms, as is our case.

According to Romero (1978), the share of cool temperate element in the "palaeoflora mixta" has been increasing since the Middle Eocene, particularly in fossil floras from West Antarctica, and more southern sites of South America. During the Oligocene, this element became the dominant one in the cool temperate forests of these southern areas. This tendency has been confirmed by investigations of Late Oligocene plant assemblages of the Point Hennequin Group (Dragon Glacier and Mount Wawel sites) on King George Island (Zastawniak 1981; Zastawniak et al. 1985). The latter fossil floras are composed predominantly of the cool temperate (subantarctic) element represented by non-entire leaves of *Nothofagus*, moreover by numerous and differentiated *Podocarpaceae*. The subtropical element is still present but only as relictic forms. In the Mount Wawel fossil flora, it is represented by *Cochlospermum* and *Dicotylophyllum* sp. div.

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STRESZCZENIE

Zbadano szczątki flory kopalnej zachowane w postaci odcisków liści, zebrane w osadach wulkanoklastycznych wieku prawdopodobnie staropaleogeńskiego na Wyspie Dufayel w Zatoce Ezcurra (Wyspa King George, Szetlandy Południowe) w Antarktyce Zachodniej. Szczątki te pochodzą z najniższej części formacji Dalmor Bank, która jest górną formacją grupy Dufayel Island. Datowanie radiometryczne metodą potasowo-argonową lawy andezytu bazaltowego znajdującej się powyżej osadów — 51.9 ± 1.5 mln lat oraz zmienionych, sfałdowanych law andezytowych poniżej kompleksu osadowego — 56.8 ± 1.2 mln lat wskazuje na staropaleogeński (wczesnoeoceński lub wczesnoeoceńsko-późnopaleoceński) wiek osadów floronośnych. Z uwagi jednak na prawdopodobne przegrzanie powyższych law w czasie trzeciorzędowej historii wulkanicznej Szetlandów Południowych istnieje prawdopodobieństwo ucieczki części argonu z law. W takim przypadku wiek stratygraficzny kompleksu osadów floronośnych na Wyspie Dufayel mógłby być nieco starszy, górnokredowo-paleoceński lub górnokredowy.

Materiał kopalny, będący przedmiotem niniejszego opracowania, został zebrany podczas dwóch wypraw antarktycznych Polskiej Akademii Nauk przez K. Birken-

majera (1977/78, 1980/81) oraz A. Gaździckiego i R. Wronę (1980/81). Zasługiwał on na przedstawienie i próbę interpretacji pomimo bardzo złej jakości odcisków liści, gdyż pochodzi z trzeciego kolejnego poziomu floronośnego w kredowo-paleogeńskim kompleksie wulkaniczno-osadowym nadgrupy Wyspy King George, którego wiek został określony metodą radiometryczną (Birkenmajer et al. 1983a, b). Dwa pozostałe poziomy to: wczesnotrzeciorzędowy (prawdopodobnie paleoceński) zespół sporomorf *Nothofagus-Pteridophyta* z ogniwa Petrified Forest w grupie Ezcurra Inlet (Stuchlik 1981) oraz późnooligoceński zespół ze szczątkami liści i nasion *Nothofagus-Podocarpaceae* grupy Point Hennequin na górze Wawel (Zastawniak et al. 1985). Tego samego, późnooligoceńskiego wieku jest flora liściowa pochodząca z moreny na Lodowcu Smoka (Dragon Glacier) w Zatoce Admiralicji, której wiek był początkowo oceniany jako dolny-środkowy miocen (Barton 1964; Orlando 1963, 1964).

Przeważająca większość z 72 odcisków szczątków roślin zachowanych na 49 ułamkach skały należy do roślin okrytonasiennych; są to liście lub/i listki roślin dwuliściennych. Nieliczne fragmenty niezbyt wąskich liści o równoległej nerwacji, charakterystycznej dla roślin jednoliściennych (fig. 7: *7*; tabl. II, *7*), potwierdziły ich obecność we florach kopalnych Antarktyki Zachodniej, stwierdzoną już wcześniej przez Duséna (1908) na materiale szczątków makroskopowych oraz przez Halla (1977) i Stuchlika (1981) na podstawie badań palinologicznych. Nie znaleziono szczątków roślin nagonasiennych, a tylko nieliczne okazy mogą być częściami liści paproci (fig. 7: *10*, *11*). Wydaje się, że taki skład tafocenozy z Wyspy Dufayel nie ma wymowy paleoklimatycznej i nie wiąże się bezpośrednio z wiekiem geologicznym flory, może być natomiast wyrazem znacznego zróżnicowania typów lasów w ówczesnej roślinności Antarktyki Zachodniej. Podobny wynik przyniosły wcześniejsze badania Stuchlika (1981), który we florze sporowo-pyłkowej starotrzeciorzędowych osadów ogniwa Petrified Forest (grupa Ezcurra Inlet) także nie stwierdził obecności roślin szpilkowych.

Dokładniejsze oznaczenie szczątków liści z Wyspy Dufayel, ze względu na stan ich zachowania, nie było możliwe. W opinii autorki części paleobotanicznej obecność w badanym materiale tylko dwóch współczesnych taksonów roślinnych — rodzaju *Nothofagus* i rodziny *Myrtaceae* nie budzi wątpliwości. Ich występowanie w stanie kopalnym w rejonie Półwyspu Antarktycznego zostało udowodnione już wcześniej przez Cranwell (1959), która oznaczyła ziarna pyłku tych roślin w próbie eoceńskiego osadu z Wyspy Seymour.

Liczne są szczątki laurolistne w postaci fragmentów liści całobrzegich, z nerwami bocznymi połączonymi pętlami. Niektóre z nich mogłyby należeć do rodziny *Lauraceae*, ale ten sam typ liści jest często spotykany także u innych rodzin *Angiospermae*. O tym, że rodzina *Lauraceae* była obecna w przeszłości w Antarktyce Zachodniej, świadczą dwa różne rodzaje drewien kopalnych, oznaczone przez Gothana (1908) z Wyspy Seymour. Z tego samego stanowiska Dusén (1908) opisał szczątki laurolistnej rośliny *Lauriphyllum nordenskjoeldii*.

Inne okazy liści przypominają taksony kopalne opisane już wcześniej z paleogeńskich flor Antarktyki Zachodniej, a mianowicie z Wyspy Seymour przy północno-

-zachodnim zakończeniu Półwyspu Antarktycznego (Dusén *op. cit.*), z Fildes Peninsula (okolice Wyspy *vel* Półwyspu Ardley) na Wyspie King George (Orlando 1963, 1964), a także z Laguna del Hunco w prowincji Chubut (Berry 1925a) i Río Pichileufu w prowincji Río Negro (Berry 1938) w Argentynie i in. Są to rodzaje: *Cochlospermum* (Berry 1938), *Dodonea* (Berry 1939; Hollick & Berry 1924), *Leguminosites* (Dusén 1908), *Sterculia* (Berry 1938), *Tetracera* (Berry 1925a, b; Engelhardt 1891).

Zespół roślin kopalnych, stwierdzony w poziomie floronośnym grupy Dufayel Island, nawiązuje w znacznym stopniu do paleogeńskich flor z Wyspy Seymour (paleocen) i Fildes Peninsula (paleocen — eocen?) i reprezentuje ten sam typ roślinności, który Romero (1978) określił jako „palaeoflora mixta". Flory kopalne z obszaru Antarktyki Zachodniej i południowej części Ameryki Południowej, należące do „palaeoflora mixta", charakteryzuje — zdaniem Romero — występowanie w tym samym zespole roślin kopalnych taksonów należących do elementu subtropikalnego i umiarkowanie chłodnego (subantarktycznego). Element subtropikalny dominował w zbiorowiskach roślinnych w okresie największego rozprzestrzenienia „palaeoflora mixta", tzn. w paleocenie i eocenie. W opisywanym materiale należą do niego szczątki liści aff. *Cochlospermum*, *?Dodonea*, *Leguminosites*, *?Sterculia*, *Tetracera patagonica* oraz szczątki roślin laurolistnych. Pod względem cech fizjonomicznych liści element ten charakteryzuje się przewagą liści dużych, całobrzegich lub klapowanych, o różnych typach nerwacji, właściwych roślinom o wyższych wymaganiach klimatycznych (klimatu umiarkowanie ciepłego lub nawet subtropikalnego).

Drugi składnik „palaeoflora mixta" — element umiarkowainie chłodny (subantarktyczny), reprezentuje w badanym materiale *Nothofagus* o lściach z brzegami ząbkowanymi oraz liście *Myrtaceae*. Romero (*op. cit.*) zalicza do tego elementu także rodzaj *Laurelia* (*Monimiaceae*), *Lomatia* (*Proteaceae*) oraz *Araucaria*, *Cupressaceae* i *Podocarpaceae* z drzew szpilkowych. Według tego autora udział elementu umiarkowanie chłodnego w „palaeoflora mixta" rośnie, poczynając od środkowego eocenu, by w oligocenie stać się dominującym w ówczesnej szacie roślinnej. Znalazło to potwierdzenie w badaniach późnooligoceńskich tafocenoz z grupy Point Hennequin na Wyspie King George, złożonych głównie ze szczątków *Nothofagus* i *Podocarpaceae* (Zastawniak 1981; Zastawniak et al. 1985). Element subtropikalny obecny jest w tej chłodno-umiarkowanej florze leśnej w formie reliktowej; we florze z góry Wawel należą do niego szczątki liści *Cochlospermum* i innych różnych roślin dwuliściennych (*Dicotylophyllum* sp. div.).

Zbiorowiska roślinne analogiczne do tych, których szczątki znaleziono w osadach Wyspy Dufayel, można odnaleźć w różnego typu lasach południowej części Ameryki Południowej, a zwłaszcza Andów Chilijsko-Argentyńskich. Szczególnie interesujące pod tym względem są dwa typy lasów wyróżnione przez Schmithüsena (1956, 1966) we florze leśnej Chile, a mianowicie lasy waldiwijskie i lasy z *Nothofagus obliqua* i *N. procera*.

Według Huecka (1966) lasy waldiwijskie są szczególnym rodzajem wiecznie zielonych lasów deszczowych, złożonych z elementu neotropikalnego i antarktycznego, uważanym za relikt roślinności trzeciorzędowej. Rosnąc w klimacie umiarko-

wanym o dużej wilgotności powietrza, tworzą bardzo bujne zbiorowiska leśne drzew i krzewów należących do rodzin *Aexotoxidaceae*, *Cunoniaceae*, *Fagaceae*, *Lauraceae*, *Monimiaceae*, *Myrtaceae*, *Proteaceae*, *Winteraceae* oraz drzew szpilkowych *Araucaria araucana*, *Cupressaceae* i *Podocarpaceae*. Towarzyszą im liany z rodzin *Gesneriaceae* i *Saxifragaceae* oraz drzewiaste bambusy *Chusquea* z rodziny *Gramineae*.

Warunki klimatyczne podawane dziś dla obszaru występowania lasów waldiwijskich są następujące: średnia temperatura roczna 10—12°C (ale bez mrozów), opady 2000—4000 mm (Hueck & Seibert 1972).

Ze względu na brak w materiale kopalnym roślin szpilkowych, badana tafocenoza z Wyspy Dufayel wydaje się jednak bardziej zbliżona do dzisiejszych lasów liściastych zrzucających liście z *Nothofagus obliqua*, które sąsiadują od północy z lasami waldiwijskimi. W klasyfikacji lasów południowoamerykańskich Hueck (1966) określa je jako lasy z *Nothofagus obliqua* i *N. procera*. Oba główne składniki tych lasów, tj. drzewa *Nothofagus obliqua* i *N. procera* zrzucają liście, ale obok nich rosną wiecznie zielone rodzaje *Laurelia* (*Monimiaceae*) i *Persea* (*Lauraceae*) oraz drzewa monotypowego rodzaju *Aexotoxicum*. Bardzo interesujące jest także zaliczone do tej grupy zbiorowisko leśne *Myrtaceae-Lauraceae*, częściowo drobnolistne, częściowo z dużymi, skórzastymi liśćmi, związane z wilgotnymi siedliskami nad brzegami rzek (Hueck *op. cit.*).

Warunki klimatyczne podawane dziś dla lasów typu *Nothofagus obliqua-Nothofagus procera* są następujące: średnia temperatura roczna 12—13°C, opady 1000—3000 mm (Hueck & Seibert 1972).

PLATES

Plate I

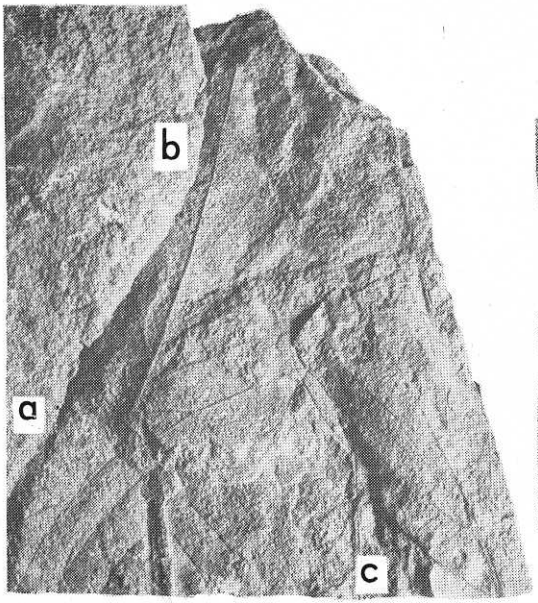
Leaf impressions from the Dufayel Island Group (Dalmor Bank Formation), Admiralty Bay, King George Island; coll. A. Gaździcki & R. Wrona 1980/81; (natural size except 7a)

1. Specimen No 173/414, a — *Nothofagus* sp., see Fig. 5, 7; b — *Nothofagus* sp., see Fig. 5, 10; c — *Dicotylophyllum* sp., see Fig. 5, 14
2. Specimen No 173/418, a — *Dicotylophyllum* sp., (?*Verbenaceae*), see Fig. 6, 5; b — ?*Tetracera patagonica* Berry, see Fig. 6, 8
3. Specimen No 173/394, laurophyllous impression, see Fig. 6, 9
4. Specimen No 173/387, *Myrtaceae*, see Fig. 6, 12
5. Specimen No 173/393, see Fig. 6, 15; a — *Nothofagus* sp., b — *Tetracera patagonica* Berry or *Nothofagus* sp.
6. Specimen No 173/399, *Dicotylophyllum* sp., see Fig. 5, 12
7. Specimen No 173/388, *Dicotylophyllum* sp., see Fig. 7, 4

7a. Ibidem, ×2

8. Specimen No 173/400, *Nothofagus* sp., see Fig. 5, 4

1—6, 8 phot. A. Pachoński
7, 7a phot. P. Szewczyk



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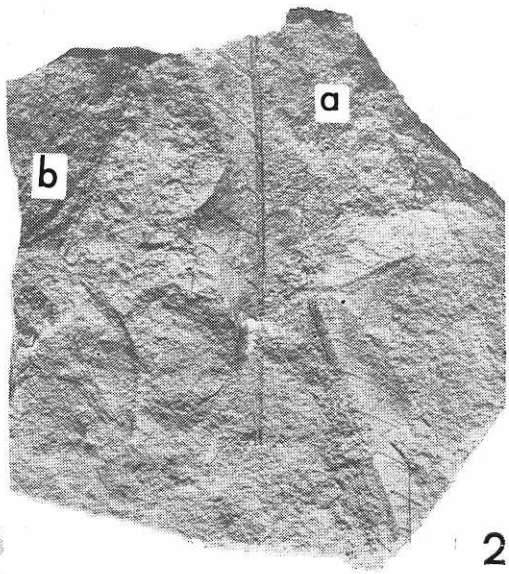

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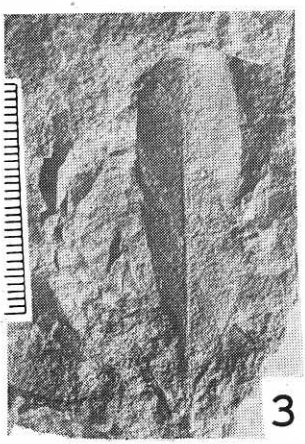

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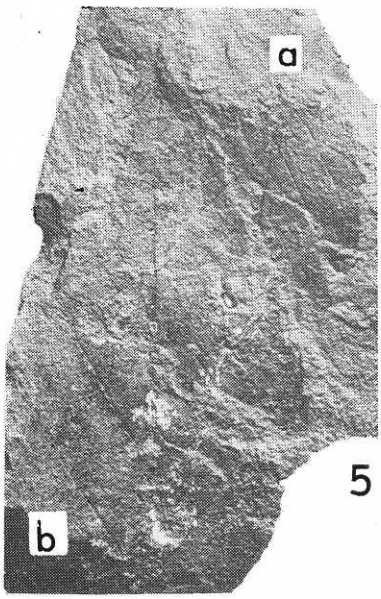
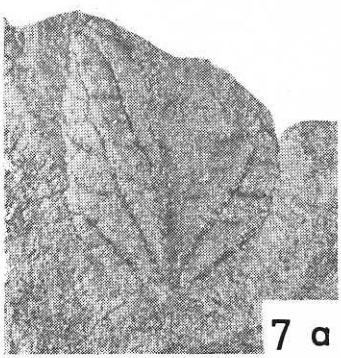
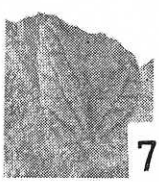


5

6



7 a



7

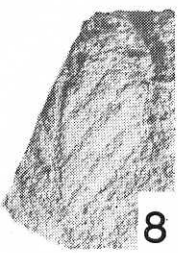


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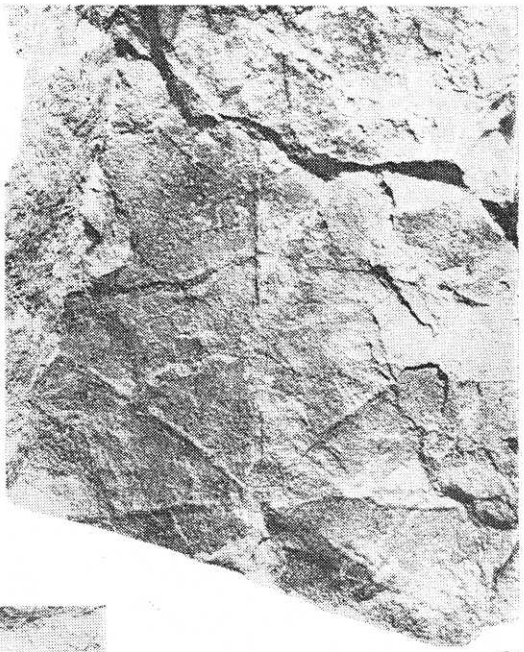
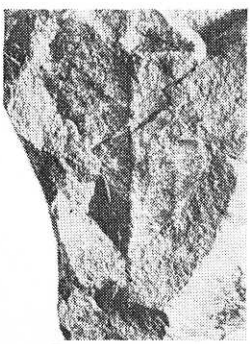
Plate II

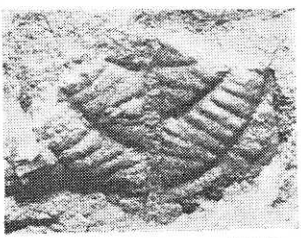
Leaf impressions from the Dufayel Island Group (Dalmor Bank Formation), Admiralty Bay, King Georg Island; coll. K. Birkenmajer 1977/78 (specimen No 173/5) and A. Gaździcki & R. Wrona 1980/81 (all the natural size)

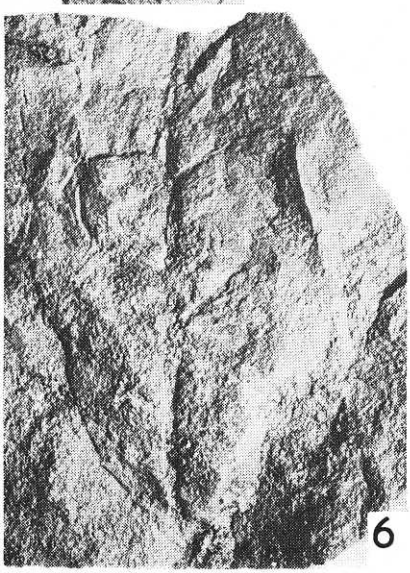
1. Specimen No 173/415, ?*Dodonea*, see Fig. 6, 15
2. Specimen No 173/385, laurophyllous impression, see Fig. 7, 9; comp. *Lauriphyllum nordenskjoeldii* Dus. (Dusén 1908, Pl. 2, Fig. 9)
3. Specimen No 173/389, aff. *Cochlospermum*, see Fig. 7, 1
4. Specimen No 173/5, *Nothofagus* sp., see Fig. 5, 5
5. Specimen No 173/410, *Dicotylophyllum* sp., see Fig. 7, 6
6. Specimen No 173/390, laurophyllous impression
7. Specimen No 173/395, monocotyledonous remains, see Fig. 7, 7

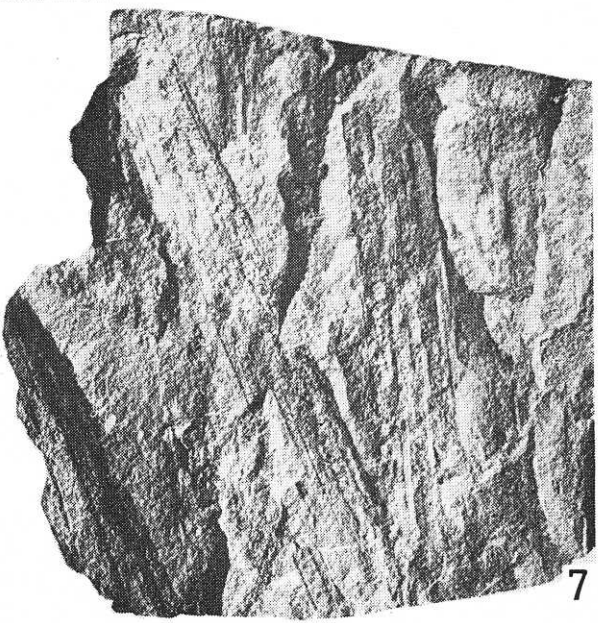
phot. A. Pachoński











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