CRETACEOUS PALYNOMORPHS FROM THE JAMES ROSS ISLAND AREA, ANTARCTICA – A PILOT STUDY

M. E. Dettmann

Department of Botany, University of Queensland, St Lucia, Queensland, Australia 4067
and

M. R. A. Thomson

British Antarctic Survey, Natural Environment Research Council, High Cross,
Madingley Road, Cambridge CB3 0ET, UK

ABSTRACT. Faunas of ammonites and bivalves, aquatic floras of dinocysts and prasinophycean/chlorophycean algae, and land-plant florules of spores, pollen, and fungal palynomorphs are reported from Cretaceous sedimentary rocks of James Ross Island, Dundee Island, and Cape Longing, Antarctic Peninsula. Ages adduced from the megafaunas are mostly verified by the dinocyst floras. Sampled horizons of the upper Kotick Point and Whisky Bay Formations are thus datable as early Albian and middle Albian–Cenomanian respectively; those of the lower Marambio Group fall within the age-range of Santonian/Campanian to Maastrichtian. Recycling from the Jurassic is also evident. Associated spore-pollen florules are less valuable for international correlation and dating.

Mid- to Late Cretaceous dinocyst assemblages of the Antarctic Peninsula confirm wide distribution, in southern high latitude oceanic regions, of the successive *Muderongia*, *Heterosphaeridium*, and *Isabelidinium* floras (recognized originally in Australia). Contemporaneous land-plant floras comprised a succession of rainforest communities having affiliations with vegetation fringing the southern Atlantic Ocean and in Australasia. Mid-Cretaceous araucarean/podocarp rainforests were modified during the Campanian by the introduction of *Nothofagus*. Evidence is advanced for step-wise migration of certain cryptogam and angiosperm elements within southern Gondwana.

The palynofloras comprise 62 cryptogam-spore, 54 pollen, 80 dinocyst, and nine prasinophycean/chlorophycean taxa. A trilete spore species, *Kraeuselisporites laceratus* Norris 1968 (senior synonym of *K. jubatus* Dettmann and Playford 1968) is newly combined with the genus *Perotrilites* Erdtman ex Couper 1953.

INTRODUCTION

The recognition that not all of the Cretaceous sedimentary rocks of James Ross Island (Fig. 1) were Campanian as once supposed, but that mid-Cretaceous strata were also present (Crame, 1981), prompted British Antarctic Survey geologists to take a new look at the sequence (Crame, 1983*a*, *b*; Thomson, 1984*a*, *b*; Ineson and others, 1986). Their work has been concentrated on molluscan biostratigraphy and sedimentology and has demonstrated that the bulk of the succession ranges from Aptian/Albian to Campanian or even younger. However, Hauterivian–Barremian fossils have also been obtained from correlated strata on the Nordenskjöld Coast (Farquharson, 1982; Thomson and Farquharson, 1984). The rocks themselves comprise a complex of siltstones, sandstones, and conglomerates that were probably deposited in submarine fan and slope apron settings. Prior to this field work, a few lithological samples were selected from earlier collections to assess the rocks for their palynological content. The samples were taken from matrix adhering to marine
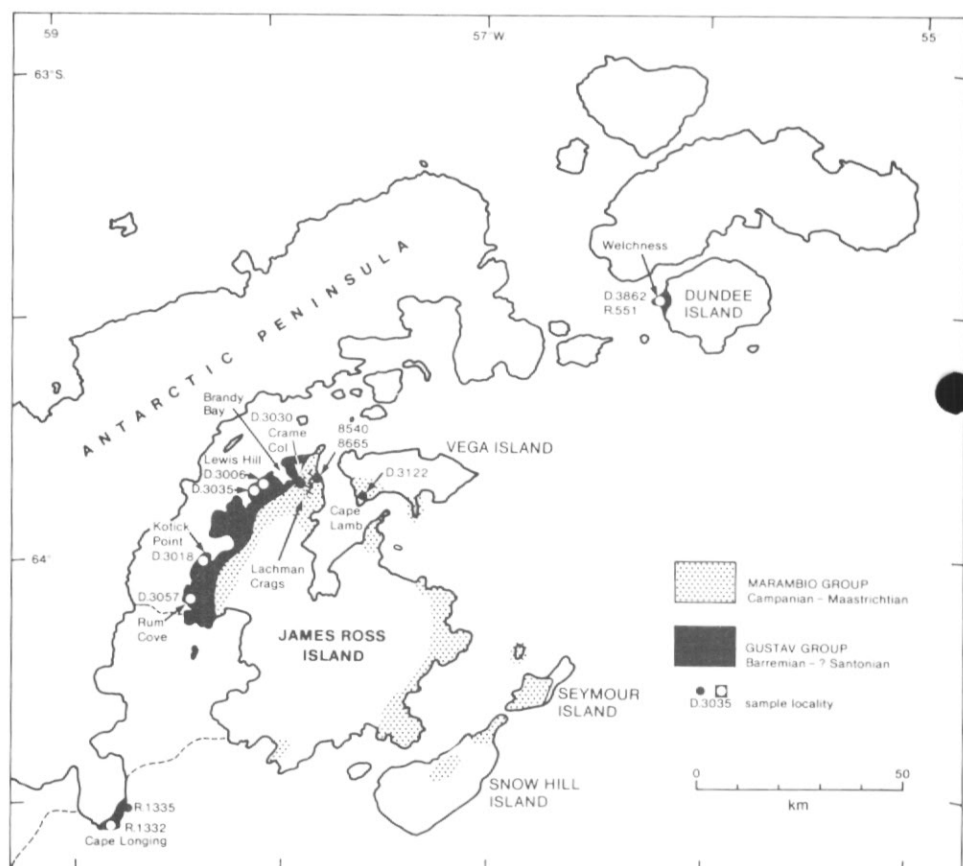
Fig. 1. Map of northern Antarctic Peninsula and James Ross Island showing location of samples investigated.

megafossils and from lithological samples, all collected on reconnaissance surv▮ undertaken between 1945 and 1959.

The results of this pilot study show that palynomorphs, including spores, pollen, and dinocysts, are not only abundant in most of the rocks processed, but they are well preserved and mostly thermally unaltered. Many of the dinoflagellate species present reflect the age of deposition of the sediments as deduced from the megafaunas; others indicate a degree of reworking, particularly from Late Jurassic strata (cf. Farquharson and others, 1984; Ineson, 1985). The dinocyst floras thus provide a basis for correlation with the palynostratigraphic schemes that have been established for Australia and New Zealand (Wilson, 1984; Helby and others, 1987) and confirm their importance for dating Cretaceous sequences in southern high-latitude regions.

Associated spore-pollen palynomorphs proved less valuable for precise age determinations and stratigraphic correlation. Many of the species display different stratigraphic ranges in disparate regions of southern Gondwana and appear to connote step-wise migration of the parent plants during the Cretaceous (Dettmann, 1981, 1986a, b).
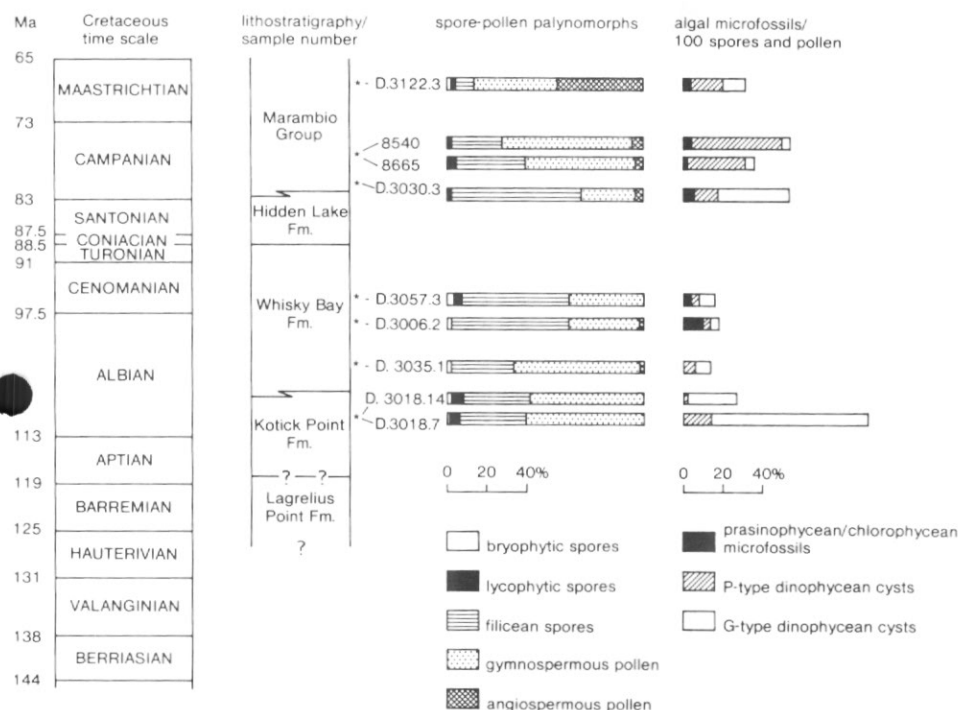
Fig. 2. Age and phyletic composition of palynomorph assemblages, James Ross Island and Vega Island. P- and G-type dinocysts as designated by Evitt (1985); Cretaceous time-scale after Harland and others (1982).

Additionally studied are samples from neighbouring Vega Island, Dundee Island, and Cape Longing (Fig. 1). The beautifully preserved palynoflora from Vega Island confirms that the sequence exposed at Cape Lamb includes sediments that are younger, possibly Maastrichtian, than thus far identified on James Ross Island. The Dundee Island and Cape Longing exposures are thermally altered but provided dinocyst and spore-pollen floras that support the mid-Cretaceous age determinations deduced from megafaunas.

Further field and laboratory studies are in hand to study in detail the palynostratigraphy of Cretaceous rocks of the James Ross Island area.

JAMES ROSS ISLAND

Location, lithostratigraphic affiliation, and suggested age of the eight samples studied from James Ross Island are shown in Figs 1 and 2. The latter also summarizes compositional attributes of the palynofloras that are detailed in Tables I–IV and discussed below.

D.3018.7 and D.3018.14, 1 km south of Kotick Point

The samples are fragments of limestone from Bibby's (1966, p. 17) Lower Kotick Point Beds (= Kotick Point Formation). Bibby was undecided as to whether the limestone was a 'nodular development or a limestone boulder', but further field

Table I. Distribution of cryptogam spore species in samples studied from James Ross Island, Vega Island, Dundee Island, and Cape Longing

Palynomorph species (stratigraphic listing)		James Ross Island								Vega Island	Dundee Island		Cape Longing		Palynomorph species (alphabetical listing)	
		D.3018.7	D.3018.14	D.3035.1	D.3006.2	D.3057.3	D.3030.3	8665	8540	D.3122.3	D.3862.3	R.551.4	R.1335.8	R.1332.9		
CRYPTOGAM SPORES																
Cyathidites australis/minor	1	+	+	+	+	+	+	+	+	+	+	+	+	+	Appendicisporites cf. insignis	44
Cyathidites sp. A	2	+	+	+	+	.	+	.	.	.	.	.	.	.	Baculatisporites comaumensis	4
Cyathidites asper/punctatus	3	+	.	+	.	.	+	.	.	+	.	.	.	.	Biretisporites sp. A	30
Baculatisporites comaumensis	4	+	+	+	+	+	+	+	+	+	+	+	.	+	Camarozonosporites ambigens	52
Osmundacites spp.	5	+	+	+	+	+	+	+	.	+	+	+	.	+	Ceratosporites equalis	9
Rugulatisporites neuquensis	6	+	+	.	.	.	.	.	.	.	.	.	.	.	Cicatricosisporites australiensis	11
Gleicheniidites circinidites	7	+	+	+	+	+	+	+	+	+	+	+	.	+	C. hughesii	13
Stereisporites antiquasporites	8	+	+	+	+	+	+	.	+	+	.	.	.	+	C. ludbrookiae	12
Ceratosporites equalis	9	+	+	+	.	.	.	.	+	+	.	.	.	.	C. sp. A	45
Retitriletes austroclavatidites	10	+	+	+	.	+	+	+	+	.	.	+	.	+	Contignisporites cooksoniae	39
Cicatricosisporites australiensis	11	+	+	+	+	.	.	.	.	.	.	.	.	.	C. fornicatus	41
Cicatricosisporites ludbrookiae	12	+	.	.	.	.	.	.	.	.	.	.	.	.	C. multimuratus	40
Cicatricosisporites hughesii	13	+	.	.	.	.	.	.	.	.	.	.	.	.	Coptospora paradoxa	50
Cyatheacidites annulatus	14	+	+	+	+	+	+	+	+	.	.	+	+	+	Coronatispora perforata	32
Cyatheacidites archangelskii	15	+	+	+	+	+	+	+	.	.	.	.	.	.	Crybelosporites striatus	38
Cyatheacidites botuliformis	16	+	+	.	+	.	+	.	.	.	.	.	.	.	C. stylosus	20
Polypodiaceoisporites elegans	17	+	+	+	+	+	.	.	+	+	.	.	.	.	Cyatheacidites annulatus	14
Densoisporites velatus	18	+	+	+	+	.	+	+	+	.	.	.	.	.	C. archangelskii	15
Ornamentifera sp. A.	19	+	+	+	+	+	.	.	.	.	.	.	.	+	C. botuliformis	16
Crybelosporites stylosus	20	+	.	+	.	.	.	.	.	.	.	.	.	.	Cyathidites asper/punctatus	3
Dictyotosporites speciosus	21	+	.	.	.	.	.	.	.	.	.	.	.	.	C. australis/minor	1
Trilites spp.	22	+	+	+	+	+	+	+	+	+	+	+	.	+	C. sp. A	2

Taxon	No.													
Triporoletes reticulatus	23	+	+	.	.	.	.	+	.	+	+	.	.	.
Staplinisporites caminus	24	+	+	.	.	.	.	.	.	.	.	.	.	.
Rogalskaisporites cicatricosus	25	+	.	+	.	.	.	.	.	.	.	.	.	.
Leptolepidites verrucatus	26	+	+	+	+	.	.	.	.	.	.	.	.	.
Ischyosporites volkheimeri	27	+	+	.	+	+	+	+	.	.	.	.	.	.
Neoraistrickia truncata	28	+	+	.	.	.	.	.	.	.	.	.	.	.
'Rugulatisporites' sp. A	29	+	.	.	.	.	.	.	.	.	.	.	.	.
Biretisporites sp. A	30	+	+	+	.	+	+	.	.	.	.	+	.	.
Foveogleicheniidites confossus	31	+	.	+	+	+	.	.	.	.	.	.	.	.
Coronatispora perforata	32	+	.	.	.	.	.	.	.	.	.	.	.	.
Klukisporites scaberis	33	+	.	.	.	.	.	.	.	.	.	.	.	.
Nodosisporites cf. *crenimurus*	34	+	+	.	+	.	.	.	.	.	.	.	.	.
Sestrosporites pseudoalveolatus	35	+	.	.	.	.	.	.	.	.	.	.	.	.
Matonisporites cooksoniae	36	+	+	.	.	.	.	.	.	.	.	.	.	.
Ischyosporites punctatus	37	+	.	.	.	.	.	.	.	.	.	.	.	.
Crybelosporites striatus	38	+	.	.	.	.	cf	.	.	.	.	.	.	.
Contignisporites cooksoniae	39	+	+	.	.	.	.	.	.	.	.	.	.	.
Contignisporites multimuratus	40	+	.	.	.	.	.	.	.	.	.	.	.	.
Contignisporites fornicatus	41	+	.	.	.	.	.	.	.	.	.	.	.	.
Klukisporites sp. A	42	+	+	+	.	.	.	.	.	.	+	.	.	.
Foraminisporis dailyi	43	+	+	.	.	.	.	.	.	.	.	.	.	.
Appendicisporites cf. *insignis*	44	+	.	.	.	.	+	.	.	.	.	.	.	.
Cicatricosisporites sp. A	45	+	.	.	.	.	.	.	.	.	.	.	.	.
Interlobites intraverrucatus	46	+	.	+	.	.	.	.	.	+	.	.	.	.
Laevigatosporites ovatus	47	+	+	.	+	+	.	.	.	+	.	.	.	.
Microfoveolatosporis canaliculatus	48	+	.	.	.	.	.	.	.	.	.	.	.	.
Stoverisporites microverrucatus	49	+	.	+	.	.	.	.	.	.	.	.	.	.
Coptospora paradoxa	50	+	.	.	.	.	.	.	.	.	.	.	.	.
Herkosporites elliottii	51	+	+	+	+	.	.	.	.	.	.	.	.	.
Camarozonosporites ambigens	52	+	.	.	cf	.	.	.	.	.	.	.	.	.
Gleicheniidites sp. A	53	+	.	.	.	.	.	.	.	.	.	.	.	.
Perotrilites laceratus	54	+	.	+	+	.	.	.	.	.	.	.	.	.
Trilites tuberculiformis	55	+	+	+	+	.	.	.	.	.	.	.	.	.
Stereisporites viriosus	56	+	.	.	.	.	.	.	.	.	.	.	.	.
Polypodiisporites spp.	57	+	+	+	.	.	.	.	.	.	.	.	.	.
Rugulatisporites mallatus	58	+	.	.	.	.	.	.	.	.	.	.	.	.
Laevigatosporites major	59	+	.	.	.	.	.	.	.	.	.	.	.	.

Table II. Distribution of gymnospermous and angiospermous pollen species in samples studied from James Ross Island, Dundee Island, Vega Island, and Cape Longing

Palynomorph species (stratigraphic listing)		D.3018.7	D.3018.14	D.3035.1	D.3006.2	D.3057.3	D.3030.3	8665	8540	D.3122.3	D.3862.3	R.551.4	R.1335.8	R.1332.9	Palynomorph species (alphabetical listing)	
GYMNOSPERMOUS POLLEN																
Alisporites grandis	1	+	+	+	+	+	+	.	.	.	+	+	.	+	Alisporites grandis	1
Alisporites similis	2	+	+	+	.	.	+	.	.	.	.	+	.	.	A. similis	2
Vitreisporites pallidus	3	+	+	+	+	+	+	.	+	.	+	+	.	.	Araucariacites australis	11
Podocarpidites ellipticus	4	+	+	+	+	+	+	+	+	+	+	+	+	+	Balmeiopsis limbatus	12
Microcachryidites antarcticus	5	+	+	+	+	+	+	+	+	+	+	.	+	+	Callialasporites dampieri	13
Trichotomosulcites sp. A	6	+	+	+	.	.	+	.	.	.	.	.	.	.	C. trilobatus	8
Trichotomosulcites subgranulatus	7	+	.	+	+	+	+	+	+	+	.	.	.	.	Classopollis chateaunovii	9
Callialasporites trilobatus	8	+	+	+	.	+	.	.	.	.	.	.	.	.	C. sp.	15
Classopollis chateaunovii	9	+	+	+	.	+	.	.	.	.	.	.	.	.	Cycadopites nitidus	10
Cycadopites nitidus	10	+	.	.	.	+	+	.	.	.	.	.	.	.	Cyclusphaera radiata	14
Araucariacites australis	11	+	+	+	+	+	+	+	+	+	.	.	.	.	Dacrycarpites australiensis	19
Balmeiopsis limbatus	.	.	12	+	+	+	.	.	.	.	.	.	+	.	+	Lygistepollenites balmei	17
Callialasporites dampieri	.	.	.	13	+	.	.	.	.	.	.	.	.	.	L. florinii	18
Cyclusphaera radiata	.	.	.	.	14	+	.	.	.	.	.	.	+	.	Microcachryidites antarcticus	5
Classopollis sp.	.	.	.	.	15	+	+	.	.	.	.	.	.	.	Phyllocladidites mawsonii	16
Phyllocladidites mawsonii	.	.	.	.	.	.	16	+	+	+	+	.	.	.	Podocarpidites ellipticus	4
Lygistepollenites balmei	.	.	.	.	.	.	17	?	+	+	+	.	.	.	?Rugubivesiculites sp. A	20
Lygistepollenites florinii	.	.	.	.	.	.	.	18	+	+	.	.	.	.	Trichotomosulcites subgranulatus	7
Dacrycarpites australiensis	.	.	.	.	.	.	.	.	19	+	.	.	.	.	T. sp. A	6
?Rugubivesiculites sp. A	.	.	.	.	.	.	.	.	20	+	.	.	.	.	Vitreisporites pallidus	3

ANGIOSPERMOUS POLLEN

Taxon	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Clavatipollenites hughesii	1	+	.	+	+	+	.	.	+	.	.	.	.	.
Asteropollis asteroides	.	.	.	2	+	.	+	.	.	.	.	.	.	.
Rousea georgensis	.	.	.	3	+	.	.	.	.	.	.	.	.	.
Tricolpites spp.	.	.	.	4	+	+	+	+	+	.	.	.	.	.
Phimopollenites pannosus	.	.	.	5	+	+	+	.	.	.	.	.	.	.
Liliacidites cf. kaitangataensis	.	.	.	.	6	+	.	.	.	.	.	.	.	.
Tricolporites lilliei	.	.	.	.	7	cf	.	.	.	+	.	.	.	.
Nyssapollenites spp.	.	.	.	.	8	+	+	+	+	.	.	.	.	.
Triorites minor	.	.	.	.	.	9	+	.	.	.	.	.	.	.
Triporopollenites sp. A	.	.	.	.	.	.	10	+	+	+	.	.	.	.
Nothofagidites senectus	.	.	.	.	.	.	11	+	+	+	.	.	.	.
Tricolpites gillii	.	.	.	.	.	.	12	+	+	+	.	.	.	.
Periporopollenites sp. A	.	.	.	.	.	.	13	+	+	+	.	.	.	.
Triporopollenites sp. 3 (Truswell 1983)	.	.	.	.	.	.	14	+	.	+	.	.	.	.
Tricolporites sp. A	.	.	.	.	.	.	.	15	+	.	.	.	.	.
Proteacidites subscabratus	.	.	.	.	.	.	.	16	+	+	.	.	.	.
Cranwellipollis palisadus	.	.	.	.	.	.	.	17	+	+	.	.	.	.
Cranwellipollis subpalisadus	.	.	.	.	.	.	.	18	+	+	.	.	.	.
Myrtaceidites eugeniioides	.	.	.	.	.	.	.	19	+	.	.	.	.	.
Proteacidites retiformis	.	.	.	.	.	.	.	20	+	.	.	.	.	.
Propylipollis sp. A	.	.	.	.	.	.	.	21	+	+	.	.	.	.
Propylipollis cf. annularis	.	.	.	.	.	.	.	.	22	+	.	.	.	.
Simpsonipollis sp. A	.	.	.	.	.	.	.	.	23	+	.	.	.	.
Tricolpites waiparaensis	.	.	.	.	.	.	.	.	24	+	.	.	.	.
Tricolpites sp. 4 (Truswell 1983)	.	.	.	.	.	.	.	.	25	+	.	.	.	.
Tricolpites sp. A	.	.	.	.	.	.	.	.	26	+	.	.	.	.
Triporopollenites sp. B	.	.	.	.	.	.	.	.	27	+	.	.	.	.
Cranwellipollis sp. 1 (Truswell 1983)	.	.	.	.	.	.	.	.	28	+	.	.	.	.
Retistephanocolporites sp.	.	.	.	.	.	.	.	.	29	+	.	.	.	.
Nothofagidites asperus	.	.	.	.	.	.	.	.	30	+	.	.	.	.
Nothofagidites lachlaniae	.	.	.	.	.	.	.	.	31	+	.	.	.	.
Nothofagidites cf. nanus	.	.	.	.	.	.	.	.	32	+	.	.	.	.
Nothofagidites spp.	.	.	.	.	.	.	.	.	33	+	.	.	.	.

Taxon	No.
Asteropollis asteroides	2
Clavatipollenites hughesii	1
Cranwellipollis palisadus	17
C. subpalisadus	18
C. sp. 1 (Truswell 1983)	28
Liliacidites cf. kaitangataensis	6
Myrtaceidites eugeniioides	19
Nothofagidites asperus	30
N. lachlaniae	31
N. cf. nanus	32
N. senectus	11
N. spp.	33
Nyssapollenites spp.	8
Periporopollenites sp. A	13
Phimopollenites pannosus	5
Propylipollis cf. annularis	22
P. sp. A	21
Proteacidites retiformis	20
P. subscabratus	16
Retisephanocolporites sp. A	29
Rousea georgensis	3
Simpsonipollis sp. A	23
Tricolpites gillii	12
T. waiparaensis	24
T. sp. 4 (Truswell 1983)	25
T. sp. A	26
T. spp.	4
Tricolporites lilliei	17
T. sp. A	15
Triporopollenites sp. A	10
T. sp. B	27
T. sp. 3 (Truswell 1983)	14
Triorites minor	9

Table III. Distribution of dinocyst and chlorophycean/prasinophycean species in samples studied from James Ross Island, Vega Island, Dundee Island, and Cape Longing

Palynomorph species (stratigraphic listing)	No.	James Ross Island								Vega Island	Dundee Island	Cape Longing		
		D.3018.7	D.3018.14	D.3035.1	D.3006.2	D.3057.3	D.3030.3	8665	8540	D.3122.3	D.3862.3	R.551.4	R.1335.8	R.1332.9
DINOPHYCEAE (cysts)														
Muderongia tetracantha	1	+	+											
Muderongia cf. staurota	2	+	+											
Batioladinium micropodum	3	+	+											
Batioladinium jaegeri	4	+												
Dingodinium cerviculum	5	+												
Canninginopsis intermedia	6	+												
Canningia sp. A (Morgan 1980)	7	+	+											
Chichaouadinium boydii	8	+	+											
Cyclonephelium hystrix	9	+	+											
Odontochitina operculata	10	+	+	+	+							+		+
Adnatosphaeridium filiferum	11	+												
Coronifera striolatum	12	+			+									
Chlamydophorella nyei	13	+	+	+			+					+		
Oligosphaeridium pulcherrimum	14	+	+	+			+		+					+
Prolixosphaeridium conulum	15	+			+									
Coronifera oceanica	16	+	+									+		
Spiniferites ramosus	17	+	+	+	+	+	+			+		+		+
Kiokansium polypes	18	+	+			+	+					+		
Cleistosphaeridium ancoriferum	19	+	+			+						+		
Circulodinium colliveri	20	+												
Palaeoperidinium cretaceum	21	+	+											
Pseudoceratium sp. A	22	+	+											
Omatia montgomeryi	23	+	+											
Cribroperidinium edwardsii	24		+	+	+	+						+	+	+
Callaiosphaeridium asymmetricum	25		+											
Pseudoceratium exquisitum	26		+											
Diconodinium cristatum	27			+			+					+		
Pseudoceratium turneri	28			+	+							+		
Batiacasphaera srobiculata	29			+										
Diconodinium pusillum	30			+	+	+						+		
Diconodinium paucigranulatum	31			+	+									
Cribroperidinium orthoceras	32			+	+							+		
Oligosphaeridium complex	33			+		+						+		
Cribroperidinium perforans	34			+										
Scriniodinium ceratophorum	35			+										
Scriniodinium crystallinum	36			+										
Leptodinium ambiguum	37			+										
Ascodinium serratum	38			+										+
Ascodinium acrophorum	39			+	+						+			+
Diconodinium cf. pelliferum	40			+	+						+			+
Rhiptocorys veligera	41				+									
Laciniadinium tenuistriatum	42				+						+	+		+

Palynomorph species (alphabetical listing)	No.
Adnatosphaeridium filiferum	11
Ascodinium acrophorum	39
A. ovale	46
A. serratum	38
Batiacasphaera scrobiculata	29
Batioladinium jaegeri	4
B. micropodum	3
Callaiosphaeridium asymmetricum	25
Canningia sp. A (Morgan 1980)	7
Canninginopsis denticulata	52
C. intermedia	6
Chatangiella cf. campbellensis	79
C. serratula	60
C. tripartita	59
Chichaouadinium boydii	8
Chlamydophorella cf. discreta	58
C. nyei	13
Circulodinium colliveri	20
Cleistosphaeridium ancoriferum	19
C. armatum	50
Coronifera oceanica	16
C. striolata	12
Cribroperidinium edwardsii	24
C. orthoceras	32
C. perforans	34
C. sp. A	75
Cyclonephelium compactum	47
C. distinctum	56
C. hystrix	9
Diconodinium cristatum	27
D. paucigranulatum	31
D. cf. pelliferum	40
D. pusillum	30
Dingodinium cerviculum	54
Dinogymnium nelsonense	65
Disphaera macropyla	54
Heterosphaeridium heteracanthum	49
H. sp.	74
Isabelidinium cf. bakeri	78
I. cretaceum	61
I. pellucidum	77
Kiokansium polypes	18

Species	No.	Occurrences
Leberidocysta chlamydata		
Pseudoceratium ludbrookiae	44	+ + + +
Microdinium ornatum	45	+ +
Ascodinium ovale	46	+
Cyclonephelium compactum	47	+ + +
Odontochitina singhii	48	+ +
Heterosphaeridium heteracanthum	49	+ + + + +
Cleistosphaeridium armatum	50	+
Odontochitina costata	51	+ + +
Canninginopsis denticulata	52	+ +
Xenascus australensis	53	+ +
Disphaera macropyla	54	+ +
Odontochitina porifera	55	+
Cyclonephelium distinctum	56	+
?Stephodinium sp. A	57	+
Chlamydophorella cf. *discreta*	58	+ + +
Chatangiella tripartita	59	+
Chatangiella serratula	60	+
Isabelidinium cretaceum	61	+ +
Manumiella lata	62	+
Spinidinium cf. *echinoideum*	63	+
Palaeohystrichophora infusorioides	64	+ + +
Dinogymnium nelsonense	65	+
Pterodinium cingulatum	66	+ + +
Spinidinium cf. *laterna*	67	+ +
Xenikoon australis	68	+ +
Nelsoniella aceras	69	+
Maduradinium sp.	70	+ +
Maduradinium pentagonum	71	+
Nelsoniella tuberculata	72	+
Odontochitina sp. A	73	+
Heterosphaeridium sp.	74	+
Cribroperidinium sp. A	75	+
Palaeocystodinium granulatum	76	+
Isabelidinium pellucidum	77	+
Isabelidinium cf. *bakeri*	78	+
Chatangiella cf. *campbellensis*	79	+
Operculodinium sp.	80	+

Index (right column):

CHLOROPHYTA/PRASINOPHYTA (microfossils)

Species	No.	Occurrences
Veryhachium spp.	1	+
Leiosphaeridiae spp.	2	+ + + + + + + + +
Botryococcus spp.	3	+ + + +
Dictyodinium spp.	4	+
Horologinella apiculata	5	+
Paralecaniella indentata	6	+ +
Palambages Form A (Manum and Cookson 1964)	7	+ + +
Crassosphaera spp.	8	+
Pterospermella australiense	9	+

FUNGI

	Occurrences
Hyphae and fruiting bodies	+ + + + + + + + +

Table IV. Relative frequency of palynomorph types and their inferred botanical affinities in samples from James Ross and Vega Islands. Percentages of spore/pollen types based on counts of 250 specimens per sample. The total number of algal palynomorphs recorded per 100 spores and pollen is shown; frequencies of these groups are expressed as percentages of the spore-pollen count. Note ' + ' denotes presence of a taxon in sample but not in count traverse. *In situ* relationships established from southern Gondwana floras are specified with an asterisk.

Palynomorph genus	James Ross Island								Vega Isl.	Suggested affinity
	D.3018.7	D.3018.14	D.3035.1	D.3006.2	D.3057.3	D.3030.3	8665	8540	D.3122.3	
BRYOPHYTIC SPORES										
Foraminisporis	.	.	.	+	1	.	.	.	.	Anthocerotae
Stereisporites	2	3	+	3	3	3	.	+	2	Musci
LYCOPHYTIC SPORES										
Ceratosporites/Herkosporites	+	1	+	.	1	+	2	2	+	Selaginella/Lycopodium
Densoisporites/Perotrilites	+	+	+	+	.	+	+	1	1	Selaginellaceae
Retitriletes	3	4	2	.	2	1	2	+	2	Lycopodium (Lycopodium)
FILICEAN SPORES										
Baculatisporites/Osmundacidites	8	4	7	2	17	10	4	9	1	Osmundaceae/Hymenophyllaceae
Biretisporites	.	+	+	2	.	2	6	.	.	multiple filicean source
Cicatricosisp./Nodosisp./Appendicisp.	+	+	1	+	.	+	.	.	.	Schizaeaceae (Anemia/Mohria)/Ceratopteris
Cyatheacidites	2	1	+	5	1	+	+	+	.	Lophosoria
Cyathidites	24	23	19	35	32	38	14	12	6	multiple filicean source
Dictyophyllidites/Matonisporites	.	.	1	7	.	.	.	.	.	?Dicksoniaceae/Matoniaceae/Dipteridaceae
Gleicheniidites/Ornamentifera/Foveogleich.	4	1	4	7	+	10	4	2	1	Gleicheniaceae
Klukisporites/Ischyosporites	.	1	1	+	+	+	+	+	.	Schizaeaceae (cf. Lygodium)
Laevigatosporites/Microfoveolatosporis	.	.	.	1	+	.	2	+	2	Schizaeaceae (cf. Schizaea)/Gleicheniaceae
Trilites/Polypodiaceoisporites	1	5	1	12	5	5	6	2	+	Dicksoniaceae/Pteridaceae

GYMNOSPERMOUS POLLEN

Alisporites	10	14	19	1	4	+	.	.	.	Pteridospermophyta
Araucariacites	8	7	5	2	5	7	14	14	1	Araucariaceae (cf. *Araucaria*)
Balmeiopsis	.	+	+	5	+	.	.	.	.	*Brachyphyllum**
Callialasporites	+	+	5	.	+	.	.	.	.	Podocarpaceae. *Apterocladus**
Classopollis	2	5	15	+	3	.	.	.	.	Cheirolepidaceae. *Tomaxellia**
Cyclusphaera	.	.	.	2	.	.	.	.	.	unknown ?gymnospermous source
Lygistepollenites	.	.	.	.	.	.	+	5	+	Podocarpaceae (*Dacrydium*)
Microcachryidites	6	4	1	2	14	2	14	8	4	Podocarpaceae (cf. *Microcachrys*)
Phyllocladidites	.	.	.	.	.	1	2	2	2	Podocarpaceae (*Lagarostrobus*)
Podocarpidites	29	25	12	10	10	16	26	37	33	Podocarpaceae
Trichotomosulcites	+	.	1	+	1	3	+	+	1	Podocarpaceae. *Trisacocladus**
Vitreisporites	+	1	6	+	+	+	.	+	.	Pteridospermophyta

ANGIOSPERMOUS POLLEN

Clavatipollenites	1	.	+	3	+	.	.	+	.	Chloranthaceae
Cranwellipollis	.	.	.	.	.	.	.	+	2	unknown angiospermous source
Nothofagidites	.	.	.	.	.	.	+	+	22	*Nothofagus*
Nyssapollenites	.	.	.	.	+	3	+	+	.	unknown angiospermous source
Proteacidites/Propylipollis	.	.	.	.	.	.	.	+	1	Proteaceae
Tricolpites	.	.	.	+	+	+	2	2	15	multiple angiospermous source
Triorites	.	.	.	.	.	1	.	.	.	unknown angiospermous source
Triporopollenites	.	.	.	.	.	.	2	+	2	unknown angiospermous source
Other spore/pollen types	.	1	.	.	.	.	.	4	2	

ALGAL MICROFOSSILS

Leiosphaerids/*Botryococcus*/*Palambages* etc.	+	+	+	10	4	6	2	5	4	Chlorophyta/Prasinophyta
Dinocysts 'R' type	+	.	.	.	.	.	.	.	.	Dinophyceae
Dinocysts 'P' type	15	+	5	4	4	12	30	44	16	Dinophyceae
Dinocysts 'G' type	82	26	10	4	9	36	4	8	12	Dinophyceae

Total algae/100 spores and pollen	97	26	15	18	17	54	36	57	32	
Fungal palynomorphs/100 spores and pollen	3	2	+	+	+	+	+	+	+	Fungi incl. Microthyriales
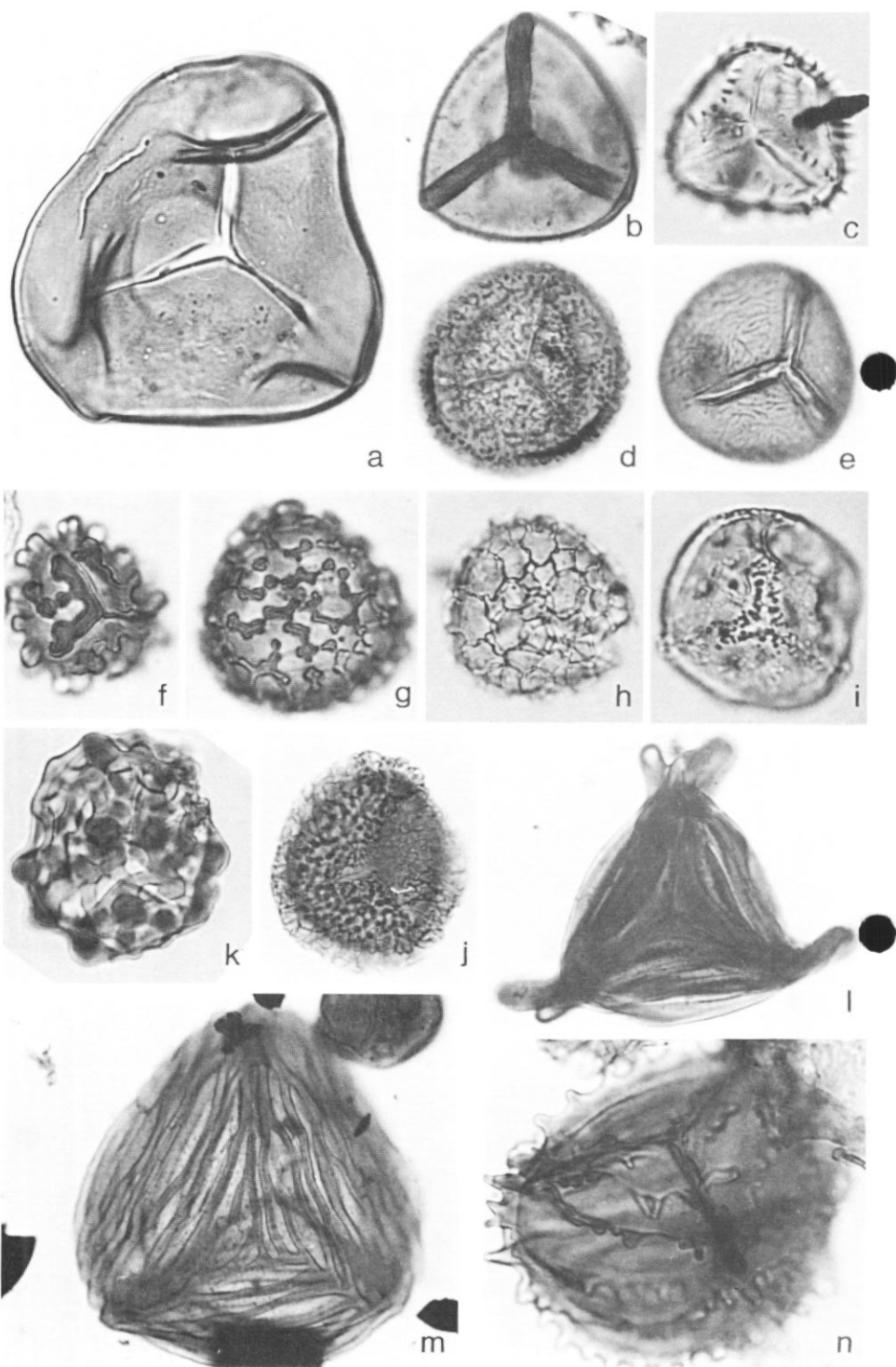
investigations by one of us (MRAT) have shown that it was a concretion, of which there are many in the lower part of the formation. Bibby noted that the limestone contained fossils but did not identify them. Further study of this material suggested that species of the bivalve *Aucellina* and the ammonite ' *Silesites* ' were present, similar to those of the Lower Cretaceous (?Albian) of Alexander Island (Thomson, 1974, 1983). New collections from both the concretions and the siltstones of the Kotick Point Formation confirm these identifications and include new finds of *Anagaudryceras buddha* (Forbes), dimitobelid belemnites (Doyle, 1987), and a smooth inoceramid bivalve related to the *I. carsoni* McCoy group (Crame, 1985). All these fossils are consistent with an Albian age. *A. buddha* is a long-ranging species (Kennedy and Klinger, 1979) but it has not been noted previously in rocks older than middle Albian.

The taxonomically varied palynomorph assemblages obtained from the samples re fairly well preserved despite moderate thermal induration of the acid resistant organic matter of the sediments. Abundant dinocysts, spores, and pollen are represented together with infrequent prasinophycean/chlorophycean and fungal microfossils (see Tables I–IV). Compositional attributes of the samples' palynofloras are similar except that frequency of dinoflagellates relative to land-plant palynomorphs is less in D.3018.14 than in D.3018.7.

The dinocyst floras bear close affinities with those reported from Australian Early Cretaceous sequences. Associations of *Muderongia tetracantha*, *Dingodinium cerviculum*, *Canninginopsis intermedia*, *Canningia* sp. A (Morgan, 1980), *Batioladinium jaegeri*, and *Pseudoceratium exquisitum* are confined to the *Muderongia tetracantha* Zone (Helby and others, 1987) and equivalent *Pseudoceratium turneri* B Subzone (Morgan, 1980) that have been dated as early Albian on associated planktic foraminiferal evidence (Haig, 1979). These Australian dinocyst zones are delineable by *Canninginopsis intermedia* which is confined to the zones, together with last appearances of *Muderongia tetracantha* and *Dingodinium cerviculum*, and earliest occurrences of *Pseudoceratium exquisitum*. However, *P. turneri*, which has consistent occurrences within the Australian zones, was not identified in the James Ross Island samples.

At Deep Sea Drilling Site 361, Cape Basin off South Africa, cores 27–32 contain the upper ranges of *Dingodinium cerviculum*, *Muderongia tetracantha*, and *M*. cf. *taurota* in dinocyst associations that are basically similar to the Antarctic ssemblages (Davey, 1978; McLachlan and Pieterse, 1978). McLachlan and Pieterse's Albian age assignment is supported by nannoplankton evidence (Proto Decima and others, 1978), although Davey argued for an Aptian age.

Coeval New Zealand assemblages are insufficiently well documented for detailed comparison with those from James Ross Island. Preliminary palynological accounts

Fig. 3. Trilete cryptogam spores; magnifications × 750 except m (× 500). (a) *Cyathidites* sp. A, proximal focus; (b) *Biretisporites* sp. A, proximal focus; (c) *Herkosporites elliottii* Stover 1973, proximal focus; (d) *Rugulatisporites neuquensis* Volkheimer 1972, proximal focus; (e) ' *Rugulatisporites* ' sp. A, proximal focus showing low, narrow proximal muri–distal surface is smooth; (f, g) *Rugulatisporites mallatus* Stover 1973, two specimens, proximal and distal focus respectively; (h) *Retitriletes austroclavatidites* (Cookson) Döring, Krutzsch, Mai, and Schulz 1963, distal focus; (i) *Stoverisporites microverrucatus* Burger 1976, proximal focus; (j) *Dictyotosporites speciosus* Cookson and Dettmann 1958, proximal focus; (k) *Klukisporites* sp. A, median focus showing knob-like protrusions of muri at angles of irregularly polygonal lumina; (l) *Appendicisporites* cf. *insignis* (Markova) Chlonova 1976, proximal focus; (m) *Cicatricosisporites* sp. A, distal focus showing adjacent mural sets coalescing in radial regions; (n) *Nodosisporites* cf. *crenimurus* (Srivastava) Davies 1985, off-polar aspect showing scalloped outline of mural crests.

of early Albian sediments on the Falkland Plateau at Sites 327 and 511 indicate that their dinocyst floras are restricted and their component species are long ranging within the Cretaceous (Harris, 1977; Hedlund and Beju, 1977; Goodman and Ford in Ludwig and others, 1983; Bair and Hart, 1984). Underlying Aptian assemblages are distinct and contain *Muderongia mcwhaei*, a species that in Australia does not range beyond the early Aptian (Morgan, 1980).

There is some evidence for Jurassic reworking in the assemblages; this is suggested by the rare occurrence of *Omatia montgomeryi*, a species hitherto reported only from the Jurassic (Cookson and Eisenack, 1958; Helby and others, 1987).

The diverse spore-pollen assemblages extracted from D.3018.7 and D.3018.14 contain high frequencies of gymnospermous pollen and fern spores, infrequent lycophytic and bryophytic derivatives, and very rare angiospermous pollen. Close links to florules of comparable age reported from Australia, New Zealand, and the Falkland Plateau are evident. Similarities to Australian and New Zealand microflora are expressed by abundant to common *Cyathidites*, *Podocarpidites*, *Alisporites*, and *Microcachryidites*, in association with *Cicatricosisporites australiensis*, *C. ludbrookiae*, *Ceratosporites equalis*, *Leptolepidites verrucatus*, *Dictyotosporites speciosus*, and *Crybelosporites stylosus*. Species shared by the Falkland Plateau and James Ross Island early Albian assemblages include the cryptogam components cited above as well as *Polypodiaceoisporites elegans*, *Cyatheacidites annulatus*, and *C. archangelskii*. However, the Falkland Plateau florules are distinct in featuring abundant *Classopollis* and common *Cyclusphaera* and ephedroid grains; these are rare or absent in the Australasian/Antarctic region.

Whereas many of the cryptogam spore species are known to be distributed widely through southern Gondwana, present records suggest that certain of them have disparate stratigraphic ranges in the separate depositional regions (Dettmann, 1986*a*, *b*). For instance, *Crybelosporites stylosus* is restricted in Australia to probable latest Jurassic–earliest Cretaceous ('Neocomian') sediments in the Otway/Gippsland Basins but ranges into the Aptian in the more northerly Eromanga Basin (Dettmann, 1986*a*). In New Zealand, the species occurs in the late Albian–Turonian *Trichotomosulcites subgranulatus* Assemblage of Raine (1984) and is recorded herein from the James Ross Island early Albian samples. The evidence implies disjunct stratigraphic distribution, but the possibility that the James Ross Island specimens have been recycled from older sediments should not be disregarded. One cryptogam spore species that may have stratigraphic utility with respect to the early Albian throughout the region is the distinctive *Dictyotosporites speciosus*. In Australia the species is a useful zonal marker, being restricted to early Neocomian–early Albian sediments; it is present in D.3018.7, and also in the early Albian sequence at Site 327A on the Falkland Plateau (Harris, 1977).

As noted above, the early Albian dinocyst flora at Site 361, Cape Basin, is comparable to those of the James Ross Island samples. The spore-pollen assemblages are, however, quite distinct and share few common features. Those from Site 361 are dominated by *Classopollis* and have low species diversity.

In summary, the dinocyst evidence documented from D.3018.7 and D.3018.14 is consistent with the Albian dating indicated by the associated fauna. The early Albian age ascribed to the samples is based on correlation with the *Muderongia tetracantha* Zone in Australia and is supported by evidence from Site 361, Cape Basin. Algal assemblages reported from Sites 327 and 511, Falkland Plateau, neither confirm nor refute this dating; their distinct compositional attributes may express environmental differences that then existed within the proto South Atlantic Ocean (Crame, 1984). The James Ross Island spore-pollen assemblages have close affinities with those

reported from the early Albian of Australia, New Zealand, and the Falkland Plateau; qualitative differences are believed to connote a vegetational zonation linked to climatic and terrain differences within southern Gondwana (see later discussion).

D.3035.1, Lewis Hill; and D.3006.2, about 1 km north of Lewis Hill

Both of these specimens are from the lower part of the Whisky Bay Formation; D.3035.1 is the older of the two and is a green-coloured pebbly sandstone from the Bibby Point Member. Fossils recently obtained from this same member include the ammonite 'Silesites' and the bivalve Aucellina, suggesting a correlation with the Kotick Point Formation (above). D.3006.2 came from a poorly fossiliferous conglomerate-dominated sequence (Lewis Hill Member); it is from a level stratigraphically below that containing the middle–late Albian inoceramid bivalve, irostrina concentrica (Parkinson).

The faunal similarities noted above between D.3035.1 and D.3018.7 and D.3018.14 are not paralleled by the dinoflagellate assemblages. D.3035.1 yielded common Diconodium spp. (including D. cristatum), together with Ascodinium serratum, features not displayed by the Kotick Point assemblages. In Australia, D. cristatum and A. serratum are known from middle–late Albian and Cenomanian respectively (Morgan, 1980), and correlation with the middle Albian–Cenomanian of Australia is further suggested by abundant Diconodinium. There is a strong Late Jurassic component in the assemblage. Leptodinium ambiguum, Scriniodinium crystallinum, S. ceratophorum, and Cribroperidinium perforans denote a Late Jurassic age in Australia, New Zealand, and on the Falkland Plateau (Harris, 1977; Goodman and Millioud in Ludwig and others, 1983; Wilson, 1984; Helby and others, 1987). The Jurassic species are probably recycled; they are darker coloured and less well preserved than the assumed in situ components of the assemblages. There is also evidence that some spores and pollen of the assemblage are recycled. The common occurrence of Callialasporites is more consistent with Late Jurassic–earliest Cretaceous palynofloras of the nearby South Shetland Islands (Askin, 1983a) than the Albian and younger assemblages documented herein. Crybelosporites stylosus may also be recycled or, as discussed above, the species may have a greater stratigraphic range in Antarctica than Australia. The extent of recycling is difficult to ascertain from the limited knowledge of Antarctic late Mesozoic spore-pollen assemblages.

As shown in Tables I and II the spore-pollen florule is diverse. It contains substantial representation of species previously reported from other areas in southern Gondwana; however, evidence from these occurrences fails to resolve the conflict in age data denoted by the fauna and the dinoflagellates. In overall character, the land-plant microfossil assemblage is more similar to those of Albian–Cenomanian age in the Australian/New Zealand region (see Dettmann and Playford, 1969; Burger, 1980; Raine, 1984) than to those reported from the Aptian–Albian of the Falkland Plateau (Kotova, 1983).

There is closer agreement between the faunal and palynological data for a late Albian age of the stratigraphically higher sample D.3006.2 although the possibility of a Cenomanian age should not be ruled out. Dinocysts are neither common nor diverse, but species identified have considerable stratigraphic resolution in Australia and New Zealand. Pseudoceratium ludbrookiae, Ascodinium acrophorum, and Laciniadinium tenuistriatum all have earliest occurrences in the late Albian and the latter two are more typically represented in the Vraconian and Cenomanian of Australia (Morgan, 1977, 1980; Helby and others, 1987). In these and other respects the assemblage is comparable to those of the late Albian Pseudoceratium ludbrookiae
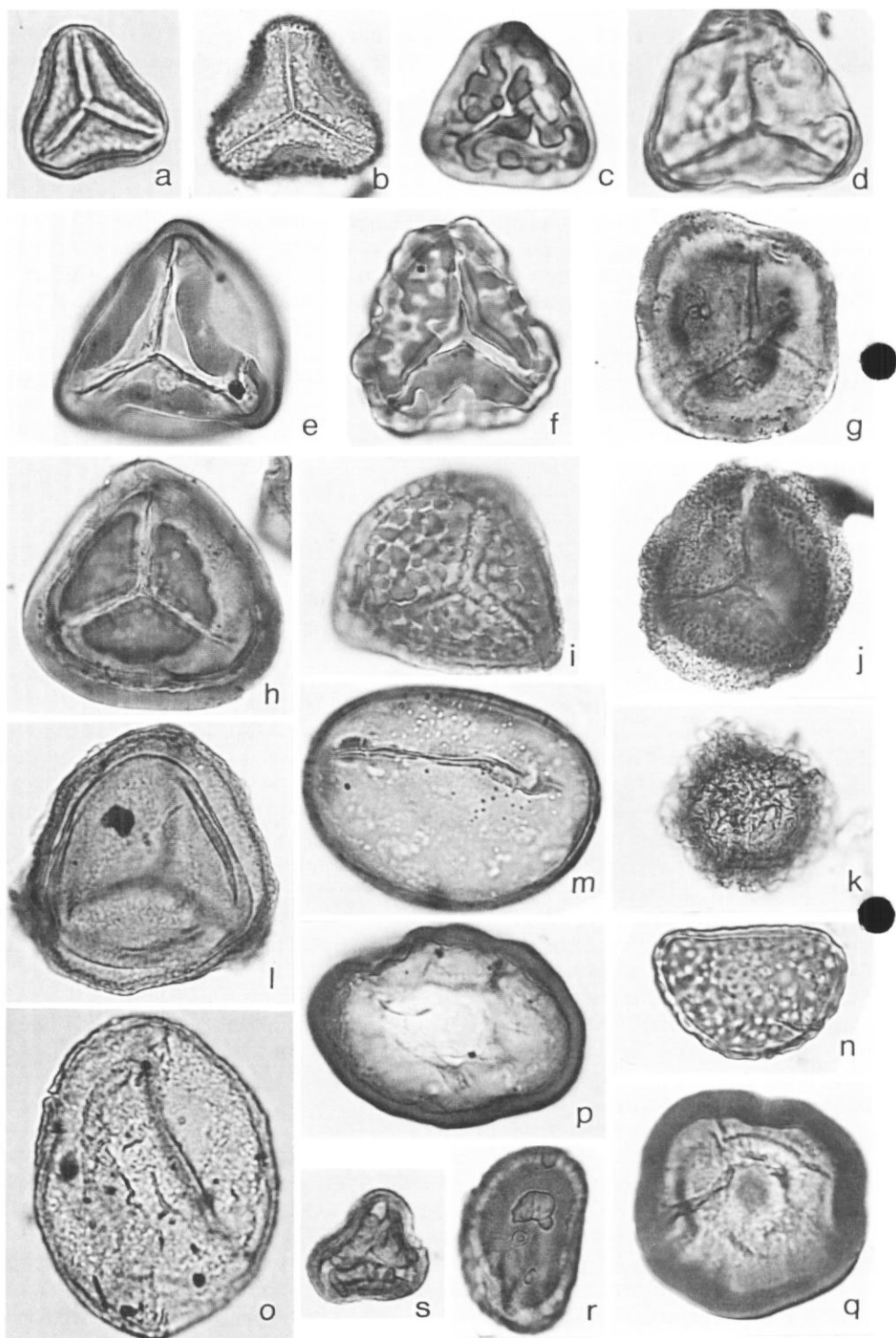
Zone and succeeding latest Albian *Xenascus asperatus* Zone in Australia (Helby and others, 1987) and to the late Albian–Cenomanian *P. ludbrookiae* Zone in New Zealand (Wilson, 1984). Ages ascribed to the zones are based upon associated foraminiferal and megafaunal evidence.

The spore-pollen assemblage obtained from D.3006.2 is diverse but is dominated by fern spores; angiospermous pollen are more varied than in D.3035.1. *Coptospora paradoxa*, *Microfoveolatosporis canaliculatus*, and *Stoverisporites microverrucatus*, together with a strong podocarpacean element, emphasize relationships to Australasian mid-Cretaceous microfloras on the one hand, and *Cyclusphaera* spp., *Polypodiaceoisporites elegans*, and *Cyatheacidites* spp. to the Falkland Plateau Albian assemblages on the other. In quantitative attributes, the palynofloras of D.3035.1 and D.3006.2 are notably different; the former yielded more common pteridospermous pollen (*Alisporites*, *Vitreisporites*) and cheirolepidacean (*Classopollis*) derivatives; whereas the latter is characterized by *Cyclusphaera*, common *Balmeiopsis*, and significant representation of chlorophycean/prasinophycean algal microfossils. These distinctions may relate to differing depositional environments and/or alterations in the source vegetation.

D.3057.3, north side of Rum Cove

The rock is a piece of bioturbated silty sandstone with a fragment of an ammonite impression and a poorly preserved inoceramid bivalve. A near-complete but squashed ammonite from the same locality, and with identical ornament to that of the impression, was described by Howarth (1966) as *Submortoniceras chicoense* (Trask) and assigned to the Lower Campanian. A more detailed collection from the same locality includes a rich fauna of excellently preserved ammonites (Thomson, 1984*a*, *b*) and inoceramid bivalves. The fauna comprises:

Inoceramus pictus Sowerby (identification J. A. Crame)
Gaudryceras cf. *stefanini* Venzo
Sciponoceras cf. *baculoides* (Mantell)
Desmoceras (?) sp.
Pseudouhligella sp.
Eucalycoceras or *Newboldiceras* sp.

Eucalycoceras is common in the Whisky Bay Formation south of Holluschickie Bay and occurs both as crushed and uncrushed specimens. It is clearly the same species as

---

Fig. 4. Trilete (a–l) and monolete (m, n) cryptogam spores, gymnospermous pollen (o–q, s) and ?resin body (r); magnifications × 750 except r (× 500). (a) *Foveogleicheniidites confossus* (Hedlund) Burger 1976, median focus; (b) *Ornamentifera* sp. A, proximal focus showing crowded, coalescent grana and spinae and interradial crassitudes; (c) *Polypodiaceoisporites elegans* Archangelsky and Gamerro 1966, distal focus; (d) *Ischyosporites volkheimeri* Filatoff 1975, optical section; (e) *Gleicheniidites* sp. A, proximal focus showing proximal inclination of interradial crassitudes; (f) *Trilites tuberculiformis* Cookson 1947, proximal focus; (g) *Foraminisporis dailyi* (Cookson and Dettmann) Dettmann 1963, proximal focus; (h) *Cyatheacidites annulatus* Cookson ex Potonié 1956,, median focus; (i) *Cyatheacidites archangelskii* Dettmann 1986, distal focus; (j) *Crybelosporites stylosus* Dettmann 1963, proximal focus; (k) *Crybelosporites* cf. *striatus* (Cookson and Dettmann) Dettmann 1963, lateral aspect showing loose-meshed reticulum; (l) *Densoisporites velatus* Weyland and Kreiger 1953, optical section showing cavate, stratified sclerine; (m) *Laevigatosporites major* (Cookson) Krutzsch 1959, proximal focus; (n) *Microfoveolatosporis canaliculatus* Dettmann 1963, lateral aspect; (o) *Araucariacites australis* Cookson 1947, high focus; (p) *Balmeiopsis limbatus* (Balme) Archangelsky 1977, showing polar rupture; (q) *Cyclusphaera radiata* Archangelsky 1983 showing thickened equatorial and polar exine; (r) ?resin body; (s) *Trichotomosulcites subgranulatus* Couper 1953, distal view showing sacci inclined over distal pole.

that previously ascribed to *Submortoniceras* yet lacks the keel and lateral tubercles typical of that genus (Thomson, 1984b). *Eucalycoceras* is a middle Cenomanian–lower Turonian genus (Kennedy, 1971) and *I. pictus* is typically late Cenomanian.

Support for a Cenomanian rather than a Turonian age is provided by the palynological evidence. However, this dating is imprecise and could also be consistent with an age as old as late Albian. The well-preserved palynoflora is dominated by land-plant derivatives, together with an algal suite of moderately diverse dino-flagellates and several prasinophycean/chlorophycean types. Dinoflagellates represented include *Pseudoceratium ludbrookiae*, *Microdinium ornatum*, *Ascodinium ovale*, *Odontochitina costata*, and *Heterosphaeridium heteracanthum*, an association indicative of a late Albian–late Cenomanian age in Australia. There, such associations are restricted to the upper *P. ludbrookiae* through to *D. multispinum* Zones (Helby and others, 1987), and in New Zealand to the *P. ludbrookiae* Zone (Wilson, 1984). A Cenomanian age may be supported by *Cleistosphaeridium armatum*, a spe● reported by Morgan (1980) as appearing within the Cenomanian of Australia, b●● known also from the Aptian of France (Verdier, 1975).

The cryptogam spore assemblage is restricted and there is very rare representation of *Cicatricosisporites* and other cicatricose types. *Cyatheacidites*, *Trilites*, and *Polypodiaceoisporites elegans* occur in low frequencies. The gymnospermous pollen component is distinguished by common bi- and trisaccate podocarpacean forms; *Classopollis* occurs infrequently. Angiospermous pollen are moderately diverse and include tricolporate as well as tricolpate and monosulcate types. Similarities to Australasian assemblages are evident in the gymnospermous element, but are less pronounced amongst the cryptogams. There are few data from other southern Gondwana sequences of similar age. The Turonian florules reported from Site 361, Cape Basin, feature high frequencies of *Classopollis* and a distinctive angiospermous suite; they bear little resemblance to the James Ross Island assemblage.

D.3030.3, back of Brandy Bay

The sample is a calcareous siltstone with macerated carbonized plant debris, from a concretion surrounding a specimen of the ammonite *Eupachydiscus grossouvrei* (Kossmat) (Howarth, 1966, list on p. 56). Also in the same concretion are fragments of a small smooth *Baculites*. The genus *Eupachydiscus* ranges from Coniacian● Campanian but Howarth (1966, p. 66) pointed out that *E. grossouvrei* is mid●●● Campanian in age in Madagascar. New collections from northern James Ross Island contain many pachydiscids. In the Brandy Bay area they occur over a stratigraphic thickness of nearly 600 m and show considerable variation from strongly ribbed *Eupachydiscus*-like forms to more weakly ornamented *Anapachydiscus*-like examples. Clearly the Antarctic species require careful revision but associated ammonites in the Crame Col area, including *Eubostrychoceras* spp., *Baculites* aff. *rectus* (Marshall), and *Polyptychoceras*, support the Campanian age deduced by Howarth.

Dinoflagellate evidence for the age of the sample is ambiguous. Many of the component species of the diverse assemblage have been reported from, and have wide distribution in, the Coniacian–Maastrichtian of southern high-latitude regions, but individual species display different stratigraphic ranges in the various areas. For instance, *Odontochitina porifera* ranges from Santonian to Campanian in Australia (Helby and others, 1987), from Campanian to Maastrichtian in New Zealand (Wilson, 1984), and is known only from the Campanian on the Falkland Plateau (Goodman and Millioud in Ludwig and others, 1983). The bases for these ranges are

provided by associated faunal evidence, which, for the Australian region at least, requires further documentation.

Summary accounts of the dinocyst floras from the Falkland Plateau (Harris, 1977; Goodman and Millioud, in Ludwig and others, 1983) indicate that those of Campanian age are closely similar to the assemblage from D.3030.3. *Odontochitina porifera*, *Manumiella lata*, and *Xenascus australensis* are common to both regions. Assemblages documented from Australian southern and western margin Late Cretaceous sequences feature many of the species occurring in the James Ross Island material. The association of *Isabelidinium cretaceum*, *Odontochitina porifera*, *Chatangiella tripartita*, and *Dinogymnium nelsonense* is indicative of the *Isabelidinium cretaceum* Zone in Australia and thereby suggests a Santonian age (Helby and others, 1987). However, based on New Zealand occurrences of *O. porifera*, *Chatangiella serratula*, *I. cretaceum* and *Chlamydophorella* cf. *discreta*, a Campanian age is indicated.

From Site 361, Cape Basin, Davey (1978) reported *C. tripartita*, *O. porifera*, and *I. cretaceum* in core 17 that lacks independent faunal control, but underlies Campanian–Maastrichtian foraminiferids and fragments of ?*Inoceramus* (Bolli and others, 1978, p. 58).

Hall (1977) reported *I. cretaceum* and *Cyclonephelium distinctum* from the Marambio Group on Seymour Island and suggested an early Senonian age. However, Zinsmeister (1982) indicated that rocks no older than late Campanian are exposed on the island and Macellari (1986) dated the ammonite faunas as late Campanian–Maastrichtian. Further details of the palynofloras will be important in this regard.

O. porifera was reported by Askin (1983*b*) from two samples of the Lopez de Bertodano Formation, cropping out on The Naze, northern James Ross Island. Associated ammonites belong to the *Gunnarites antarcticus* fauna variously dated as late Campanian (Spath, 1953) or early to middle Campanian (Howarth, 1958). However, the presence also of the heteromorph *Diplomoceras lambi* would favour a late Campanian or even a Maastrichtian age (cf. Macellari, 1986). Apart from *O. porifera*, other dinocyst species recorded from The Naze samples (Askin, in press) are unknown from sample D.3030.3.

The diverse spore-pollen assemblage from D.3030.3 is dominated by cryptogam spores, and has common araucarean and podocarpacean gymnospermous pollen and frequent angiospermous grains. The cryptogam spore association reflects a varied fern component and displays marked similarities to those reported from the mid-Cretaceous samples, suggesting that many of the constituent species are long-ranging within the Cretaceous in the peninsula region. Species that fall into this category are *Cyatheacidites annulatus*, *C. archangelskii*, *C. botuliformis*, *Polypodiaceoisporites elegans*, *Nodosisporites* cf. *crenimurus*, and *Foveogleicheniidites confossus*. There is some resemblance to Australian and New Zealand cryptogam spore florules of comparable age, but the most striking similarities are amongst the gymnospermous pollen associations. The latter display only minor variation throughout austral areas embracing Australia, New Zealand, and James Ross Island. One incongruence is the apparent absence from the Late Cretaceous of New Zealand of *Lygistepollenites balmei*, which is reported herein from James Ross Island and is known from Santonian and later in southern Australia (Dettmann and Playford, 1969; Stover and Evans, 1973; Stover and Partridge, 1973). The angiospermous component at James Ross Island includes sulcate, tricolporate, and triporate types. It reflects closer taxonomic affinities to coeval assemblages of Australia than New Zealand.

The close relationships noted above between the dinocyst floras of James Ross
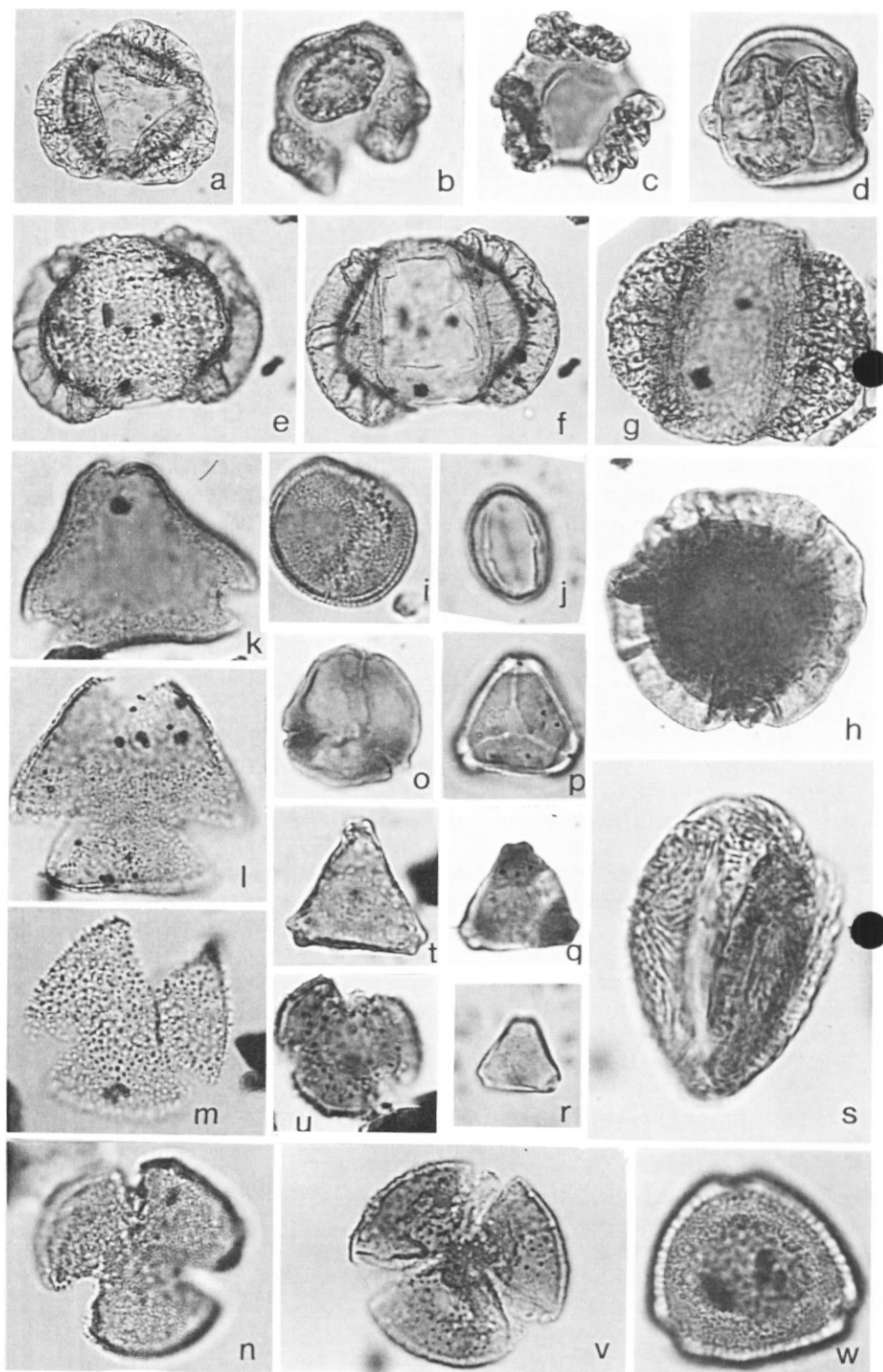
Island and the Cape Basin are not matched by the spore-pollen record. The angiospermous/cryptogam associations are distinct; those of the Cape Basin have affiliations with assemblages from more northerly African regions.

8540 and 8665, east side of Lachman Crags

Two samples of bioturbated sandstone with small pebbles, and fine- to medium-grained sandstone, respectively, were selected from large collections made at this locality. Although these actual samples contain no specifically identifiable marine megafossils, rich faunas have been collected there (e.g. Spath, 1953, p. 44; Bibby, 1966, p. 23) and were considered to be Campanian in age. All this material was collected loose or from stratigraphically uncorrelated exposures.

Although low yielding, both samples provided diverse, well-preserved paly-morph assemblages that are similar in quantitative/qualitative attributes. Spores, pollen, dinoflagellates, and chlorophycean/prasinophycean microfossils are varied and land plant derivatives dominate the assemblages.

Xenikoon australis occurs abundantly in the algal assemblages which also contain common *Isabelidinium*, *Nelsoniella*, and *Maduradinium*; gonyaulacoid and chloro-phycean/prasinophycean types occur infrequently. The assemblages are closely comparable to those reported from Australian southern and western margin sequences where *Xenikoon australis* is confined to, and diagnostic of, the *X. australis* Zone. In the Perth Basin, the zone is dated as Campanian on the basis of Foraminifera and nannoplankton (Helby and others, 1987; N. Marshall, pers. comm.). Other dinocyst associates of the zone in Australia and also represented in the James Ross Island samples include *Nelsoniella aceras*, *N. tuberculata*, *Maduradinium pentagonum*, and *Palaeohystrichophora infusorioides*. Several of these elements were reported by Harris (1977) from Site 328 on the Falkland Plateau. *Xenikoon australis* and *Nelsoniella aceras* occur in cores 10 and 11 of Campanian–Maastrichtian age. The former species was also recorded from core 7, Site 328B, in association with the Turonian–Coniacian species *Conosphaeridium striatoconum*, but according to Barker and others (1977, p. 99) this core may have been contaminated.

Xenikoon australis is not known from New Zealand, but Wilson (1984) reported *Nelsoniella aceras* from eastern coastal sections within the upper *Odontochitina porifera* Zone and the succeeding *Alterbia acutula* Zone. The range of *N. aceras* in New Zealand is thus mid-Campanian–Maastrichtian (Wilson, 1984). The species is

Fig. 5. Gymnospermous (a–h) and angiospermous (i–w) pollen; magnifications × 1000 unless otherwise specified. (a) *Dacrycarpites australiensis* Cookson and Pike 1953, × 500; (b) *Microcachryidites antarcticus* Cookson 1947, × 750; (c) *Trichotomosulcites* sp. A showing triangular corpus outline and frilled, distally inclined sacci, × 750; (d) *Phyllocladidites mawsonii* Cookson ex Couper 1953, × 750; (e, f) ?*Rugubivesiculites* sp. A, proximal and distal foci, × 500, showing verrucate-rugulate cappa ornament and finely reticulate sacci; (g) *Alisporites grandis* (Cookson) Dettmann 1963, × 500; (h) *Callialasporites trilobatus* (Balme) Dev 1961, × 500; (i) *Clavatipollenites hughesii* Couper 1958; (j) *Tricolporites* sp. A, lateral aspect showing psilate, colporate exine; (k) *Tricolpites gillii* Cookson 1956; (l) *Tricolpites* sp. A, polar aspect showing fine surficial clavae; (m) *Tricolpites* sp. 4 of Truswell 1983, polar view showing spinulae; (n) *Tricolpites waiparaensis* Couper 1960, showing long colpi and finely reticulate sexine; (o) *Nyssapollenites* sp. A, polar aspect showing faintly patterned sexine; (p) *Myrtaceidites eugeniioides* Cookson and Pike 1953; (q) *Triorites minor* Couper 1953; (r) *Proteacidites subscabratus* Couper 1960; (s) *Simpsonipollis* sp. A, lateral aspect showing fine striae that converge in mesocolpal regions; (t) *Triporopollenites* sp. A, polar view showing finely granulate surficial sculpture; (u) *Tricolporites* cf. *lilliei* (Couper) Stover and Evans 1973; (v) *Tricolporites lilliei* (Couper) Stover and Evans 1973, (w) *Cranwellipollis palisadus* (Couper) Martin and Harris 1974.
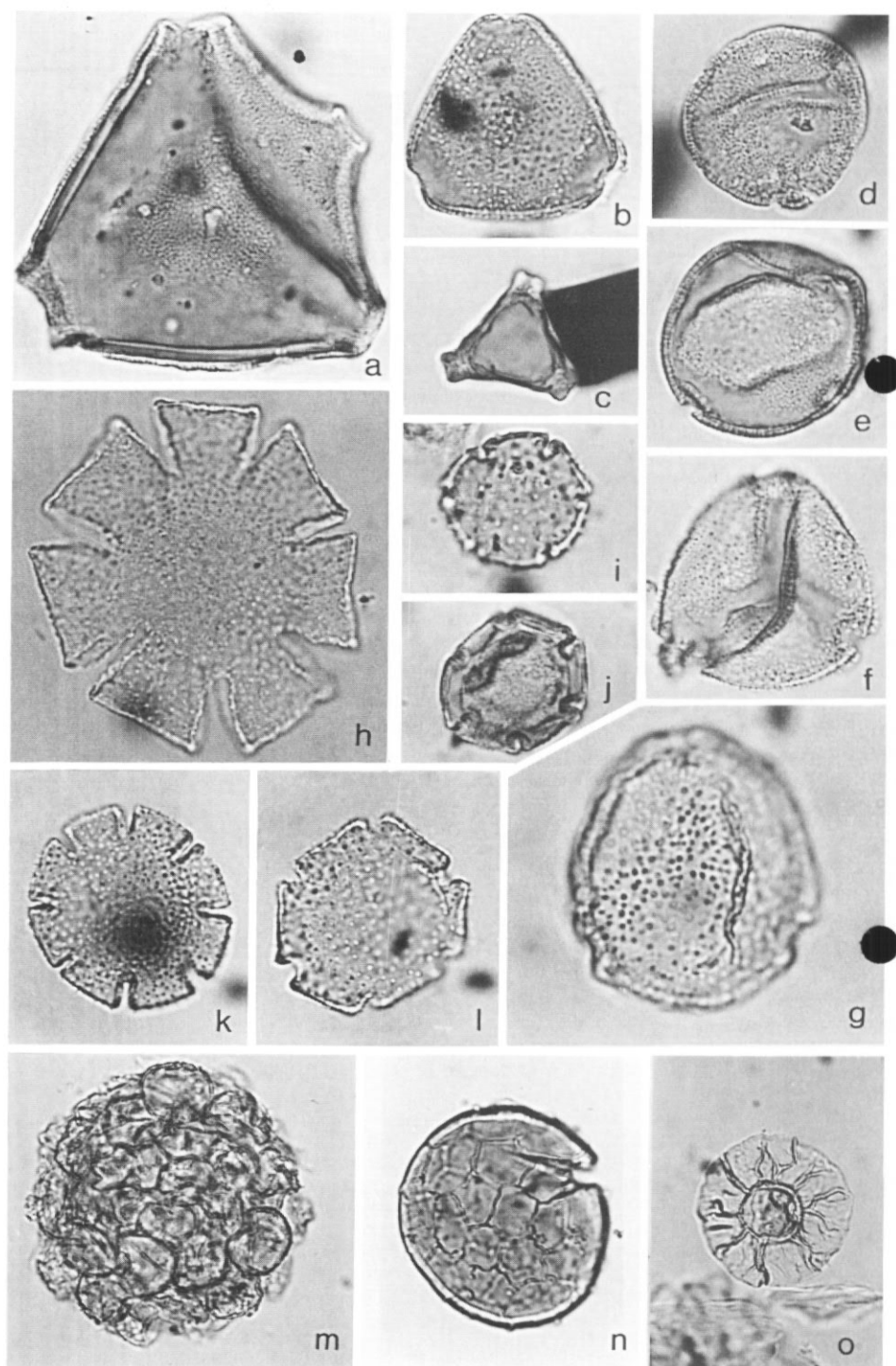
also known from the Cape Basin at Site 361 in cores stratigraphically above planktic foraminiferids of Campanian–early Maastrichtian age (Davey, 1978). *N. aceras* is associated there with *N. tuberculata* which, as noted above, occurs in the James Ross Island assemblages.

Nelsoniella aceras, possible *N. tuberculata*, *Isabelidinium cretaceum*, and *Odontochitina* spp. are known from Tierra del Fuego in subsurface sequences that are not certainly dated as Maastrichtian (Menendez, 1965; Pöthe de Baldis, 1966; Troncoso and Doubinger, 1980). These forms occur in dinocyst assemblages extracted from cuttings that may be contaminated by latest Cretaceous–Tertiary sediments.

Taking into account the various aspects of the dinoflagellate evidence, a Campanian age seems likely for samples 8540 and 8665.

The spore-pollen florules of samples 8540 and 8665 contain abundant podocarpacean pollen and common *Araucariacites*, *Cyathidites*, and *Baculatisporites*. Other fern and lycophytic/bryophytic spores are infrequent as are angiospermous pollen. The last-mentioned are taxonomically diverse and reflect links with Australian and New Zealand Late Cretaceous palynofloras of the *Nothofagidites senectus/ Tricolporites lilliei* Zones and the *Phyllocladidites mawsonii* Assemblage respectively (Dettmann and Playford, 1969; Stover and Evans, 1973; Stover and Partridge, 1973; Raine, 1984). Common to these austral palynofloras are *Nothofagidites senectus*, *Tricolpites gillii*, *Triorites minor*, and *Cranwellipollis subpalisadus*. The gymnospermous component underlines the close floral affiliations that existed between James Ross Island and the Australasian region. *Phyllocladidites mawsonii*, *Lygistepollenites balmei*, *Microcachryidites antarcticus*, *Podocarpidites*, and *Araucariacites* were widely disseminated through the region during the Campanian.

However, there is evidence that several forms had earlier appearances at James Ross Island than in the Australian/New Zealand region. *Myrtaceidites eugeniioides*, *Rugulatisporites mallatus*, and *Herkosporites elliottii* are unknown from the Campanian in Australasia. By contrast, *Perotrilites laceratus* appears to have persisted later at James Ross Island; alternatively specimens recovered may be recycled from older Cretaceous sediments.

Comparisons with the Falkland Plateau microfloras are hampered by lack of data, but *Proteacidites*, *Podocarpidites*, and *Nothofagidites* were reported by Harris (1977) from the Campanian section. *Araucariacites* occurs in the latest Cretaceous at Site 361, Cape Basin, but in other respects the southern African spore-pollen assemblages are distinct from those of James Ross Island.

Fig. 6. Angiosperm pollen (a–l), × 1000, and chlorophycean/prasinophycean microfossils (m–o), × 500. (a) *Propylipollis* cf. *annularis* (Cookson) Martin and Harris 1974, large 4-porate grain; (b) *Proteacidites retiformis* Couper 1960; (c) *Propylipollis* sp. A, showing internally striate post atrium to pores and faintly patterned polar sexine; (d) *Periporopollenites* sp. A, showing small operculate pores and reticulate sexine; (e) *Retistephanocolporites* sp. A, specimen with 4 pores and reticulate simplicolumellate sexine; (f) *Triporopollenites* sp. 3 of Truswell 1983; (g) *Triporopollenites* sp. B, showing surficial columellae; (h) *Nothofagidites asperus* (Cookson) Romero 1973; (i) *Nothofagidites senectus* Dettmann and Playford 1968; (j) *Nothofagidites lachlaniae* (Couper) Pocknall and Mildenhall 1984; (k) *Nothofagidites* sp., specimen with peritreme outline and rimmed colpi; (l) *Nothofagidites* cf. *nanus* Romero 1977; (m) *Palambages* Form A of Manum and Cookson 1964; (n) *Dictyodinium* sp.; (o) *Pterospermella australiense* (Deflandre and Cookson) Eisenack 1972.
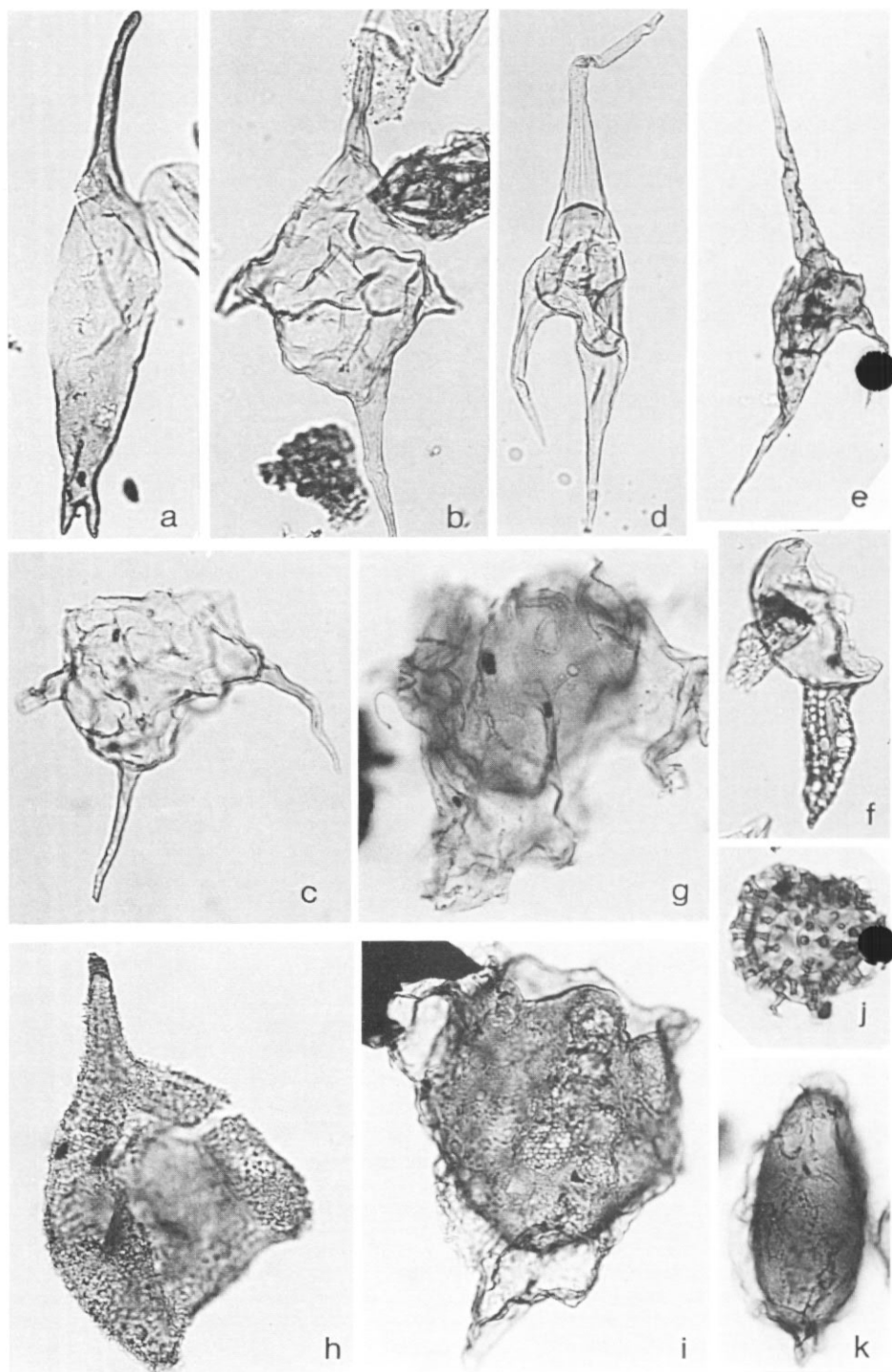
VEGA ISLAND

D.3122.3, east side of Cape Lamb

Cretaceous sandstones of Cape Lamb have produced a variety of bivalves and ammonites of supposed Campanian age (Bibby, 1966; Howarth, 1966; Del Valle and Medina, 1980). Although the precise stratigraphical relationship of this exposure on Vega Island to those on James Ross Island has yet to be established, field work by MRAT and colleagues indicates that it is certainly younger than the sequence on the eastern side of Lachman Crags and is of approximately the same age as exposures at The Naze and on Humps Island. The presence of ammonites such as *Diplomoceras lambi, Kitchinites darwini, Gunnarites* spp. and *Maorites densicostatus* suggest a correlation with strata on Seymour Island and a probable Maastrichtian age. The ●ple was taken from a calcareous concretion surrounding an example of the bivalve *Nordenskjoldia nordenskjoldi* Wilckens.

The diverse and well-preserved palynomorph assemblage obtained from D.3122.3 provides clear evidence that the sample is stratigraphically higher in the sequence than the James Ross Island material examined. D.3122.3 yielded abundant algal microfossils of dinophycean and prasinophycean/chlorophycean affinity and a land plant assemblage in which angiospermous pollen are common and highly diversified.

The dinocyst association displays features regarded by Helby and others (1987) as characteristic of late Campanian–Maastrichtian in Australia, and by Wilson (1984) as indicative of ?late Maastrichtian in New Zealand. The presence of *Isabelidinium pellucidum* with *I. cretaceum* is diagnostic of the *I. korojonense* Zone in southern and western margin sequences of Australia; faunal evidence from the latter area provides the basis for the late Campanian–early Maastrichtian dating of the zone (N. Marshall, pers. comm.). In terms of the New Zealand dinocyst biostratigraphy, the presence of *Palaeocystodinium granulatum* with *I. cretaceum* and a form similar to *Chatangiella campbellensis* suggests a Maastrichtian (possibly late) age and reference to Wilson's (1984) *Alterbia acutula* Zone. Also present in D.3122.3 are forms similar to *I. bakeri*, a species known from the *A. acutula* Zone in New Zealand and from possible latest Maastrichtian of Tierra del Fuego (Troncoso and Doubinger, 1980), but hitherto reported only from the Paleocene in Australia (see Stover, 1973).

The conflict of age evidence provided by the dinoflagellates may reflect uncertainties ●orrelation between the Australian and New Zealand sequences, or it may denote that certain of the dinocyst taxa have disparate stratigraphic ranges in the separate regions. Alternatively, the Vega Island sediments may be late Maastrichtian or even Paleocene but contain a significant reworked component derived from slightly older, Campanian–early Maastrichtian, sequences. Recycling from early- to mid-Cretaceous is denoted by occasional dinocysts and spore-pollen palynomorphs including *Diconodinium cristatum, Callialasporites trilobatus,* and *Crybelosporites* cf. *striatus*; all of these are of darker colouration, and hence of higher thermal alteration index, than the indubitably latest Cretaceous palynomorphs. It should also be added that

---

Fig. 7. Dinophycean 'R' (a) and 'G' (b–j) cysts; magnifications × 500 unless specified otherwise. (a) *Batioladinium jaegeri* (Alberti) Brideaux 1975, × 400; (b) *Muderongia* cf. *staurota* Sarjeant 1966; (c) *Muderongia tetracantha* (Gocht) Alberti 1961; (d) *Odontochitina* sp. A, × 300; (e) *Odontochitina operculata* (Wetzel) Deflandre and Cookson 1955, × 300; (f) *Odontochitina porifera* Cookson 1956, × 300; (g) *Xenascus australensis* Cookson and Eisenack 1969; (h) *Pseudoceratium* sp. A; (i) *Pseudoceratium ludbrookiae* (Cookson and Eisenack) Eisenack 1961; (j) *Cleistosphaeridium ancoriferum* (Cookson and Eisenack) Davey, Downie, Sarjeant, and Williams 1966; (k) *Omatia montgomeryi* Cookson and Eisenack 1958.

extensive reworking of mid- and Late Cretaceous forms into Eocene sediments of Seymour Island has been noted by Wrenn and Hart (1984).

Comparisons are evident between the dinocyst assemblages of D.3112.3 and those of middle-late Campanian age reported by Askin (1983*b*, in press) from the same area. All contain *I. cretaceum*, *I.* cf. *bakeri*, and *Palaeocystodinium*. However, Askin (in press) reports common *Odontochitina porifera*, a species not observed in D.3112.3 and whose last appearances are below Askin's Zone 1. Moreover, D.3112.3 contains the pollen *Tricolporites lilliei*, which, according to Askin (in press), is characteristic of her Zone 1 as thus far identified on neighbouring Seymour Island.

The spore-pollen florule of D.3112.3 contains high ratios of gymnospermous and angiospermous pollen and a significantly lesser proportion of cryptogam spores (Fig. 2). *Nothofagidites* spp. and *Tricolpites gillii* dominate the diverse angiosperm assemblage in which are represented many of the triporate and tricolporate pollen types reported by Truswell (1983) as recycled in Recent Antarctic shelf sediments (Table II); of these, *Tricolpites* sp. 4 occurs in the Sobral and Cross Valley Formations (Maastrichtian–Paleocene) on Seymour Island (Askin and Fleming, 1982). Noteworthy also is the presence of species described from southern Australia and New Zealand, and several of these taxa have considerable correlative significance. *Tricolporites lilliei*, *Nothofagidites senectus*, *Tricolpites waiparaensis*, *Tricolpites gillii*, and *Cranwellipollis subpalisadus* fall into this category.

In south-eastern Australia, association of these species is restricted to the *Tricolporites lilliei* and succeeding *Tricolpites longus* Zones of Stover and Evans (1973) (see also Stover and Partridge, 1973; Helby and others, 1987), and denote a mid-Campanian–Maastrichtian age if the age data detailed for the associated *Isabelidinium korojonense* and *Manumiella druggii* dinoflagellate zones prove valid. In New Zealand, several of the species are represented in Raine's (1984) PM 2 Zone (*Phyllocladidites mawsonii* Assemblage), the base of which is delineated by initial appearances of *Tricolporites lilliei*. According to Raine, the New Zealand range of *T. lilliei* is late Campanian–Maastrichtian, and the species occurs in radiolarian-dated Campanian sediments on the Campbell Plateau (Wilson, 1975). *T. lilliei* is also known from the central coastal region of Queensland, occurring in terrestrial sediments of uncertain age that underlie marine late Oligocene strata (Hekel, 1972; Kemp, 1978).

Comparison of the Vega Island angiospermous pollen florule with those contained in South American and Falkland Plateau sequences is hampered by the lack of detailed palynological data from those areas. Several of the *Nothofagidites* species described by Menendez and Caccaveri (1975), Archangelsky and Romero (1974*a*), and Doubinger (1975) from Maastrichtian sequences in Tierra del Fuego and Patagonia occur in D.3122.3. Of these *N. asperus* is known only from the Tertiary in Australia and New Zealand. Apart from containing *Nothofagidites* and proteaceous types, the diverse angiosperm pollen florule detailed by Takahashi (1977) from Quiriquina Island, central Chile, appears to have little in common with the Vega Island assemblage reported herein.

Many of the Vega Island gymnospermous and cryptogam palynomorph species are known from the latest Cretaceous of Australia, New Zealand, and southern South America. However, the species are mostly long-ranging with respect to the latest Cretaceous and early Tertiary. One exception is *Camarozonosporites ohaiensis* which is reportedly restricted to the Late Cretaceous in New Zealand and Australia (Dettmann and Playford, 1969; Stover and Evans, 1973; Raine, 1984).

DUNDEE ISLAND

D.3862.3, Welchness, Dundee Island

The only rocks exposed *in situ* at this locality occur in a wavecut platform, below high-water mark and surrounding the extensive raised beach flats that form the promontory of Welchness. The sample selected is a green-coloured mudstone from the platform. No shelly fossils have been collected but a nearby moraine (below) contains abundant clasts of green siltstone and sandstone with Albian bivalves that were presumably derived from the bedrock of the island.

The low yield of acid-resistant organic matter from the sample is thermally degraded and suggestive of palaeotemperatures in excess of 170°C. The contained palynomorphs are mostly fragmented and poorly preserved, but identification of a number of species proved possible. Amongst the dinoflagellates occur *Laciniadinium tenuistriatum*, *Diconodinium* cf. *pelliferum*, *Ascodinium acrophorum*, and *Odontochitina costata*. This association confirms a mid-Cretaceous (late Albian–Cenomanian) age and invites comparison with that from D.3006.2 from James Ross Island.

Spores and pollen occur infrequently. They include bi- and trisaccate gymnospermous types and occasional cryptogam spores, identified species of which are long-ranging in the James Ross Island Cretaceous sequence.

R.551.4, moraine along the eastern margin of Welchness

The sample was taken from a piece of green-coloured bioturbated sandy siltstone. Inoceramid bivalves from other fragments include *Birostrina concentrica* (Parkinson) and *Inoceramus* sp. ex gr. *anglicus* Woods (Crame, 1980, 1985) and indicate the presence of derived middle-upper Albian sedimentary rocks.

Palynomorphs occur abundantly and are slightly better preserved than those from the *in situ* sample, D.3862.3, from Welchness. The palynoflora is dominated by dinoflagellates that are mostly of gonyaulacoid morphology; land-plant derivatives occur infrequently.

The occurrence of the dinocyst species *Xenascus australensis*, *Pseudoceratium ludbrookiae*, *P. turneri*, *Canninginopsis denticulata*, *Laciniadinium tenuistriatum*, *Microdinium ornatum*, and *Heterosphaeridium heteracanthum* provides clear evidence that the sample is of late Albian or Cenomanian age. Association of these species supports correlation with the *Xenascus asperatus* Zone and lower *Diconodinium multispinum* Zone in Australia and the *Pseudoceratium ludbrookiae* Zone in New Zealand (Wilson, 1984; Helby and others, 1987). The assemblage is similar to that obtained from D.3057.3 within the Whisky Bay Formation on James Ross Island. However, neither *Xenascus australensis* nor *Canninginopsis denticulata* was observed in the latter.

CAPE LONGING

R.1335.8, northern outcrop, Cape Longing; and R.1332.9, west end, Cape Longing outcrop

The stratigraphic relationship between these two specimens is unknown. R.1335.8 is a green coarse-grained sandstone, and R.1332.9 is a piece of interbedded siltstone and fine sandstone. *Inoceramus*, from the top of the outcrop at Cape Longing, belongs to the group of *I. lamarcki* Parkinson and suggests an early–middle Turonian age (Crame, 1983*a*, p. 302). Howarth (1958) compared a slightly crushed ammonite
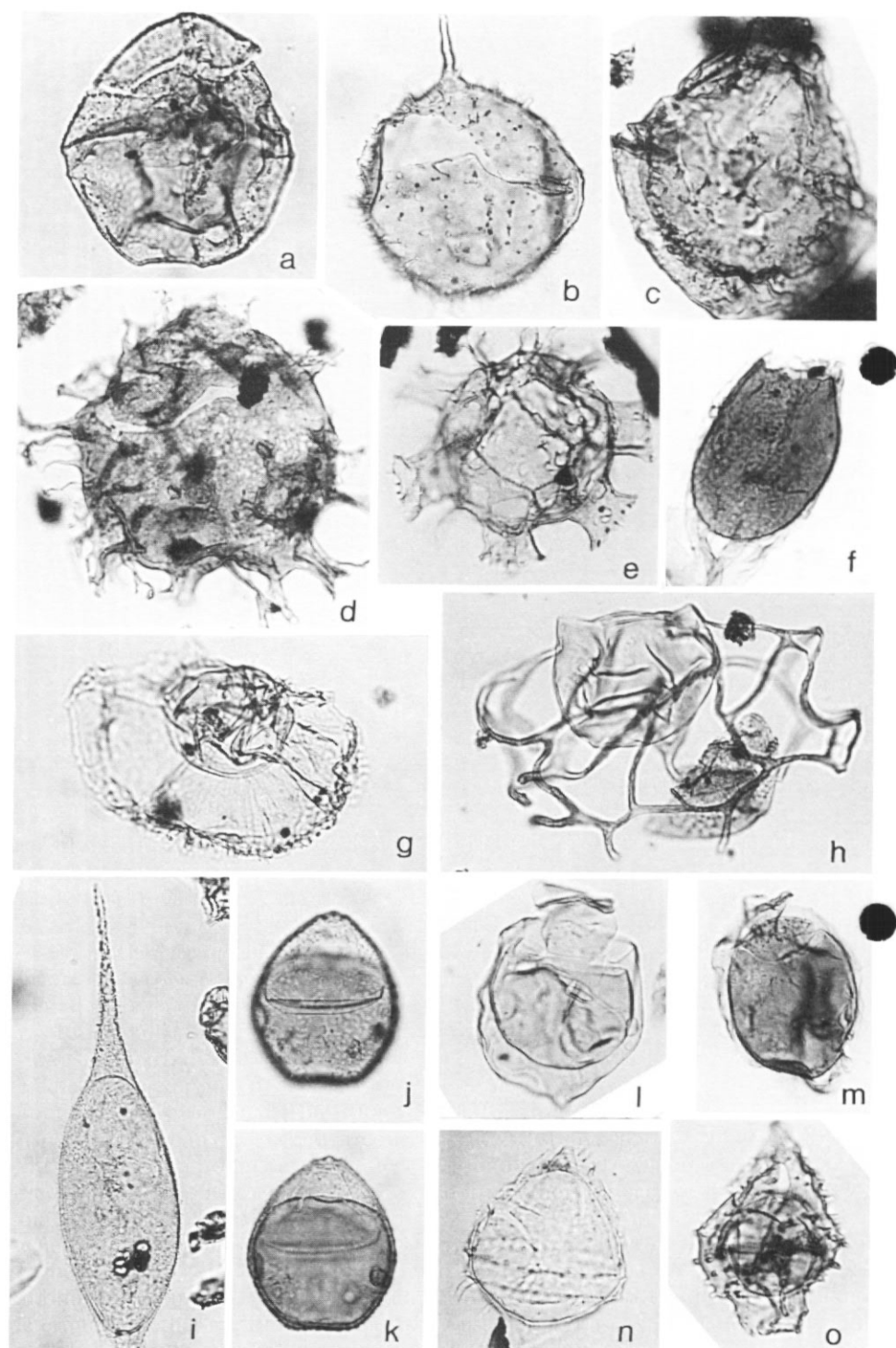
from Cape Longing to *Tetragonites epigonus* (Kossmat) whose type specimens came from the Turonian or Coniacian of southern India. However, because of its poor preservation he indicated that it was not possible to date the Antarctic example accurately. A specimen, closely similar to that from Cape Longing, has recently been collected from sandstone just above the *Eucalycoceras/Newboldiceras* beds on the south side of Gin Cove. Its age is probably Cenomanian, or early Turonian at the youngest.

Palynomorphs extracted from R.1335.8 and R.1332.9 are overmature, poorly preserved, and dominantly of dinophycean affinities.

R.1335.8 yielded common *Cribroperidinium* together with rare *Pseudoceratium ludbrookiae* and *Canninginopsis denticulata*. A late Albian–Cenomanian age is indicated.

A greater number of species was identified in residues of R.1332.9. *Oligosphaeridium* ad *Cyclonephelium* occur commonly in the dinocyst flora that also includes *Ascodinium acrophorum*, *A. serratum*, *Laciniadinium tenuistriatum*, and *Diconodinium* cf. *pelliferum*. This association supports a middle Albian–Cenomanian age. Amongst the spores and pollen there are frequent bi- and trisaccate forms and occasional cryptogam spores including *Cyatheacidites annulatus* and *Interlobites intraverrucatus*.

BIOGEOGRAPHIC IMPLICATIONS

Megafaunas

The palaeogeographic implications of the ammonites, belemnites and inoceramid bivalves from the Cretaceous of James Ross Island have been discussed by Thomson (1981), Macellari (1985, 1986), Crame (1987) and Doyle (1987). It was during Cretaceous times that the dispersal of the Gondwana continental fragments became marked as they were gradually separated by new oceans (South Atlantic, Indian and Southern). However, by Late Cretaceous times South America and the Antarctic Peninsula were probably still joined by a shallow-water shelf, if not a complete land link, and Australasia was only just beginning its separation from Antarctica (e.g. Smith and others, 1981). Faunal analyses show that, during the late Mesozoic, high-latitude marine faunas of the Southern Hemisphere included a distinct austral component. In the case of the cephalopods there were several generic groups which ere entirely restricted to this region, whereas among the bivalves some genera appear to be common to both polar regions. It is tempting to see a climatic control having had some influence on the distributions observed, but this theory is by no means subscribed to by all students of Mesozoic faunas and an explanation of the phenomenon is the subject of considerable debate. Other possible controls which have been suggested include environmental stability, geography and salinity. Whatever the answer proves to be, the important fact is that a recognizable austral faunal realm was

Fig. 8. Dinophycean 'G' (a–h) and 'P' (i–o) cysts; magnifications × 500 unless specified otherwise. (a) *Canninginopsis intermedia* Morgan 1980; (b) *Cribroperidium* sp. A, × 330; (c) *Scriniodinium crystallinum* (Deflandre) Klement 1960; (d) *Heterosphaeridium heteracanthum* (Deflandre and Cookson) Eisenack and Kjellström 1971; (e) *Callaiosphaeridium asymmetricum* (Deflandre and Courteville) Davey and Williams 1966; (f) *Leberidocysta chlamydata* (Cookson and Eisenack) Stover and Evitt 1978; (g) ?*Stephodinium* sp. A; (h) *Adnatosphaeridium filiferum* (Cookson and Eisenack) Williams and Downie 1969; (i) *Palaeocystodinium granulatum* (Wilson) Lentin and Williams 1976, × 400; (j, k) *Xenikoon australis* Cookson and Eisenack 1960, surface focus and optical section; (l) *Ascodinium acrophorum* Cookson and Eisenack 1960; (m) *Ascodinium ovale* Cookson and Eisenack 1970; (n) *Palaeohystrichophora infusorioides* Deflandre 1935; (o) *Spinidinium* cf. *echinoideum* (Cookson and Eisenack) Lentin and Williams 1976.
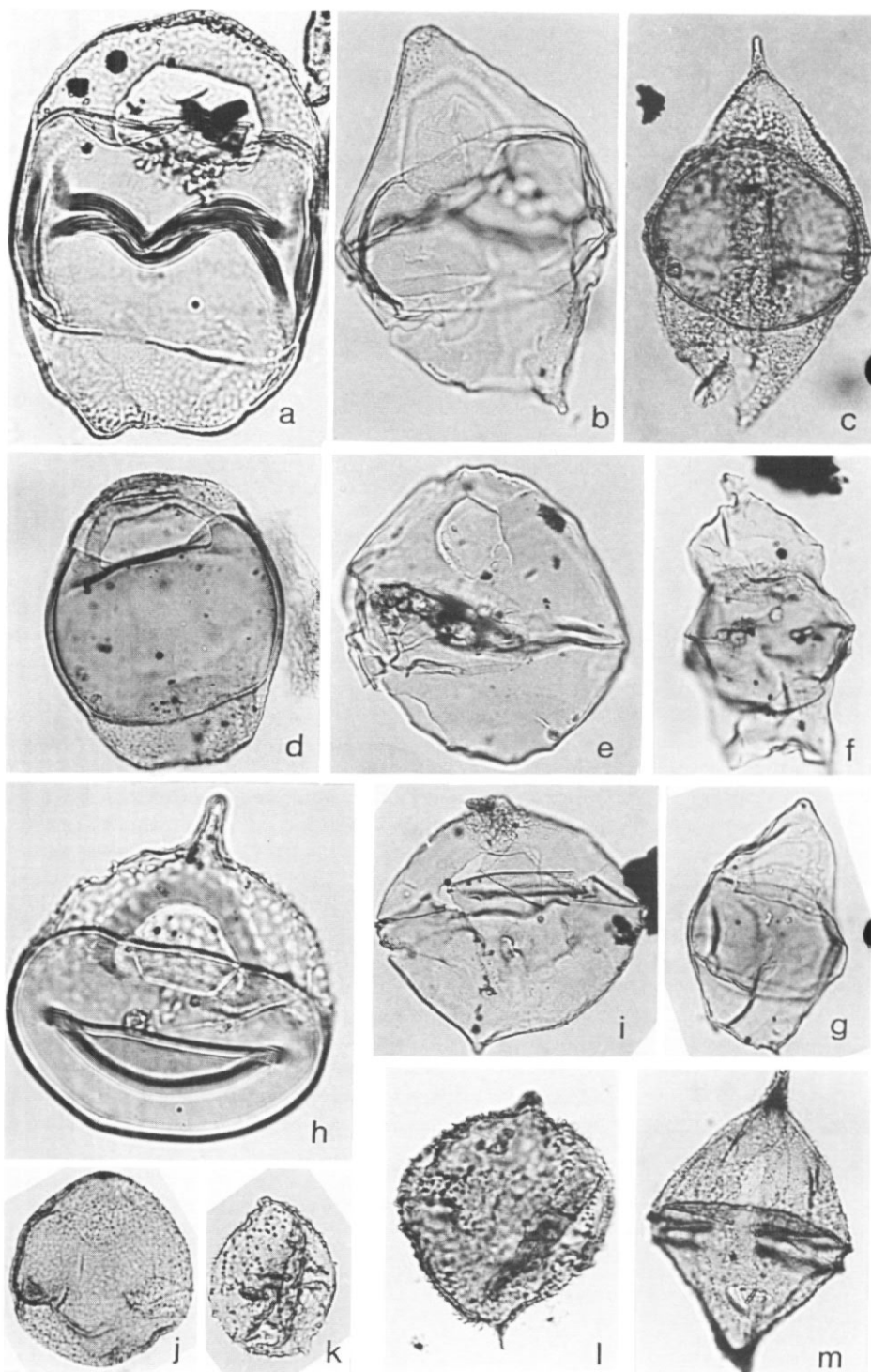
developed and that strong links between the Antarctic Peninsula region and southern South America on the one hand, and between the peninsula and Australasia on the other, were particularly marked.

Dinoflagellate floras

Prior to this study there were few data on Cretaceous dinocyst floras of Antarctica. Traces of algae, including *Botryococcus* and *Pediastrum*, were alluded to by Cranwell (1959, 1969) in sediments of possible Late Cretaceous age from Seymour Island. From the same area, Hall (1977) reported two dinocyst species, *Cyclonephelium distinctum* and *Isabelidinium cretaceum*, and also provided listings of taxa occurring in younger rocks of latest Cretaceous or Paleocene and Eocene ages. Subsequent studies on Antarctic Late Cretaceous dinoflagellate floras include that of Palamarczuk and others (1984) who reported an assemblage regarded by them as Campanian in age from the Lopez de Bertodano Formation on Seymour Island. The taxonomically restricted flora includes *Palaeocystidinium granulatum*, *Operculodinium*, *Eisenackia*, and two deflandroid species (reported as *Isabelidinium thomasii* and gen. et sp. nov.). The austral character of Campanian–latest Cretaceous dinoflagellate floras from James Ross Island, Vega Island, and Seymour Island is hinted at in brief notes by Askin (1983b, 1984, 1985) and confirmed in her (in press) outline of the Campanian – early Tertiary palynological succession of the region. Knowledge of Early Cretaceous cyst floras is sketchy, consisting of preliminary notes on assemblages obtained from latest Jurassic–possibly Barremian sediments exposed on the South Shetland Islands (Askin, 1981, 1983a).

Whereas the record herein of some 80 dinocyst taxa from the early Albian–Cenomanian and Senonian–latest Cretaceous adds to our knowledge of Cretaceous dinocyst floras of the Antarctic Peninsula, it provides only hints of their diversity level and does not (because of the limited sampling base) delineate the precise stratigraphic ranges of many of the component species. For the Campanian–Maastrichtian portion of the James Ross Island, Vega Island and Seymour Island sequences, Askin (in press) has determined more precisely the ranges of several component species within the framework of her palynostratigraphic zonation which is based largely on dinocysts. Both the present and Askin's study emphasize that affiliations of the Antarctic floras are with those of other southern high-latitude regions. Specifically, the floras are referable to the three younger dinocyst floras – the *Muderongia*, *Heterosphaeridium*, and *Isabelidinium* floras – as delineated by Helby and others (in press) from the Australian Cretaceous. Characteristics of these floras and the biogeographic significance of the Antarctic data are discussed below.

Several of the James Ross Island samples yielded recycled Jurassic species which

Fig. 9. Dinophycean 'P' cysts; magnifications × 500 unless specified otherwise. (a) *Isabelidinium* cf. *bakeri* (Deflandre and Cookson) Lentin and Williams 1977; (b) *Isabelidinium pellucidum* (Cookson and Eisenack) Lentin and Williams 1977; (c) *Chatangiella* cf. *campbellensis* (Wilson) Lentin and Williams 1976, pericyst bears closely-spaced setae and grana, × 400; (d) *Isabelidinium cretaceum* (Cookson) Lentin and Williams 1977; (e) *Manumiella lata* (Cookson and Eisenack) Bujak and Davies 1983; (f) *Chatangiella tripartita* (Cookson and Eisenack) Lentin and Williams 1976; (g) *Chatangiella serratula* (Cookson and Eisenack) Lentin and Williams 1976, cingulum faintly developed; (h) *Nelsoniella tuberculata* Cookson and Eisenack 1960; (i) *Maduradinium pentagonum* Cookson and Eisenack 1970, × 400; (j) *Laciniadinium tenuistriatum* (Eisenack and Cookson) Morgan 1980; (k) *Chichaouadinium boydii* (Morgan) Bujak and Davies 1983; (l) *Diconodinium* cf. *pelliferum* (Cookson and Eisenack) Eisenack and Cookson 1960; (m) *Diconodinium cristatum* Cookson and Eisenack 1974.

Fig. 10. Early Albian distribution of *Muderongia* dinocyst flora and regional variations within contemporaneous spore-pollen florules; see text for data sources. Map is South Polar Lambert equal-area for the Albian (adapted from Smith and others, 1981; map 28, with modification after De Wit, 1977). Australian shorelines after Frakes and others (1987, map 5).

suggest that Antarctic Jurassic floras also had close links with Australia. More rigorous study of the Jurassic elements may reveal important data on sediment provenance of the enclosing Cretaceous sequences, thus furthering knowledge on the sedimentary/structural history of the region.

(1) *Muderongia dinocyst flora*. The oldest of the Antarctic Cretaceous assemblages reported here are from the Kotick Point Formation and are of Albian, probably early Albian, age. They are rich in gonyaulacoid species (Fig. 2, Table IV) and contain *Muderongia* and common *Spiniferites*, features that distinguish the *Muderongia* dinocyst flora of Helby and others (1987). The flora was established during the Valanginian in western and northern marginal basins in Australia and in adjacent regions of New Guinea and the Indian Ocean (Wiseman and Williams, 1974; Wiseman, 1980; Helby and others, 1987). An Aptian spread into the intracratonic basins of Australia and to the proto South Atlantic Ocean region is confirmed by records of *Muderongia* and associates from the Eromanga/Surat Basins of Australia (Burger, 1980, 1982; Morgan, 1980; Helby and others, 1987), the Cape Basin, South Africa (Davey, 1978), and the Falkland Plateau (Bair and Hart, 1984). This

Fig. 11. Late Albian–Cenomanian distribution of *Heterosphaeridium* dinocyst flora and regional variations within contemporaneous spore-pollen florules; see text for data sources. Map is South Polar Lambert equal-area for the earliest Cenomanian (adapted from Smith and others, 1981; map 28, with modification after De Wit, 1977). Australian shorelines after Frakes and others (1987, map 6).

evidence may imply that connections between the Indian and South Atlantic oceanic regions were initiated during the Aptian.

The early Albian distribution of the flora is equally widespread and includes the Antarctic Peninsula (Fig. 10). However, the timing of its introduction into the region is as yet unknown. Askin (1981, 1983*a*) discussed poorly preserved dinocyst assemblages of Tithonian–possibly Barremian age from the South Shetland Islands, but *Muderongia* was not recorded as a component of the associations. The genus is unknown from New Zealand where marine Cretaceous sediments older than the late Aptian remain unidentified. The New Zealand dinocyst assemblages of late Aptian–early Albian age have certain species in common with the Australian/ Antarctic florules but await detailed documentation (Wilson, 1984).

(2) *Heterosphaeridium dinocyst flora.* In Australia, the *Heterosphaeridium* dinocyst flora succeeds the *Muderongia* flora and was introduced during the middle Albian. It is characterized by diverse gonyaulacoid cysts, including common *Cyclonephelium*, *Heterosphaeridium*, and *Cribroperidinium*, and by increased ratios of peridinioid
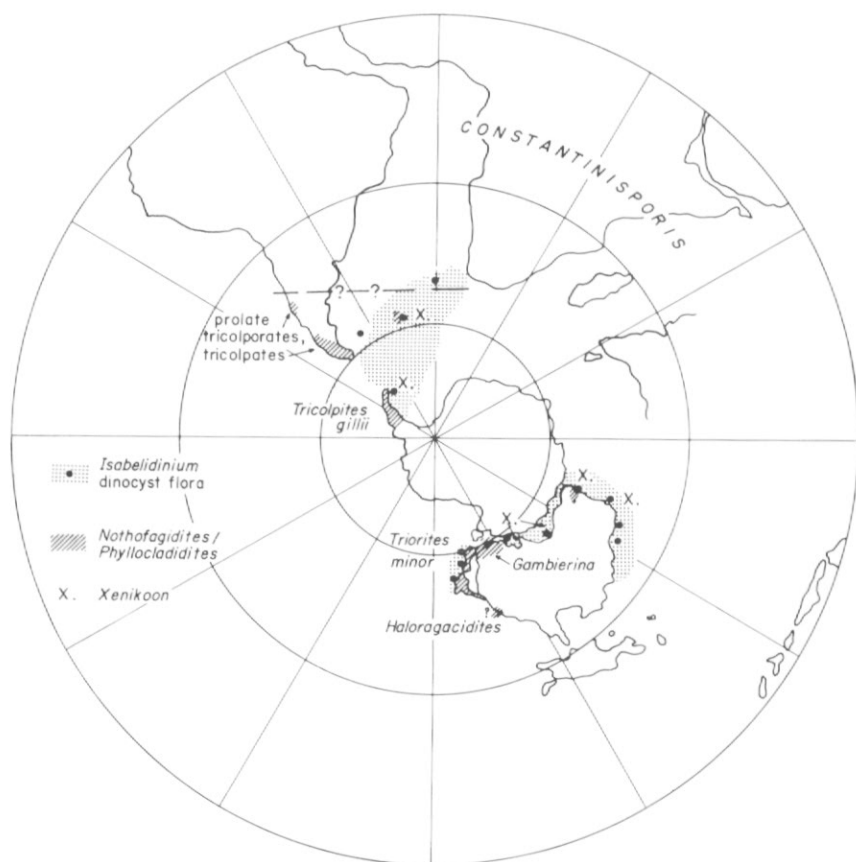
Fig. 12. Mid-Campanian–Maastrichtian distribution of *Isabelidinium* dinocyst flora and regional variations within Maastrichtian spore-pollen florules; see text for data sources. Map is South polar Lambert stereographic for the Santonian (adapted from Smith and Briden, 1977, map 32, p. 43).

cysts, notably of *Diconodinium*. Distribution of the flora in Australia reflects spatial extent of mid-Cretaceous marine sediments. Middle–late Albian occurrences are in the intracratonic and marginal basins; those of Cenomanian–Coniacian age are restricted to marginal areas including the southern rift valley that had developed between Australia and Antarctica. Its replacement by the succeeding *Isabelidinium* dinocyst flora is dated as Santonian (Helby and others, 1987).

A succession of assemblages similar to those delineated by Helby and others (1987) has been reported by Wilson (1984) from eastern New Zealand sequences. Here the flora may have survived later (Campanian) than in Australia.

Older assemblages of the flora are unknown from the South Atlantic Deep Sea Drilling sites where middle Albian–Cenomanian sediments have failed to yield dinocysts or are unrepresented (Davey, 1978; Ludwig and others, 1983). Younger assemblages occur at Site 361 (Cape Basin), Site 327 (Falkland Plateau), and Site 358 (off central South America), according to data of Harris (1977), Ioanides and Colin (1977), Davey (1978) and McLachlan and Pieterse (1978). Associated faunas suggest

that these occurrences range from Turonian to Santonian or early Campanian age.

As evidenced by the present study, Albian–Cenomanian manifestations of the *Heterosphaeridium* dinocyst flora occur in Antarctic Peninsula sequences on James Ross Island, Dundee Island, and Cape Longing. The assemblages share many species with those of middle Albian–Cenomanian age in Australia, but compositional features of the oldest James Ross Island assemblage (from D.3035.1) may have been modified by recycling (Fig. 2, Table IV). Younger (Turonian and later) assemblages of the flora have not been identified in the material studied. Southern Hemisphere distribution of middle Albian–Cenomanian occurrences is shown in Fig. 11.

(3) *Isabelidinium dinocyst flora*. This dinocyst flora is characterized by a succession of assemblages with abundant and diverse peridinioid forms having intercalary archeopyles. In Australia the flora occurs in southern margin basins and in the Perth and Carnarvon Basins of Western Australia. Farther north there is a decrease in representation of peridinioid cysts, and distinct north–south compositional differences are evident (Helby and others, 1987). Initial appearances of the flora in Australia are dated as Santonian (Helby and others, 1987), but in New Zealand and on the Falkland Plateau this event may have been during the Campanian according to age data of associated faunas (Wilson, 1984; Ludwig and others, 1983). In all regions substantial floral modifications are evident at or near the Cretaceous–Tertiary boundary.

Assemblages of the *Isabelidinium* dinocyst flora occur in Late Cretaceous sequences of the Antarctic Peninsula, but sampling has been insufficient to ascertain its precise stratigraphic range. Present evidence indicates that the flora was established by the Santonian or Campanian and ranged into the Maastrichtian. Whereas the Campanian assemblages suggest close links to Australia, the Vega Island Maastrichtian assemblage includes a strong New Zealand component.

Despite certain compositional differences, the *Isabelidinium* flora may be an analogue of the Williams dinocyst suite that characterizes Campanian marine sequences fringing the North Atlantic Ocean (Lentin, 1976; Lentin and Williams, 1980). Whereas the Williams suite was restricted to the North Atlantic, data detailed above suggest that the *Isabelidinium* flora had circumpolar distribution in southern high latitudes (Fig. 12).

Land plant floras

Until 1980, data on the Cretaceous land plant vegetation of Antarctica were few. Cranwell (1959) identified pollen of *Nothofagus* and of the southern gymnospermic genera *Dacrydium*, *Lagarostrobus*, and *Podocarpus*, from probable Late Cretaceous sediments on Seymour Island. Later (Cranwell, 1964) she suggested that Antarctica may have been a cradle area for certain of these floral elements. Subsequent accounts (Hernandez and Azcarate, 1971; Domack and others, 1980; Askin, 1981, 1984, 1986; Askin and Fleming, 1982; Medina and others, 1982) covered a broader stratigraphic range but vegetational knowledge remained sketchy for the Antarctic Peninsula region until details were published on Early Cretaceous megafloras from Alexander Island (Jefferson, 1983), on latest Jurassic–probably Barremian palynofloras of the South Shetland Islands (Askin, 1983a), and on possibly Cretaceous spores and pollen recycled into Recent Antarctic Shelf sediments (Truswell, 1983). On the basis of these data and from the spore-pollen florules detailed herein, Dettmann (1986b) concluded that a succession of podocarp rainforest communities flourished over the Peninsula

region during most of the Cretaceous. Floral affiliations were with Australia and New Zealand, and to a lesser extent with the Patagonia–Falkland Plateau region.

As discussed below, the Antarctic spore-pollen evidence confirms the southern Gondwanian character of its Cretaceous vegetation. It also emphasizes that there was pronounced floral regionalism within southern Gondwana, with a zonation of forest communities across the latitudes, and of understorey associations in an east–west direction. The characteristics of the Antarctic spore-pollen assemblages and their similarities/differences to coeval assemblages of other southern regions are discussed below in sequential order (see Figs 10–12; Tables I, II, IV). As will be evident from this discussion, the Antarctic assemblages are not entirely conformable with the Microfloras or Assemblages that have been delineated in Australian and New Zealand Cretaceous sequences (Dettmann, 1963; Balme, 1964; Raine, 1984; Helby and others, 1987).

(1) *Early Albian.* The early Albian florules from James Ross Island characterized by strong representation of podocarpaceous pollen including *Micro-cachryidites* together with common araucarean and pteridospermous pollen, and in these respects they are similar to coeval assemblages reported from Australia and New Zealand. Other similarities are evident; all the assemblages have low proportions of *Classopollis* and share many cryptogam spore species. However, when viewed quantitatively in terms of phyletic composition, the cryptogam spore assemblages connote a regional variation amongst understorey communities of the podocarp/ araucarean rainforests. Dettmann (1986*b*) believed this regionalism expressed habitat differences imposed by terrain variations, more so than by a pronounced climatic gradient. For instance, fern spores dominate the James Ross Island associations and reflect rainforest ferns (Osmundaceae and/or Hymenophyllaceae, *Lophosoria*, ?dicks-onoid types) that grew on the steep terrain. The plentiful lycopods in New Zealand assemblages (Couper, 1953, 1960; Raine, 1984) are affiliated with *Lycopodium* (*Lycopodium*) that today inhabit open moorland and areas fringing cool temperate rainforests. In the Gippsland and Otway Basins of south-eastern Australia, the early Albian florules have common fern and lycopod derivatives that are indicative of rainforest as well as dry-zone ferns together with *Lycopodium* (*Lycopodium*) communities; these evidently thrived on the slopes of, and in, the rift valley between Australia and Antarctica. The low relief areas adjacent to the more northerly Surat and Eromanga Basins may have been colonised by extensive hepatic/moss/fern communities as suggested by the spore-pollen evidence (Dettmann, 1963; Burg 1980). Components of the parental cryptogam associations evidently migrated within southern Gondwana in a step-wise fashion as suitable habitats became available. This is suggested by successively younger appearances in different regions by certain of the cryptogam spore species (Dettmann, 1986*a*, *b*).

The rare occurrence of *Clavatipollenites* in the Kotick Point assemblages of James Ross Island indicates that angiosperms, possibly of chloranthaceous stock, were represented in Antarctica by the early Albian. Comparable pollen are widely dispersed in the early Albian of eastern Australia, although initial appearances may not have been synchronous in different depositional regions (Dettmann, 1986*a*).

Early Albian palynoassemblages of the Falkland Plateau contain many of the spore-pollen species that occur in the James Ross Island material. However, there are notable differences. In the former, *Classopollis* occurs abundantly and podocarp/ araucarean pollen are infrequent. These data suggest that the climax vegetation of the Falkland Plateau region was predominantly of dry-zone and mangrove cheirolepidacean communities in contrast to the rainforest vegetation of the Antarctic Peninsula. These floral differences may signify that a steep climatic gradient existed between the two regions during the early Albian (Dettmann, 1986*b*).

(2) *mid-Albian–Cenomanian*. The mid-Albian–Cenomanian vegetation of the Antarctic Peninsula appears to have been similar to that of the early Albian but assemblages are distinguished by more diverse angiospermous pollen, more frequent *Balmeiopsis*, and by the presence of *Cyclusphaera*. The last-mentioned is well-represented and sometimes the dominant component of older assemblages from the Barremian of Neuquén and Patagonia, South America, and Barremian–early Albian of the Falkland Plateau and the Cape Basin, South Africa (Volkheimer and others, 1977; McLachlan and Pieterse, 1978; Archangelsky and others, 1981; Kotova, 1983); well-dated middle Albian–Cenomanian palynoassemblages have yet to be reported from these regions.

Similarities noted for the early Albian between the Antarctic and Australasian florules are diminished in those of middle Albian–Cenomanian age. In Australia, *Hoegisporis*, of possible gymnospermous origin, is widely distributed and the cryptogam associations display modifications that are not paralleled in the Antarctic assemblages. Those from Australia appear to reflect a broadening of the rift valley in the Gippsland/Otway basinal region and withdrawal of the sea from the interior during the latest Albian–Cenomanian (Fig. 11). Nevertheless, the forest vegetation was probably similar consisting of podocarp/araucarean communities (Dettmann, 1981, 1986*b*).

Coeval New Zealand assemblages reflect extensive rainforest development and initial migration of angiosperms into the region (Raine and others, 1981; Raine, 1984). The latter event was late Albian, and thus later than angiosperm introduction into Australia and on the Antarctic Peninsula.

(3) *Santonian/Campanian-Maastrichtian*. There are no data on Turonian and Coniacian palynofloras from the Antarctic Peninsula. By the Santonian or early Campanian, the podocarp/araucarean rainforests included *Lagarastrobus* whose distinctive pollen, *Phyllocladidites mawsonii*, had Turonian introductions in Australia and New Zealand (Playford and Dettmann, 1978; Raine, 1984). Pteridospermous pollen, *Cyclusphaera*, *Classopollis*, and *Balmeiopsis*, all of which occur in the mid-Cretaceous assemblages, are virtually absent. The cryptogam associations include a mixture of forms that range from the Cenomanian together with newly introduced taxa including *Herkosporites elliottii* which has younger (Tertiary) appearances in Australia (Stover and Partridge, 1973).

More profound vegetational changes occurred during, or just prior to, the mid-Campanian. Pollen of *Dacrydium*, *Nothofagus*, Proteaceae, Myrtaceae, and a variety of other angiosperms occur in the assemblages. The timing of introduction of these floral elements in Antarctica is however not precisely delineable from the set of samples investigated. The oldest *Nothofagus* pollen observed is referable to *Nothofagidites senectus* which Dettmann and Playford (1968) compared with the *brassi* type of extant pollen. However, more recent studies (unpublished) suggest that the pollen species is morphologically distinct from the extant groups of *Nothofagus* pollen and may represent an ancestral type. Cryptogam spore assemblages are taxonomically restricted. Notable is the lack of schizaeaceous spores of the *Anemia* and *Mohria* type, and the presence of *Rugulatisporites mallatus* which is restricted to the Tertiary in Australia (Stover and Partridge, 1973).

As discussed previously, Santonian–Campanian gymnospermous vegetation of James Ross Island has close affiliations with that of New Zealand, Australia, and the Falkland Plateau. Close floral parallelism is also expressed by some angiosperms including *Nothofagus*, but not by others or by certain of the cryptogams.

The youngest sample investigated (from Vega Island) suggests that further floral modification occurred on the Antarctic Peninsula very late in the Cretaceous (Maastrichtian). This sample contains abundant and diverse angiospermous pollen.

Nothofagidites is represented by a dozen or so pollen forms including *fusca* and *menziesii* types. There is also common and diverse *Tricolpites*, including *T. gillii*, and less frequent but equally diverse polyorate and triporate pollen. Gymnospermous derivatives are mostly podocarpaceous and the inferred vegetation evidently included mixed *Nothofagus*/podocarpacean rainforest communities. Similar rainforests were apparently widespread throughout southern Gondwana very late in the Cretaceous according to data from Australia, New Zealand, and Patagonia (Couper, 1953, 1960; Dettmann and Playford, 1968, 1969; Romero, 1973; Stover and Evans, 1973, Stover and Partridge, 1973; Archangelsky and Romero, 1974*a*, *b*; Menendez and Caccaveri, 1975). However, the pollen assemblages from each of these areas display distinctive attributes that seem to imply strong angiosperm regionalism (see Fig. 12). Affinities of many of the commonly occurring, distinguishing angiosperm taxa are largely unknown, but *Haloragacidites harrisii*, reported as common in Queensland sediments not certainly dated as latest Cretaceous, may suggest the presence of Casuarinace (Muller, 1981).

TAXONOMIC LISTING OF PALYNOMORPHS

The well-preserved palynomorph assemblages extracted from the James Ross and Vega Island samples are exceptionally varied taxonomically and contain a substantial proportion of forms that await detailed description, illustration, and formal binomial designation. The listing given below and in Tables I–III is weighted towards the formally named species but also denotes some of the more distinctive and/or commonly occurring types that require detailed systematic appraisal; illustrations together with brief morphological explanations of some of these latter are provided in Figs 3–9. Quantitative attributes of the palynofloras are given in Table IV.

Assemblages obtained from the Dundee Island and Cape Longing samples are poorly preserved and the palynomorph walls are brown to black indicating thermal alteration indices of 3.0+ on the Staplin (1982) scale; palaeotemperatures in excess of 170°C are implied. Because many of the forms could not be identified confidently at generic or specific level the sum of records provided in Tables I–III should not be taken as indicative of the palynofloral diversity level. Moreover, quantitative assessments were not attempted because of the poor preservation.

Amongst the palynomorph taxa identified and recorded herein, nine are possibly of bryophytic affinity, 10 lycophytic, 43 filicean, 20 gymnospermous, 34 angiospermous, 80 dinophycean and nine chlorophycean/prasinophycean; additionally there are several unclassified fungal microfossils. The taxa are arranged below, in alphabetical order, within those broad phyletic groupings. The figure numbers/letters within parentheses refer to illustrations in the present paper.

BRYOPHYTIC SPORES
    Coptospora paradoxa (Cookson and Dettmann) Dettmann 1963
    Foraminisporis dailyi (Cookson and Dettmann) Dettmann 1963 (Fig. 4g)
    Interlobites intraverrucatus (Brenner) Paden Phillips and Felix 1971
    Rogalskaisporites cicatricosus Rogalska ex Danzé-Corsin and Laveine 1963
    Staplinisporites caminus (Balme) Pocock 1962
    Stereisporites antiquasporites (Wilson and Webster) Dettmann 1963
    Stereisporites viriosus Dettmann and Playford 1968
    Stoverisporites microverrucatus Burger 1976 (Fig. 3i)
    Triporoletes reticulatus (Pocock) Playford 1971

Lycophytic spores

Camarozonosporites ambigens (Fradkina) Playford 1971
Ceratosporites equalis Cookson and Dettmann 1958
Coronatispora perforata Dettmann 1963
Densoisporites velatus Weyland and Krieger 1953 (Fig. 4h)
Herkosporites elliottii Stover 1973 (Fig. 3c)
Leptolepidites verrucatus Couper 1953
Neoraistrickia truncata (Cookson) Potonié 1956
Perotrilites laceratus (Norris) Dettmann comb. nov. Basionym: *Kraeuselisporites laceratus* Norris 1968
(p. 322; figs 52–56). Junior synonym: *Kraeuselisporites jubatus* Dettmann and Playford 1968 (p. 81; pl.
7, figs 8–12)
Retitriletes austroclavatidites (Cookson) Döring, Krutzsch, Mai, and Schulz 1963 (Fig. 3h)
Sestrosporites pseudoalveolatus (Couper) Dettmann 1963

cean spores

Appendicisporites cf. *insignis* (Markova) Chlonova 1976 (Fig. 3l)
Baculatisporites comaumensis (Cookson) Potonié 1956
Biretisporites sp. A (Fig. 3b)
Cicatricosisporites australiensis (Cookson) Potonié 1956
Cicatricosisporites hughesii Dettmann 1963
Cicatricosisporites ludbrookiae Dettmann 1963
Cicatricosisporites sp. A (Fig. 3m)
Contignisporites cooksoniae (Balme) Dettmann 1963
Contignisporites fornicatus Dettmann 1963
Contignisporites multimuratus Dettmann 1963
Crybelosporites striatus (Cookson and Dettmann) Dettmann 1963
Crybelosporites cf. *striatus* (Cookson and Dettmann) Dettmann 1963 (Fig. 4k)
Crybelosporites stylosus Dettmann 1963 (Fig. 4j)
Cyatheacidites annulatus Cookson ex Potonié 1956 (Fig. 4h)
Cyatheacidites archangelskii Dettmann 1986 (Fig. 4i)
Cyatheacidites botuliformis Dettmann 1986
Cyathidites asper (Bolkhovitina) Dettmann 1963
Cyathidites australis Couper 1953
Cyathidites minor Couper 1953
Cyathidites punctatus (Delcourt and Sprumont) Delcourt, Dettmann, and Hughes 1963
Cyathidites sp. A (Fig. 3a)
Dictyotosporites speciosus Cookson and Dettmann 1958 (Fig. 3j)
Foveogleicheniidites confossus (Hedlund) Burger 1976 (Fig. 4a)
Gleicheniidites circinidites (Cookson) Dettmann 1963
Gleicheniidites sp. A (Fig. 4e)
Ischyosporites punctatus Cookson and Dettmann 1958
Ischyosporites volkheimeri Filatoff 1975 (Fig. 4d)
Klukisporites scaberis (Cookson and Dettmann) Dettmann 1963
Klukisporites sp. A (Fig. 3k)
Laevigatosporites major (Cookson) Krutzsch 1959 (Fig. 4a)
Laevigatosporites ovatus Wilson and Webster 1946
Matonisporites cooksoniae Dettmann 1963
Microfoveolatosporis canaliculatus Dettmann 1963 (Fig. 4n)
Nodosisporites cf. *crenimurus* (Srivastava) Davies 1986 (Fig. 3n)
Ornamentifera sp. A (Fig. 4b)
Osmundacidites spp.
Polypodiaceoisporites elegans Archangelsky and Gamerro 1966 (Fig. 4c)
Polypodiisporites spp.
Rugulatisporites mallatus Stover 1973 (Fig. 3f, g)
Rugulatisporites neuquensis Volkheimer 1972 (Fig. 3d)
' *Rugulatisporites* ' sp. A (Fig. 3e)
Trilites tuberculiformis Cookson 1947 (Fig. 4f)
Trilites spp.

GYMNOSPERMOUS POLLEN

Alisporites grandis (Cookson) Dettmann 1963 (Fig. 5g)
Alisporites similis (Balme) Dettmann 1963
Araucariacites australis Cookson 1947 (Fig. 4o)
Balmeiopsis limbatus (Balme) Archangelsky 1977 (Fig. 4l)
Callialasporites dampieri (Balme) Dev 1961
Callialasporites trilobatus (Balme) Dev 1961 (Fig. 4h)
Classopollis chateaunovii Reyre 1970
Classopollis sp.
Cycadopites nitidus (Balme) de Jersey 1964
Cyclusphaera radiata Archangelsky 1983 (Fig. 4q)
Dacrycarpites australiensis Cookson and Pike 1953 (Fig. 5a)
Lygistepollenites balmei (Cookson) Stover and Evans 1973
Lygistepollenites florinii (Cookson and Pike) Stover and Evans 1973
Microcachryidites antarcticus Cookson 1947 (Fig. 5b)
Phyllocladidites mawsonii Cookson ex Couper 1953 (Fig. 5d)
Podocarpidites ellipticus Cookson 1947
?Rugubivesiculites sp. A (Fig. 5e, f)
Trichotomosulcites subgranulatus Couper 1953 (Fig. 4s)
Trichotomosulcites sp. A (Fig. 5c)
Vitreisporites pallidus (Reissinger) Nilsson 1958

ANGIOSPERMOUS POLLEN

Asteropollis asteroides Hedlund and Norris 1968
Clavatipollenites hughesii Couper 1958 (Fig. 5i)
Cranwellipollis palisadus (Couper) Martin and Harris 1974 (Fig. 5w)
Cranwellipollis subpalisadus (Couper) Martin and Harris 1974
Cranwellipollis sp. 1 of Truswell 1983
Liliacidites cf. *kaitangataensis* Couper 1953
Myrtaceidites eugeniioides Cookson and Pike 1953 (Fig. 5p)
Nothofagidites asperus (Cookson) Romero 1973 (Fig. 6h)
Nothofagidites lachlaniae (Couper) Pocknall and Mildenhall 1984 (Fig. 6j)
Nothofagidites cf. *nanus* Romero 1977 (Fig. 6l)
Nothofagidites senectus Dettmann and Playford 1968 (Fig. 6i)
Nothofagidites spp.
Nyssapollenites sp. A (Fig. 5o)
Periporopollenites sp. A (Fig. 6d)
Phimopollenites pannosus (Dettmann and Playford) Dettmann 1973
Propylipollis cf. *annularis* (Cookson) Martin and Harris 1974 (Fig. 6a)
Propylipollis sp. A (Fig. 6c)
Proteacidites retiformis Couper 1960 (Fig. 6b)
Proteacidites subscabratus Couper 1960 (Fig. 5r)
Retistephanocolporites sp. A (Fig. 6e)
Rousea georgensis (Brenner) Dettmann 1973
Simpsonipollis sp. A (Fig. 5s)
Tricolpites gillii Cookson 1956 (Fig. 5k)
Tricolpites waiparaensis Couper 1960 (Fig. 5n)
Tricolpites sp. A (Fig. 5l)
Tricolpites sp. 4 of Truswell 1983 (Fig. 5m)
Tricolpites spp.
Tricolporites lilliei (Couper) Stover and Evans 1973 (Fig. 5v)
Tricolporites cf. *lilliei* (Couper) Stover and Evans 1973 (Fig. 5u)
Tricolporites sp. A (Fig. 5j)
Triporopollenites sp. A (Fig. 5t)
Triporopollenites sp. B (Fig. 6g)
Triporopollenites sp. 3 of Truswell 1983 (Fig. 6f)
Triorites minor Couper 1953 (Fig. 5q)

DINOFLAGELLATE CYSTS

Nomenclature follows Lentin and Williams (1985) with modifications after Helby (1987).

Adnatosphaeridium filiferum (Cookson and Eisenack) Williams and Downie 1969 (Fig. 8h)

Ascodinium acrophorum Cookson and Eisenack 1960 (Fig. 8l)

Ascodinium ovale Cookson and Eisenack 1970 (Fig. 8m)

Ascodinium serratum Cookson and Eisenack 1960

Batiacasphaera scrobiculata (Deflandre and Cookson) Burger 1980

Batioladinium jaegeri (Alberti) Brideaux 1975 (Fig. 7a)

Batioladinium micropodum (Eisenack and Cookson) Brideaux 1975

Callaiosphaeridium asymmetricum (Deflandre and Courteville) Davey and Williams 1966 (Fig. 8e)

Canningia sp. A of Morgan 1980

Canninginopsis denticulata Cookson and Eisenack 1962

Canninginopsis intermedia Morgan 1980 (Fig. 8a)

Chatangiella cf. *campbellensis* (Wilson) Lentin and Williams 1976 (Fig. 9c)

Chatangiella serratula (Cookson and Eisenack) Lentin and Williams 1976 (Fig. 9g)

Chatangiella tripartita (Cookson and Eisenack) Lentin and Williams 1976 (Fig. 9f)

Chichaouadinium boydii (Morgan) Bujak and Davies 1983 (Fig. 9k)

Chlamydophorella cf. *discreta* Clarke and Verdier 1967

Chlamydophorella nyei Cookson and Eisenack 1958

Circulodinium colliveri (Cookson and Eisenack) Helby 1986

Cleistosphaeridium ancoriferum (Cookson and Eisenack) Davey, Downie, Sarjeant, and Williams 1966 (Fig. 7j)

Cleistosphaeridium armatum (Deflandre) Davey 1969

Coronifera oceanica Cookson and Eisenack 1958

Coronifera striolata (Deflandre) Stover and Evitt 1978

Cribroperidium edwardsii (Cookson and Eisenack) Davey 1969

Cribroperidium orthoceras (Eisenack) Davey 1969

Cribroperidinium perforans (Cookson and Eisenack) Morgan 1980

Cribroperidinium sp. A (Fig. 8b)

Cyclonephelium compactum Deflandre and Cookson 1955

Cyclonephelium distinctum Deflandre and Cookson 1955

Cyclonephelium hystrix (Eisenack) Davey 1978

Diconodinium cristatum Cookson and Eisenack 1974 (Fig. 9m)

Diconodinium paucigranulatum Burger 1980

Diconodinium cf. *pelliferum* (Cookson and Eisenack) Eisenack and Cookson 1960 (Fig. 9l)

Diconodinium pusillum Singh 1971

Dingodinium cerviculum Cookson and Eisenack 1958

Dinogynium nelsonense (Cookson) Evitt, Clarke, and Verdier 1967

Disphaera macropyla Cookson and Eisenack 1960

Heterosphaeridium heteracanthum (Deflandre and Cookson) Eisenack and Kjellström 1971 (Fig. 8d)

Heterosphaeridium sp.

Isabelidinium cf. *bakeri* (Deflandre and Cookson) Lentin and Williams 1977 (Fig. 9a)

Isabelidinium cretaceum (Cookson) Lentin and Williams 1977 (Fig. 9d)

Isabelidinium pellucidum (Deflandre and Cookson) Lentin and Williams 1977 (Fig. 9b)

Kiokansium polypes (Cookson and Eisenack) Below 1982

Laciniadinium tenuistriatum (Eisenack and Cookson) Morgan 1977 (Fig. 9j)

Leberidocysta chlamydata (Cookson and Eisenack) Stover and Evitt 1978 (Fig. 8f)

Leptodinium ambiguum (Deflandre) Helenes 1984

Maduradinum pentagonum Cookson and Eisenack 1970 (Fig. 9i)

Maduradinium sp.

Manumiella lata (Cookson and Eisenack) Bujak and Davies 1983 (Fig. 9e)

Microdinium ornatum Cookson and Eisenack 1960

Muderongia cf. *staurota* Sarjeant 1966 (Fig. 7b)

Muderongia tetracantha (Gocht) Alberti 1961 (Fig. 7c)

Nelsoniella aceras Cookson and Eisenack 1960

Nelsoniella tuberculata Cookson and Eisenack 1960 (Fig. 9h)

Odontochitina costata Alberti 1961

Odontochitina operculata (Wetzel) Deflandre and Cookson 1955 (Fig. 7e)

Odontochitina porifera Cookson 1956 (Fig. 7f)

Odontochitina singhii Morgan 1980

Odontochitina sp. A (Fig. 7d)
Oligosphaeridium complex (White) Davey and Williams 1966
Oligosphaeridium pulcherrimum (Deflandre and Cookson) Davey and Williams 1966
Omatia montgomeryi Cookson and Eisenack 1958 (Fig. 7k)
Operculodinium sp.
Palaeocystodinium granulatum (Wilson) Lentin and Williams 1976 (Fig. 8i)
Palaeohystrichophora infusorioides Deflandre 1935 (Fig. 8n)
Palaeoperidinium cretaceum Pocock 1962
Prolixosphaeridum conulum Davey 1969
Pseudoceratium exquisitum (Morgan) Helby 1987
Pseudoceratium ludbrookiae (Cookson and Eisenack) Eisenack 1961 (Fig. 7i)
Pseudoceratium turneri Cookson and Eisenack 1958
Pseudoceratium sp. A (Fig. 7h)
Pterodinium cingulatum (Wetzel) Below 1981
Rhiptocorys veligera (Deflandre) Lejeune-Carpentier and Sarjeant 1983
Scriniodinium ceratophorum Cookson and Eisenack 1960
Scriniodinium crystallinum (Deflandre) Klement 1960 (Fig. 8c)
Spinidinium cf. *echinoideum* (Cookson and Eisenack) Lentin and Williams 1976 (Fig. 8o)
Spinidinium cf. *lanterna* Cookson and Eisenack 1970
Spiniferites ramosus (Ehrenberg) Loeblich and Loeblich 1966
?*Stephodinium* sp. A (Fig. 8g)
Xenascus australensis Cookson and Eisenack 1969 (Fig. 7g)
Xenikoon australis Cookson and Eisenack 1960 (Fig. 8j, k)

PRASINOPHYCEAN/CHLOROPHYCEAN MICROFOSSILS
Botryococcus spp.
Crassosphaera sp.
Dictyodinium sp. (Fig. 6n)
Horologinella apiculata Cookson and Eisenack 1962
Leiosphaeridiae spp.
Palambages Form A Manum and Cookson 1964 (Fig. 6m)
Paralecaniella indentata (Deflandre and Cookson) Cookson and Eisenack 1970
Pterospermella australiense (Deflandre and Cookson) Eisenack 1972 (Fig. 6o)
Veryhachium spp.

FUNGAL MICROFOSSILS
Hyphae and fruiting bodies

PREPARATION METHODS AND REPOSITORY OF PALYNOMORPHS

Palynological sample processing followed techniques outlined by Phipps and Playford (1984). Dissolution of carbonates with dilute hydrochloric acid was followed by silicate removal using warm 50% hydrofluoric acid. Oxidation was with warm nitric acid or Schulze solution for 2–3 minutes and soluble humic acids were then removed with weak (1–2%) potassium or ammonium hydroxide. Residues were mounted in glycerine jelly (lightly stained with Safranin O) under no. O coverslips for examination in transmitted light. Photographic documentation was with Ilford Pan F or Kodak Panatomic X film.

All illustrated specimens are housed in the micropalaeontological collection of the British Museum (Natural History).

A register of illustrated specimens is available from the authors.

REFERENCES

ARCHANGELSKY, S., BALDONI, A., GAMERRO, J. C., PALAMARCZUK, S. *and* SEILER, J. 1981. Palinológia estratigráfica del Cretácico de Argentina Austral. Diagramas del grupos polinicos de suroeste de Chubut y noroeste de Santa Cruz. *Actas VIII Congreso Geológico Argentino, San Luis 1981*, 719–42.

ARCHANGELSKY, S. *and* ROMERO, E. J. 1974a. Los registros mas antiguos del polen de *Nothofagus* (Fagaceae) de Patagonia (Argentina y Chile). *Boletin Societe Mexicana de Botanie*, **33**, 13–30.

ARCHANGELSKY, S. *and* ROMERO, E. J. 1974b. Polen de gimnospermas (coniferas) del Cretácico superior y Paleoceno de Patagonia. *Ameghiniana*, **11**, 217–36.

ASKIN, R. A. 1981. Jurassic–Cretaceous palynology of Byers Peninsula, Livingston Island, Antarctica. *Antarctic Journal of the United States*, **16**, Pt. 5, 11–13.

ASKIN, R. A. 1983a. Tithonian (uppermost Jurassic)–Barremian (Lower Cretaceous) spores, pollen and microplankton from the South Shetland Islands, Antarctica. (*In* OLIVER, R. L., JAMES, P. R. *and* JAGO, J. B. eds. *Antarctic earth science*. Canberra, Australian Academy of Science, and Cambridge, Cambridge University Press, 295–7.)

ASKIN, R. A. 1983b. Campanian palynomorphs from James Ross and Vega Islands, Antarctic Peninsula. *Antarctic Journal of the United States*, **18**, Pt. 5, 63–5.

ASKIN, R. A. 1984. Palynological investigations of the James Ross Island basin and Robertson Island, Antarctic Peninsula. *Antarctic Journal of the United States*, **19**, Pt. 5, 6–7.

ASKIN, R. A. 1985. Palynological studies in the James Ross Island basin, Antarctic Peninsula: a progress report. *Antarctic Journal of the United States*, **20**, Pt. 5, 44–5.

ASKIN, R. A. In press. Campanian to Paleocene palynological succession of Seymour and adjacent islands, northeastern Antarctic Peninsula. (*In* FELDMAN, R. M. *and* WOODBURNE, M. O. eds. *Geology and paleontology of Seymour Island, Antarctic Peninsula. Geological Society of America Memoir*.)

ASKIN, R. A. *and* FLEMING, R. F. 1982. Palynological investigations of Campanian to lower Oligocene sediments on Seymour Island, Antarctic Peninsula. *Antarctic Journal of the United States*, **17**, Pt. 5, 70–1.

BAIR, J. *and* HART, G. F. 1984. Palynology of some Lower Cretaceous sediments from the Malvinas area, South Atlantic. (*In* PERRILLIAT, M. DE C. ed. *Memoria, III congreso Latinoamericano de Paleontologia, México, 1984*. México City, Universidad Nacional Autonoma de México, Instituto de Geológia, 280–8.)

BALME, B. E. 1964. The palynological record of Australian pre-Tertiary floras. (*In Ancient Pacific floras*. Honolulu, University of Hawaii Press, 49–80.)

BARKER, P. F., DALZIEL, I. W. D. *and others*. 1976. *Initial Reports of the Deep Sea Drilling Project*, **76**, Washington, United States Government Printing Office. 1080 pp.

BIBBY, J. S. 1966. The stratigraphy of part of north-east Graham Land and James Ross Island. *British Antarctic Survey Scientific Reports*, No. 53, 37 pp.

BOLLI, H. M., RYAN, W. B. F. *and others*. 1978. *Initial Reports of the Deep Sea Drilling Project*, **40**, Washington, United States Government Printing Office. 1079 pp.

BURGER, D. 1980. Palynology of the Lower Cretaceous in the Surat Basin. *Bulletin Bureau of Mineral Resources, Geology and Geophysics, Australia*, No. 189, 106 pp.

BURGER, D. 1982. A basal Cretaceous dinoflagellate suite from northeastern Australia. *Palynology*, **6**, 161–92.

COOKSON, I. C. *and* EISENACK, A. 1958. Microplankton from Australian and New Guinea Upper Mesozoic sediments. *Proceedings of the Royal Society of Victoria*, **70**, 19–79.

COUPER, R. A. 1953. Upper Mesozoic and Cainozoic spores and pollen grains from New Zealand. *Palaeontological Bulletin New Zealand Geological Survey*, No. 22, 77 pp.

COUPER, R. A. 1960. New Zealand Mesozoic and Cainozoic plant microfossils. *Palaeontological Bulletin New Zealand Geological Survey*, No. 32, 87 pp.

CRAME, J. A. 1980. The occurrence of the bivalve *Inoceramus concentricus* on Dundee Island, Joinville Island group. *British Antarctic Survey Bulletin*, No. 49 (for 1979), 283–6.

CRAME, J. A. 1981. Upper Cretaceous inoceramids (Bivalvia) from the James Ross Island group and their stratigraphical significance. *British Antarctic Survey Bulletin*, No. 53, 29–56.

CRAME, J. A. 1983a. Lower Cretaceous bivalve stratigraphy of Antarctica. *Zitelliana*, **10**, 399–406.

CRAME, J. A. 1983b. Cretaceous inoceramid bivalves from Antarctica. (*In* OLIVER, R. L., JAMES, P. R. *and* JAGO, J. G. *eds. Antarctic earth science*. Canberra, Australian Academy of Science and Cambridge, Cambridge University Press, 298–302.)

CRAME, J. A. 1984. Preliminary bivalve zonation of the Jurassic–Cretaceous boundary in Antarctica. (*In* PERRILLIAT, M. DE C. *ed. Memoria, III Congreso Latinoamericano de Paleontologia, México, 1984*. México City, Universidad Nacional Autonoma de México, Instituto de Geológia, 242–52.)

CRAME, J. A. 1985. Lower Cretaceous inoceramid bivalves from the Antarctic Peninsula region. *Palaeontology*, **28**, 475–525.

CRAME, J. A. 1987. Late Mesozoic bivalve biogeography of Antarctica. (*In* McKENZIE, G. D. *ed. Gondwana six: stratigraphy, sedimentology, and paleontology*. Washington D.C., American Geophysical Union. Monograph No. 41, 93–102.)

CRANWELL, L. M. 1959. Fossil pollen from Seymour Island, Antarctica. *Nature, London*, **184**, 1782–5.

CRANWELL, L. M. 1964. Antarctica: cradle or grave for its *Nothofagus*? (*In Ancient Pacific floras*, Honolulu, University of Hawaii Press, 87–93.)

CRANWELL, L. M. 1969. Antarctica and circum-Antarctic palynological contributions. *Antarctic Journal of the United States*, **4**, 197–8.

DAVEY, R. J. 1978. Marine Cretaceous palynology of Site 361, DSDP Leg 40 off southwestern Africa. (*In* BOLI, H. M., Ryan, W. B. F. *and others. Initial Reports of the Deep Sea Drilling Project*, **40**. United States Government Printing Office, Washington, 883–913.)

DEL VALLE, R. A. *and* MEDINA, A. F. 1980. Nuevos invertebrados fósiles de Cabo Lamb (Isla Vega) y Cabo Morro (Isla James Ross). *Contribuciones científicas del Instituto Antártico Argentino*, **3**, No. 228, 51–67.

DETTMANN, M. E. 1963. Upper Mesozoic microfloras from south-eastern Australia. *Proceedings of the Royal Society of Victoria*, **77**, 1–148.

DETTMANN, M. E. 1981. The Cretaceous flora. (*In* KEAST, A. *ed. Ecological biogeography of Australia*. The Hague. Junk, 357–75.)

DETTMANN, M. E. 1986a. Early Cretaceous palynoflora of subsurface strata correlative with the Koonwarra Fossil Bed, Australia. *Memoir Association Australasian Palaeontologists*, **3**, 79–110.

DETTMANN, M. E. 1986b. Significance of the spore genus *Cyatheacidites* in tracing the origin and migration of *Lophosoria* (Filicopsida). *Special Papers in Palaeontology*, No. 35, 63–94.

DETTMANN, M. E. *and* PLAYFORD, G. 1968. Taxonomy of some Cretaceous spores and pollen grains from eastern Australia. *Proceedings of the Royal Society of Victoria*, **81**, 69–93.

DETTMANN, M. E. *and* PLAYFORD, G. 1969. Palynology of the Australian Cretaceous: a review. (*In* CAMPBELL, K. S. W. *ed. Stratigraphy and palaeontology. Essays in honour of Dorothy Hill*. Canberra, Australian National University Press, 174–210.)

DE WIT, M. J. 1977. The evolution of the Scotia Arc as a key to the reconstruction of Gondwanaland. *Tectonophysics*, **37**, 35–81.

DOMACK, E. W., FAIRCHILD, W. W. *and* ANDERSON, J. B. 1980. Lower Cretaceous sediment from the East Antarctic continental shelf. *Nature, London*, **287**, 625–6.

DOUBINGER, J. 1975. Grains de pollen de *Nothofagus* du Crétacé–Tertiare du Chili. *Comptes Rendus du 100 Congrès National des Sociétés Savantes, Paris, 1975*. Fascicule II, 59–62.

DOYLE, P. 1987. The Cretaceous Dimitobelidae (Belemnitidae) of the Antarctic Peninsula region. *Palaeontology*, **30**, 147–77.

EVITT, W. R. 1985. *Sporopollenin dinoflagellate cysts. Their morphology and interpretation*. Texas, American Association of Stratigraphic Palynologists, Harts Graphics. 333 pp.

FARQUHARSON, G. W. 1982. Late Mesozoic sedimentation in the northern Antarctic Peninsula and its relationship to the southern Andes. *Journal of the Geological Society of London*, **139**, 721–8.

FARQUHARSON, G. W., HAMER, R. D. *and* INESON, J. R. 1984. Proximal volcaniclastic sedimentation in a Cretaceous back-arc basin, northern Antarctic Peninsula. (*In* KOKELAAR, B. P. *and* HOWELLS, M. F. *eds. Marginal basin geology. Geological Society of London Special Publication*, No. 16, Oxford, Blackwell Scientific Publications, 219–29.)

FRAKES, L. A., BURGER, D., *and others*. Australian Cretaceous shorelines, stage by stage. *Palaeogeography, Palaeoclimatology, Palaeoecology*. **59**, 31–48.

HAIG, D. W. 1979. Cretaceous foraminiferal biostratigraphy of Queensland. *Alcheringa*, **3**, 171–87.

HALL, S. A. 1977. Cretaceous and Tertiary dinoflagellates from Seymour Island, Antarctica. *Nature, London*, **267**, 239–41.

HARLAND, W. B., COX, A. V., LLEWELLYN, P. G., PICTON, C. A. G., SMITH, A. G. *and* WALTERS, A. 1982. *A geological time scale*. Cambridge, Cambridge University Press. 131 pp.

HARRIS, W. K. 1977. Palynology of cores from Deep Sea Drilling Sites 327, 328, and 330, South Atlantic Ocean. (*In* BARKER, P. F., DALZIEL, I. W. D. *and others. Initial Reports Deep Sea Drilling Project*. **36**. Washington, United States Government Printing Office, 761–815.)

HEDLUND, R. W. *and* BEJU, D. 1977. Stratigraphic palynology of selected Mesozoic samples DSDP Hole 327A and Site 330. (*In* BARKER, P. F., DALZIEL, I. W. D. *and others. Initial Reports Deep Sea Drilling Project*, **36**. Washington, United States Government Printing Office, 817–27.)

HEKEL, H. 1972. Pollen and spore assemblages from Queensland Tertiary sediments. *Geological Survey of Queensland Publication* No. 355, 31 pp.

HELBY, R. J. 1987. *Muderongia* Cookson and Eisenach emend. Stover and Evitt and related genera in the Late Jurassic–Early Cretaceous of Australia. *Memoir Association Australasian Palaeontologists*, **4**.

HELBY, R. J., MORGAN, R. *and* PARTRIDGE, A. D. 1987. A palynological zonation of the Australian Mesozoic. *Memoir Association Australasian Palaeontologists*, **4**, 1–93.

HERNÁNDES, T. *and* AZCÁRATE, V. 1971. Estudio paleobotánico preliminar sobre restos de una tafoflora de las Península Byers (Cerro Negro), Isla Livingston, Islas Shetland del Sur, Antártica. *Serie científica Instituto antártico chileno*, **2**, 15–50.

HOWARTH, M. K. 1958. Upper Jurassic and Cretaceous ammonite faunas of Alexander Land and Graham Land. *Falkland Islands Dependencies Survey Scientific Reports*, No. 21, 16 pp.

HOWARTH, M. K. 1966. Ammonites from the Upper Cretaceous of the James Ross Island group. *British Antarctic Survey Bulletin*, No. 10, 55–69.

INESON, J. R. 1985. Submarine glide blocks from the Lower Cretaceous of the Antarctic Peninsula. *Sedimentology*, **32**, 659–70.

INESON, J. R., CRAME, J. A. *and* THOMSON, M. R. A. 1986. Lithostratigraphy of the Cretaceous strata of west James Ross Island, Antarctica. *Cretaceous Research*, **7**, 141–59.

IOANNIDES, N. S. *and* COLIN, J. P. 1977. Palynology of Sites 358, 356, 355, DSDP, Leg 39, southwestern Atlantic Ocean. (*In* SUPKO, P. R., PERCH-NIELSEN, K. *and others. Initial Reports of the Deep Sea Drilling Project*, **39**. Washington, United States Government Printing Office, 885–97.)

JEFFERSON, T. H. 1983. Palaeoclimatic significance of some Mesozoic Antarctic fossil floras (*In* OLIVER, R. L., JAMES, P. R. *and* JAGO, J. B. *eds. Antarctic earth science*. Canberra, Australian Academy of Science and Cambridge, Cambridge University Press, 593–8.)

KEMP, E. M. 1978. Tertiary climatic evolution and vegetation history in the southeast Indian Ocean region. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **24**, 169–208.

KENNEDY, W. J. 1971. Cenomanian ammonites from southern England. *Special Papers in Palaeontology*, No. 8, 133 pp.

KENNEDY, W. J. *and* KLINGER, H. C. 1979. Cretaceous faunas from Zululand and Natal, South Africa. The ammonite family Gaudryceratidae. *Bulletin of the British Museum (Natural History), Geology Series*, **31**, 121–74.

KOTOVA, I. Z. 1983. Palynological study of Upper Jurassic and Lower Cretaceous sediments, Site 511, Deep Sea Drilling Project Leg 71 (Falkland Plateau). (*In* LUDWIG, W. J., KRASHENINNIKOV, V. A. *and others. Initial Reports of the Deep Sea Drilling Project*, **71**, Washington, United States Government Printing Office, 879–906.)

LENTIN, J. K. 1976. Provincialism in Upper Cretaceous fossil peridinioids. *Abstracts, Joint Meeting American Association of Stratigraphic Palynologists and Commission Internationale de Microflore du Paléozoique, Halifax 1976*, **14**.

LENTIN, J. K. *and* WILLIAMS, G. L. 1980. Dinoflagellate provincialism with emphasis on Campanian Peridiniaceans. *American Association of Stratigraphic Palynologists, Contributions Series*, **7**, 46 pp.

LENTIN, J. K. *and* WILLIAMS, G. L. 1985. Fossil dinoflagellates. Index to genera and species. *Canadian Technical Report of Hydrography and Ocean Resources*, **60**, 451 pp.

LUDWIG, W. J., KRASHENINNIKOV, V. A. *and others*. 1983. *Initial Reports of the Deep Sea Drilling Project*, **71**, Washington, United States Government Printing Office. 1185 pp.

McLachlan, I. R. *and* Pieterse, R. E. 1978. Preliminary palynological results. Site 361 Leg 40, Deep Sea Drilling Project. (*In* Bolli, H., Ryan, W. B. F. *and others. Initial Reports of the Deep Sea Drilling Project*, **40**. Washington, United States Government Printing Office, 857–81.

Macellari, C. E. 1985. Paleogeografia y edad de la fauna de *Maorites-Gunnarites* (Ammonoidea) de la Antártida y Patagonia. *Ameghiniana*, **21**, Nos 2–4, 223–42.

Macellari, C. E. 1986. Late Campanian–Maastrichtian ammonite fauna from Seymour Island (Antarctic Peninsula). *Journal of Paleontology*, **60**, Supplement to No. 2, 55 pp. [The Paleontological Society Memoir No. 18.]

Medina, F. A., Rinaldi, C. A., Del Valle, R. A. *and* Baldoni, A. M. 1983. Edad de la Formación Lower Kotick Point en la Isla James Ross, Antártida. *Ameghiniana*, **19**, 263–72.

Menendez, C. A. 1965. Microplancton fósil de sedimentos Terciarios y Cretácicos del norde de Tierra del Fuego (Argentina). *Ameghiniana*, **4**, 7–18.

Menendez, C. A. *and* Caccavari, De Filice, M. A. 1975. Las especies de *Nothofagidites* (polen fosil de *Nothofagus*) de sedimentos Tertiarios y Cretácicos de Estancia la Sara, norte de Tierra del Fuego, Argentina. *Ameghiniana*, **12**, 165–83.

Morgan, R. 1977. Elucidation of the Cretaceous dinoflagellate *Diconodinium* Eisenack and Cookson, 1960, and related peridinioid species from Australia. *Palynology*, **1**, 123–38.

Morgan, R. 1980. Palynostratigraphy of the Australian Early and middle Cretaceous. *Memoirs of the Geological Survey of New South Wales, Palaeontology*, No. 18, 153 pp.

Muller, J. 1981. Fossil pollen records of extant angiosperms. *Botanical Review*, **47**, 1–142.

Norris, G. 1968. Plant microfossils from the Hawks Crag Breccia, southwest Nelson, New Zealand. *New Zealand Journal of Geology and Geophysics*, **11**, 312–44.

Palamarczuk, S., Ambrosini, G., Villar, H., Medina, F., Martinez Macchiavello, J. C. *and* Rinaldi, C. 1984. Las formaciones Lopez de Bertodano y Sobral en la Isla Vicecomodoro Marambio, Antartida. (*In* Bariloche, S. C. *ed.* Actas, IX Congreso Geológica Argentino, 399–419).

Phipps, D. *and* Playford, G. 1984. Laboratory techniques for extraction of palynomorphs from sediments. *Papers of the Department of Geology, University of Queensland*, No. 11, 1–23.

Playford, G. *and* Dettmann, M. E. 1978. Pollen of *Dacrydium franklinii* Hook. f. and comparable early Tertiary microfossils. *Pollen et Spores*, **20**, 513–34.

Pöthe de Baldis, E. D. 1966. Microplancton del Terciario de Tierra del Fuego. *Ameghiniana*, **4**, 219–28.

Proto Decima, F., Medizza, F. *and* Todesco, L. 1978. Southeastern Atlantic Leg 40 calcareous nannofossils. (*In* Bolli, H. M., Ryan, W. B. F. *and others. Initial Reports of the Deep Sea Drilling Project*, **40**. Washington, United States Government Printing Office, 571–634.)

Raine, J. I. 1984. Outline of a palynological zonation of Cretaceous to Paleogene terrestrial sediments in west coast region, South Island, New Zealand. *Reports of the New Zealand Geological Survey*, **109**, 82 pp.

Raine, J. I., Speden, I. G. *and* Strong, C. P. 1981. New Zealand. (*In* Reyment, P. A. *and* Bengtson, P. *ed. Aspects of mid-Cretaceous regional geology*, London, Academic Press, 221–67.)

Romero, E. 1973. Polen fósil de *Nothofagus* (*Nothofagidites*) del Cretácico y Paleoceno de Patagonia. *Revista del Museo de La Plata, N.S. Paleontología*, **47**, 291–303.

Smith, A. G. *and* Briden, J. C. 1977. *Mesozoic and Cenozoic paleocontinental maps*. Cambridge, Cambridge University Press, 63 pp.

Smith, A. G., Hurley, A. M. *and* Briden, J. C. 1981. *Phanerozoic paleocontinental world maps*. Cambridge, Cambridge University Press, 102 pp.

Spath, L. F. 1953. The Upper Cretaceous Cephalopod fauna of Graham Land. *Falkland Islands Dependencies Survey Scientific Reports*, No. 3, 60 pp.

Staplin, F. L. 1982. Determination of thermal alteration index from color of exinite (pollen spores). *Society of Economic Paleontologists and Mineralogists, Short Course*, No. 7, 7–9.

Stover, L. E. 1973. Palaeocene and Eocene species of *Deflandrea* (Dinophyceae) in Victorian coastal and offshore basins, Australia. (*In* Glover, J. E. *and* Playford, G. *ed. Mesozoic and Cainozoic palynology: essays in honour of Isabel Cookson*, 167–88, Special Publications, Geological Society of Australia, **4**.)

Stover, L. E. *and* Evans, P. R. 1973. Upper Cretaceous–Eocene spore-pollen zonation, offshore Gippsland Basin, Australia. (*In* Glover, J. E. *and* Playford, G. *ed. Mesozoic and Cainozoic palynology: essays in honour of Isabel Cookson*, 55–72, Special Publications, Geological Society of Australia, **4**.)

Stover, L. E. *and* Partridge, A. D. 1973. Tertiary and Late Cretaceous spores and pollen from the Gippsland Basin, southeastern Australia. *Proceedings of the Royal Society of Victoria*, **85**, 237–86.

Takahashi, K. 1977. Upper Cretaceous palynoflora from Quiriquina Island, Chile. *Bulletin of Faculty of Liberal Arts, Nagasaki University, Natural Sciences*, **17**, 29–53.

THOMSON, M. R. A. 1974. Ammonite faunas of the Lower Cretaceous of south-eastern Alexander Island. *British Antarctic Survey Scientific Reports*, No. 80, 44 pp.

THOMSON, M. R. A. 1981. Mesozoic ammonite faunas and the break-up of Gondwana. (*In* CRESSWELL, M. M. *and* VELLA, P. *eds. Gondwana five.* Rotterdam, A. A. Balkema, 269–75.)

THOMSON, M. R. A. 1983. 'European' ammonites in the Cretaceous of Antarctica. *Zitelliana*, **10**, 407–12.

THOMSON, M. R. A. 1984a. Preliminary ammonite zonation of the mid-Cretaceous rocks of James Ross Island. *British Antarctic Survey Bulletin*, No. 64, 85–91.

THOMSON, M. R. A. 1984b. Cretaceous ammonite biostratigraphy of western James Ross Island, Antarctica. (*In* PERRILLIAT, M. DE C. *ed. Memoria, III Congreso latinamericano de Paleontología, México, 1984*, México City, Universidad Nacional Autónoma de México, 308–14.)

THOMSON, M. R. A. *and* FARQUHARSON, G. W. 1984. Discovery and significance of the ammonite genus *Favrella* in the Antarctic Peninsula area. *British Antarctic Survey Bulletin*, No. 62, 7–14.

TRONCOSO, A. *and* DOUBINGER, J. 1980. Dinoquistes (Dinophyceae) del limite Cretacico–Tertiario del pozo el Ganso No. 1 (Magallanes, Chile). *Actas II Congreso Argentino de Paleontología y Biostratigrafía y I Congreso Latinoamericano de Paleontología, Buenos Aires, 1978*, **2**, 93–125.

TRUSWELL, E. M. 1983. Recycled Cretaceous and Tertiary pollen and spores in Antarctic marine sediments: a catalogue. *Palaeontographica, Abt. B*, **186**, 121–74.

VERDIER, J. 1975. Les kystes de dinoflagellés de la section de Wissant et leur distribution stratigraphique au Crétacé Moyen. *Revue de Micropaléontologie*, **17**, 191–7.

VOLKHEIMER, W., CACCAVARI DE FILICE, M. A. *and* SEPULVEDA, E. 1977. Datos palinológicos de la Formación Ortiz (Grupo la Amarga). Cretácico inferior de la cuenca Neuqina (Republica Argentina). *Ameghiniana*, **14**, 59–74.

WILSON, G. J. 1975. Palynology of deep-sea cores from DSDP Site 275, southeast Campbell Plateau (*In* KENNETT, J. P., HOUTZ, R. E. *and others. Initial Reports of the Deep Sea Drilling Project*, **29**. Washington, United States Government Printing Office, 1031–5.)

WILSON, G. J. 1984. New Zealand Late Jurassic to Eocene dinoflagellate biostratigraphy – a summary. *Newsletters on Stratigraphy*, **13**, 104–17.

WISEMAN, J. F. 1980. Palynostratigraphy near the Jurassic–Cretaceous boundary in the Carnarvon Basin, Western Australia. *Proceedings of the IV International Palynological Conference, Lucknow, 1976*, **2**, 333–49.

WISEMAN, J. F. *and* WILLIAMS, A. J. 1974. Palynological investigation of samples from Sites 259, 261, and 263, Leg 27, Deep Sea Drilling Project (*In* ROBINSON, P. T. *and* BOLLI, H. M., *Initial Reports of the Deep Sea Drilling Project*, **27**. Washington, United States Government Printing Office, 915–24.)

WRENN, J. *and* HART, G. F. 1984. Dinocyst biostratigraphy of Tertiary deposits of Seymour Island, Antarctica (*In* PERRILLIAT, M. DE C. *ed. Memoria, III Congreso Latinamericano de Paleontología, México, 1984*. Mexico City, Universidad Nacional Autónoma de México, Instituto de Geología, 546–54.)

ZINSMEISTER, W. J. 1982. Review of the Upper Cretaceous–Lower Tertiary sequence on Seymour Island, Antarctica. *Journal of the Geological Society of London*, **139**, 779–85.