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3. PALYNOLOGY OF SITE 1166, PRYDZ BAY, EAST ANTARCTICA[1]

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ABSTRACT

Twenty-three core catcher samples from Site 1166 (Hole 1166A) in Prydz Bay were analyzed for their palynomorph content, with the aims of determining the ages of the sequence penetrated, providing information on the vegetation of the Antarctic continent at this time, and determining the environments under which deposition occurred. Dinocysts, pollen and spores, and foraminiferal test linings were recovered from most samples in the interval from 142.5 to 362.03 meters below seafloor (mbsf). The interval from 142.5 to 258.72 mbsf yielded palynomorphs indicative of a middle–late Eocene age, equivalent to the lower–middle *Nothofagidites asperus* Zone of the Gippsland Basin of southeastern Australia. The Prydz Bay sequence represents the first well-dated section of this age from East Antarctica.

Dinocysts belonging to the widespread "Transantarctic Flora" give a more confident late Eocene age for the interval 142.5–220.5 mbsf. The uppermost two cores within this interval, namely, those from 142.5 and 148.36 mbsf, show significantly higher frequencies of dinocysts than the cores below and suggest that an open marine environment prevailed at the time of deposition. The spore and pollen component may reflect a vegetation akin to the modern rainforest scrubs of Tasmania and New Zealand.

Below 267 mbsf, sparse microfloras, mainly of spores and pollen, are equated with the *Phyllocladidites mawsonii* Zone of southeastern Australia, which is of Turonian to possibly Santonian age. Fluvial to marginal marine environments of deposition are suggested. The parent vegetation from this interval is here described as "Austral Conifer Woodland." The same Late Cretaceous microflora occurs in two of the cores above the postulated unconformity at 267 mbsf. In the core at 249.42 mbsf,

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the Late Cretaceous spores and pollen are uncontaminated by any Tertiary forms, suggesting that a clast of this older material has been sampled; such a clast may reflect transport by ice during the Eocene. At 258.72 mbsf, Late Cretaceous spores and pollen appear to have been recycled into the Eocene sediments.

INTRODUCTION

Site 1166 provides a key sequence for understanding the stratigraphy of Prydz Bay and adjacent regions. It was drilled to sample the earliest Cenozoic sediments, date the onset of glaciation, and provide information on preglacial environments. Palynomorphs recovered from this site have in large part fulfilled the requirements of providing age control on the sequences penetrated. They have also allowed the best reconstruction yet attempted of the Tertiary preglacial vascular vegetation of East Antarctica. Palynomorphs were recovered from both the Tertiary and Mesozoic sections encountered at this site. They are discussed under separate headings below. Summary data for age and depositional environments and for yield and preservation of palynomorphs are presented in Tables T1 and T2. Age determinations are summarized in Table T3, vegetation and depositional environments in Table T4, and detailed species distribution in Tables T5 and T6. Preliminary palynological investigations from the site were described in two reports submitted shortly after completion of the Leg 188 drilling (M.K. Macphail and E.M. Truswell, unpubl. data). This review synthesizes, and develops, the preliminary findings.

MATERIAL AND METHODS

It was intended that Leg 188 should include a site to sample the Cenozoic section between intervals reached at Sites 739 and 742 during Ocean Drilling Program (ODP) Leg 119 (Barron, Larsen, et al., 1991), in order to investigate the glacial–preglacial transition. The original site proposed for Leg 188 was on the western side of Prydz Bay. However, persistent pack ice forced the drilling of an alternative site on the eastern side of the bay, Site 1166, which lies ~40 km southwest of Site 742 (see locality map, Fig. F1). Hole 1166A penetrated to a depth of 381.30 meters below seafloor (mbsf). Recovery from the site consisted of a series of poorly sorted sands, fine-grained sediments, and diamicton. The sediments were divided into five lithostratigraphic units (see Fig. F2, from O'Brien, Cooper, Richter, et al., 2001). Four of these, Units II–V, were sampled in the present study and found to be palynologically productive.

Briefly, from Unit II (135.63–156.45 mbsf) a glaciomarine sequence of dark gray claystones deposited during a period of marine transgression was sampled. From Unit III (156.45–276.44 mbsf) beds of possible deltaic origin, laid down in a proglacial or preglacial environment, and consisting of organic-rich silty clays were examined. Unit IV (276.44–314.91 mbsf) consists of black carbonaceous clays and laminated sandy silts and records deposition within a restricted marine or lagoonal environment. Unit V (342.80–342.96 mbsf) is represented by fragments of gray claystones with laminations and fine sandy silt. From regional seismic stratigraphic correlations, it appears to lie below a regional unconformity that can be traced to Site 741, some 110 km away.

T1. Zonal summary, p. 25.

T2. Basic sample data, p. 26.

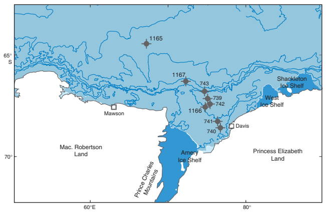
T3. Age determination, p. 27.

T4. Paleoenvironments, p. 28.

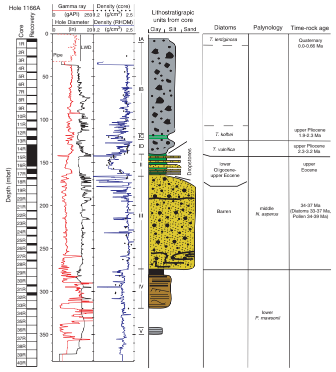
T5. Eocene plant microfossil taxa, p. 29.

T6. Late Cretaceous plant microfossil taxa, p. 32.

F1. Site 1166 and other Leg 188 sites, p. 23.



F2. Stratigraphic sequence in Hole 1166A, p. 24.



All samples were processed using standard techniques designed to recover spores, pollen, algal cysts, and other acid-resistant microfossils (Traverse, 1988). This involved removal of inorganic sands, silts, and clays using a combination of hydrofluoric acid and heavy liquid separation ($ZnBr_2$; specific gravity = 1.65) and oxidation of the more labile compounds using Schultze solution. The extracts were filtered through a 5-µm Millipore sieve cloth and mounted on microscope slides using Eukit. When possible, a minimum of 250 pollen and spores were counted using a Zeiss Photomicroscope II fitted with Planapo objectives, allowing magnifications of up to 1250× (Tables T5, T6; Plates P1, P2, P3, P4, P5, P6, P7, P8, P9, P10). The relative abundance of all identifiable plant microfossils was calculated as a percentage of the pollen and spore count excluding reworked taxa and modern contaminants.

CENOZOIC

Age Control

Relatively abundant palynomorphs were recovered from the interval 142.5–267.18 mbsf. Spores, pollen, dinocysts, and foraminiferal test linings were present in most cores examined. Age control is provided primarily by the dinocysts, which indicate an age of middle–late Eocene for the interval as a whole. Spore and pollen species provide support for this age determination. Key taxa and age determinations are listed in Table T3. There is a marked increase in abundance of dinocysts in the uppermost two cores, suggesting that there was a transition between marginal marine and open marine conditions (perhaps reflected in a flooding surface) between 148.36 and 156.99 mbsf.

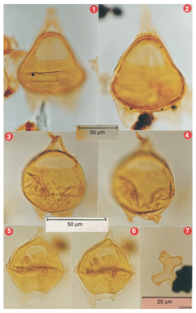
Dinocysts

Dinocysts from cores in the interval from 142.5 mbsf to a probable unconformity at ~267 mbsf can be assigned to the "Transantarctic Flora"—a flora whose major elements are restricted to high southern latitudes. This suite was named by Wrenn and Beckmann (1982), and its composition and distribution was elaborated by Wrenn and Hart (1988). It was first identified in erratics from McMurdo Sound and is now known from sites on the Antarctic Peninsula, the Ross and Weddell Seas, and the South Atlantic. Three points are important in relation to this flora: (1) the assemblage is usually of limited diversity, being based on a small number of species held in common; (2) age control on the assemblage remains imprecise because sequences from which it has been recovered are often short and there are few sites where it is associated with other fossils that provide a firm and independent age control; and (3) there is a high degree of endemism at the species level, which is particularly evident in the assemblages from the East Antarctic margin. The distribution of this dinocyst flora in time and space was recently reviewed by Truswell (1997) in connection with floras from sites south of Tasmania and by Levy and Harwood (2000) in the course of a reevaluation of the floras from glacial erratics in McMurdo Sound.

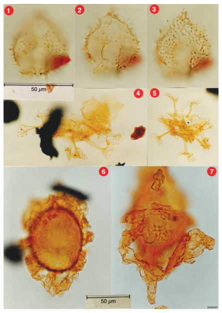
142.5–220.85 mbsf

Dinoflagellate cysts are abundant and generally well preserved in this interval; they compose 70%–80% of the total palynomorphs in cores from 142.5 and 148.36 mbsf and 6%–20% in the deeper cores (see Table

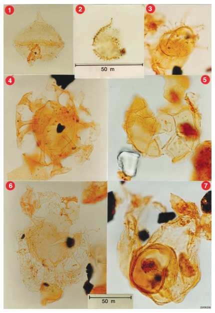
P1. *Deflandrea* and *Tritonites*, p. 34.



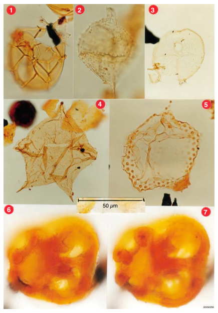
P2. *Vozzhenikovia, Enneadocysta,* and *Turbiosphaera*, p. 35.



P3. *Spinidinium, Hemicystodinium, Hystrichosphaeridium, Schematophora, Adnatosphaeridium,* and *Thalassiophora*, p. 36.



P4. *Impagidinium, Spinidinium, Cyclopsiella, Lejeunecysta, Selenopemphix,* and *Fischeripollis*, p. 37.



T5 for relative abundances of major groups and detailed distributions of observed fossil taxa).

Typically, the dinocyst suites at this latitude are dominated by species of *Deflandrea,* with morphotypes similar, but not identical to or intermediate between, *Deflandrea phosphoritica, Deflandrea flounderensis,* and/or *Deflandrea antarctica* (see Pl. P1, figs. 1–4). The first species, described from East Prussia in 1954, is one of the most widespread and commonly occurring Eocene *Deflandrea* in southeast Australia (see Stover, 1973): *Deflandrea* sp. cf. *D. flounderensis* and *D. antarctica* are common in Eocene erratics at McMurdo Sound (Levy and Harwood, 2000). Other Transantarctic species, present in low numbers at Site 1166, include *Deflandrea cygniformis* and a morphotype related to *Deflandrea asymmetrica* (Pl. P1, figs. 5, 6).

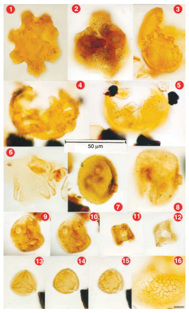
More prominent among the undescribed types in the *D. antarctica–flounderensis–phosphoritica* plexus at Site 1166 is a large morphotype characterized by a pear-shaped (pyriform) endophragm, for which we proposed the informal name *Deflandrea "prydzensis"* (M.K. Macphail and E.M. Truswell, unpubl. data). Other records of this species come from upper Eocene sediments at Site 1171, drilled on the South Tasman Rise (M.K. Macphail, unpubl. data) and (two records only) correlative sediments in the Gippsland Basin (M.K. Macphail, unpubl. data).

Other distinctive types include *Paucilobimorpha* (al *Tritonites*) *spinosus* (Pl. P1, fig. 7), first described from the southern margins of Australia (see Marshall and Partridge, 1988), *Corrudinium* sp. cf. *Corrudinium incompositum* (Pl. P5, fig. 16), *Enneadocysta partridgei* (Pl. P2, figs. 4, 5), *Homotryblium tasmaniense, Spinidinium* sp. cf. *Spinidinium rotundum, Vozzhenikovia* sp., *Turbiosphaera sagena,* cf. *Gippslandica extensa* (Pl. P2, figs. 1–3), and types provisionally assigned to *Schematophora obscura* (Pl. P3, fig. 5) and *Svalbardella hampdenensis*. In all, the association of species appears to be unique to East Antarctica, although individual taxa have been recorded elsewhere.

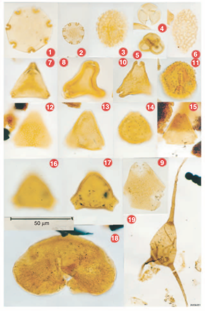
A middle–late Eocene age has been assigned to this assemblage in its broad sense. A more precise age control is provided by the stratigraphic distribution of species in the Gippsland Basin of southeastern Australia (Stover and Partridge, 1973; Marshall and Partridge, 1988; A.D. Partridge and M.K. Macphail, unpubl. data). A key species in this regard is *Tritonites spinosus* (Cookson) Marshall and Partridge (but note that the genus may be a junior synonym of *Paucilobimorpha* de Coninck), which occurs at sample depths of 142.5 and 220.85 mbsf. In southern Australian basins *T. spinosus* has a first appearance datum of latest middle Eocene and ranges into the latest Eocene. Other species that may offer time constraints are *Vozzhenikovia* sp. cf. *Gippslandica extensa* (late Eocene), and *Corrudinium* sp. cf. *C. incompositum*. Also, a solitary occurrence of the manuscript species *D. "prydzensis"* in late Eocene sediments in the Gippsland Basin (Esso–BHP Petroleum Exploration well Whiptail No. 1 at 1147.8 m; M.K. Macphail, unpubl. data) is noteworthy. The presence of all of these taxa at Site 1166 suggests that this interval may be late rather than middle Eocene in age.

In much of Antarctica, the flora is distinguished by the presence of *Arachnodinium antarcticum* (see Truswell, 1997, fig. 5, for distribution of this signature species). *A. antarcticum* has not been observed in the Site 1166 material. Its absence may be due to environmental factors but seems more likely to be attributable to an age difference, with Site 1166 assemblages being of late Eocene age and, hence, younger than the peak occurrence of *A. antarcticum*. In this context, it should be noted that A.D. Partridge (in McGowran et al., 2000) defines an *A. antarcticum*

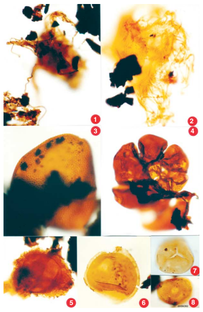
P5. *Fischeripollis, Nothofagidites, Integricorpus, Periporopollenites, Stereisporites,* and *Corrudinium*, p. 38.



P6. *Nothofagidites, Ilexpollenites, Tricolporites, Tetradites, Liliacidites, Forcipites, Gambierina, Beaupreadites, Tetracolporites, Proteacidites, Lygistepollenites,* and *Octodinium*, p. 39.



P7. Unidentified megaspores, foveolate spores, foraminifers, and sporomorphs; *Exesipollenites,* and *Microbaculispora*, p. 40.



range zone, having an open marine character, within the Gippsland Basin; the range zone is middle Eocene in age, possibly equivalent to foraminiferal Zones P8 to P10–P11 (A.D. Partridge, unpubl. data).

240.36–267.18 mbsf

The interval between 240.36 and 267.18 mbsf is the basal unit of the transgressive Eocene sequence recorded above. Dinocysts are rare but include species characteristic of the "Transantarctic Flora." Samples at 249.42 and 258.72 mbsf incorporate clasts of Late Cretaceous (Turonian–?Santonian) sediments (see below) and have been transported to the site, presumably by glacial or fluvioglacial action.

Dinoflagellate cysts reported from the Tertiary samples in this interval belong either to the "Transantarctic Flora," for example, *D. "prydzensis"* (ms), or are wide-ranging types such as *E. partridgei*. The paucity of dinocysts in this interval allows only an age determination somewhat broader than that for the interval above—a middle–late Eocene age is assigned. The sample at 267.18 mbsf is effectively barren and is assumed to be located close to an unconformity representing Campanian–early Eocene time.

Spores and Pollen

Fossil spores and pollen were recorded in frequencies of 29% and 19% in the uppermost sampled cores (viz. at 142.5 and 148.36 mbsf, respectively). Below this, frequencies increased rapidly and spores and pollen represented 80%–95% in the remainder of the Cenozoic section.

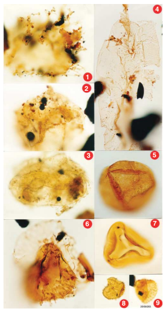
Pollen frequencies suggest that Site 1166 was located relatively close to the Eocene shoreline. All palynofloras are dominated by *Nothofagidites* (41%–57%), with fewer gymnosperms. The *Nothofagidites* pollen comprises a diverse range of morphologies, and many grains cannot be assigned with confidence to fossil species or to the major extant subgenera of *Nothofagus*. The fossil species *Nothofagidites lachlaniae* (15%–33%) has not been identified in southeastern Australia, whereas values of *Nothofagidites flemingii* (up to 10%) and *Nothofagidites goniatus* (up to 2%) are uncommon in that region.

The gymnosperms include two taxa that are characteristic of freshwater swamps, *Phyllocladidites mawsonii* and the *Trichotomosulcites subgranulatus* complex. The spores of ferns and fern allies (cryptogams) are uncommon, and some cannot readily be separated from recycled Cretaceous species.

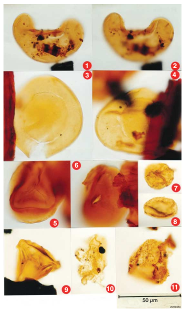
Whereas many of the taxa have been assigned to formally described species, the morphological fit is inexact, since many of the commonly occurring types exhibit unusually high degrees of variation. Examples are the gymnosperm genera *Phyllocladidites, Podosporites, Podocarpidites,* and *Trichotomosulcites,* as well as *Nothofagidites*. Reasons for this include:

1. Most fossil species have been described using end-members—specimens that may be linked to other species by intermediate morphotypes. This is particularly prevalent for *Nothofagidites* species belonging to *Brassospora* and *Fuscospora*, two of the three extant subgenera of *Nothofagus* (see Stover and Evans, 1973; Dettmann et al., 1990; Hill and Read, 1991). In the case of the third extant subgenus—*Nothofagus*—taxonomically unreliable characters such as size and amb shape have been used to elevate closely related morphotypes into separate species (e.g., *Nothofagidites rocaensis* and *Nothofagidites saraensis* in South America).

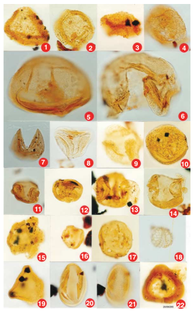
P8. *Heterosphaeridium, Isabelidinium, Wuroia, Osmundacidites, Kraeuselisporites, Dictyophyllidites,* and *Ceratosporites*, p. 41.



P9. *Laevigatosporites, Coptospora, Camarazonosporites, Dilwynites,* and *Gleicheniidites,* p. 42.



P10. *Dilwynites, Araucariacites, Phyllocladidites, Cupressacites, Trichotomosulcites, Microcachryidites, Australopollis, Periporopollenites, Retimonocolpites, Proteacidites, Ailanthipites,* and *Stereisporites*, p. 43.



2. Environmental stresses may lead to different morphotypes being produced by the same plant. For example, fossil *Nothofagus* foliage preserved in the putatively Pliocene Sirius Group in the Transantarctic Mountains is associated with pollen referable to *N. lachlaniae* (*Fuscospora* type; see Hill and Truswell, 1993). This assignment depends on whether the margins of the colpi are thickened or not (Hill and Truswell, 1993; M.K. Macphail, unpubl. data). Dettmann et al. (1990) raised the possibility that species such as *N. lachlaniae* and *Nothofagidites heterus,* which have no known living equivalents, represent extinct subgenera of *Nothofagus.*
3. What may prove to be conspecific types have been assigned to different species in Australia, New Zealand, and South America. Examples are *Nothofagidites cinctus* and *N. flemingii*, placed in synonymy by Stover and Evans (1973), and *Nothofagidites asperus, Nothofagidites americanus,* and *Nothofagidites tehuelchesii.*

For the reasons outlined, we prefer to regard many of the morphotypes present at Prydz Bay as members of species complexes (Pl. P6, figs. 1, 2); for example, *Podosporites parvus, Podosporites microsaccatus,* and *T. subgranulatus* together form the *Trichotomosulcites subgranulosus* complex; *N. asperus, N. americanus,* and *N. teheulchesii* form the *N. asperus* complex; *N. flemingii, N. rocaensis,* and *N. saraensis* form the *N. flemingii* complex; *Nothofagidites brachyspinulosus* and *Nothofagidites incrassata* form the *N. brachyspinulosus* complex; and *N. lachlaniae, N. heterus,* and *Nothofagidites waipawensis* form the *N. lachlaniae* complex. It is possible that the grains encompassed within the last group include pollen sourced from the subgenus *Brassospora* as well as *Fuscospora* species.

Whereas the emphasis in dating the sequence has been placed on individual dinocyst species because of their generally shorter ranges in time, a number of the spore and pollen species provide broad support for the middle–late Eocene age ranges suggested. For example, *N. goniatus* first appears in the early Eocene in southeastern Australia. Also, the rare species *Periporopollenites hexaporus* has only been found in Tasmania at two localities, both of which are associated with cool to cold conditions—the earliest Oligocene tillite sequences in northwest Tasmania (Macphail et al., 1993; Macphail and Hill, 1994) and the late Oligocene–early Miocene Monpeelyata site on the Central Plateau (Macphail et al., 1991) (Pl. P5, figs. 6, 11, 12). The Prydz Bay sequence includes a new species of *Periporopollenites,* which differs from *P. hexaporus* in being ornamented with scattered spinules.

The rare droseracean pollen type that we have designated *Fischeripollis* sp. A (Truswell and Macphail, in press) is similar in basic form to morphotypes found in early–late Eocene microfloras in the Gippsland Basin (M.K. Macphail and A.D. Partridge, unpubl. data) and identical to forms from the earliest Oligocene Lemonthyme Tillite (Macphail et al., 1993) (Pl. P4, figs. 6, 7; Pl. P5, figs. 1–6). The only described Australian species of *Fischeripollis, Fischeripollis halensis,* was described from middle–late Eocene sediments in the Hale Basin of central Australia (Truswell and Marchant, 1986).

Last appearances in Antarctica are less well established. Within the Prydz Bay Eocene assemblages a number of species are present, for example, *Battenipollis sectilis, Forcipites longus, Forcipites sabulosus, Gambierina edwardsii, Gambierina rudata,* and an undescribed member of the Triprojectacites, which all became extinct in the Paleocene or early Eocene in the Gippsland and Otway Basins. These occurrences may represent extended ranges in Antarctica, or else, perhaps less likely, they represent local recycling.

The relative proportions of major groups (fungi, pollen and spores, and marine dinocysts) expressed as a percentage of the total pollen count (excluding reworked Paleozoic taxa) are given in Tables **T5** and **T6.**

142.5–220.85 mbsf

This interval is interpreted as a transgressive sequence, in which marginal marine environments were replaced by open marine conditions during probable late Eocene time. Palynofloras in two cores at 142.5 and 148.36 mbsf are wholly dominated by marine dinocysts (70%–80%), chiefly small undescribed types but also *D. "prydzensis"* (ms) and *Spinidinium* spp.

Selenopemphix, a genus of dinoflagellates typical of estuarine environments, is frequent at 148.36 mbsf (Pl. **P4,** fig. 5). The spore and pollen component is dominated by gymnosperms and *N. lachlaniae* complex species. The gymnosperms include two taxa characteristic of freshwater swamps (*P. mawsonii* and *T. subgranulatus* complex), but all are uncommon relative to values in the unit immediately below. The combined data point to this interval being deposited in a nearshore marine environment but relatively close to the paleoshoreline.

In the interval 156.99–220.85 mbsf, the frequency of marine dinocysts is lower, ranging from 6% to 21% of the total pollen count. The high relative abundance of terrestrial palynomorphs suggests that this part of the sequence was deposited in a marginal marine environment, perhaps in tidal channels and backswamps within a fluvio-deltaic complex rather than a lagoon, as estuarine dinocysts are present in most samples. What appear to be the remains of an unidentified invertebrate are present at 180.4 mbsf. The marked increase in the relative abundance of marine dinoflagellates (from an average of 6% to an average of 74%) indicates that rapid marine flooding of the site occurred between 156.99 and 148.36 mbsf; an unconformity surface representing this flooding may be present between these depths. Flooding is likely to have been rapid given that the dinocyst floras are similar in composition throughout the sampled section.

240.36–267.18 mbsf

Within the basal part of the Eocene section, marine dinocyst frequencies are low, as is evident in cores at 240.36 mbsf (5%) and 258.72 mbsf (2%) (see Table **T5**). In this section, two cored intervals are interpreted as having sampled clasts of Cretaceous age incorporated within the Eocene sequence. At 249.42 mbsf, the microflora appears to belong to the *P. mawsonii* Zone of the underlying sequence (see below). This is dominated by cryptogams (37%) and gymnosperms (57%) and includes taxa that are diagnostic of, or have first or last appearances within, the Turonian–?Santonian of southeastern Australia. These include *Camarozonosporites bullatus, Coptospora* sp. A, *Gleicheniidites* sp. A, *Laevigatosporites* sp. A, *Dilwynites* spp. A and B, *P. mawsonii,* and *Phyllocladidites reticulosaccatus* (Pl. **P9,** figs. 1–9; Pl. **P10,** figs. 1–4). Tertiary species are absent. Detailed distributions of taxa are shown in Table **T5.**

At 258.72 mbsf palynofloras are of mixed age, with Late Cretaceous (*P. mawsonii* Zone) spores and pollen associated with rare dinocysts of the Eocene "Transantarctic Flora."

Combined data from this interval suggest deposition within a marginal marine environment—perhaps a fluvio-deltaic complex with tidal channels. Sediments at the site include reworked Late Cretaceous material, with some clasts that appear to have survived transport and redeposition without being contaminated by Tertiary microfossils from the host sediment. One possible explanation is that such clasts may have been frozen at the time of deposition; seasonal ice with associated meltwater may have been the transporting agency.

The sample at 267.18 mbsf is effectively barren and is presumed to be located close to an unconformity representing Campanian–middle to late Eocene time.

Parent Vegetation

Consideration of the relative abundance data suggests that the source vegetation was a form of floristically impoverished gymnosperm—*Nothofagus* rainforest or rainforest scrub (see Table **T4**). However, interpretation of plant community structure using fossil pollen is made difficult by the fact that most living Podocarpaceae and *Nothofagus* tree species are able to survive (and flower) as low shrubs under adverse conditions; the same was almost certainly true during the early Tertiary. *Nothofagus cunninghamii* in Tasmania ranges in size from a 40-m tree in lowland evergreen forest to a shrub <1 m high in the alpine zone.

Two observations hint that the Prydz Bay communities were more likely to be rainforest scrub than forest. These are (1) the diversity and relative abundance of angiosperms other than *Nothofagus* is very low, and (2) cryptogams are rare (<2%). The reasoning is based on field observations in Tasmania and New Zealand cool to cold temperate communities. These indicate that the interiors of tall rainforests are inhabited by diverse cryptogam communities, whereas small tree and shrub communities are well developed under breaks in the canopy and along forest margins, especially along rivers. Conversely, rainforest scrub found in the upper subalpine–alpine zone provides far fewer opportunities for other species to establish themselves under the low closed canopy. The major factors limiting the size of cool to cold climate stands include topographic—chiefly exposure to wind and fire—and edaphic—such as soil drainage—as well as mean summer temperatures.

Uncommon to rare taxa such as *Proteacidites* spp., *Cupaneiidites* sp. cf. *Cupaneiidites orthoteichus, Malvacipollis* spp., and *P. hexaporus* hint at the existence of other shrub associations (Pl. **P5**). It is tempting to argue that *Integricorpus* and other extinct angiosperm lineages such as *Battenipollis* and *Gambierina* survived into late Eocene time in East Antarctica. The carnivorous parent plant of *Fischeripollis* sp. A implies the presence of open areas with damp, probably nitrogen-poor soils on the banks of the tidal channels bordering Prydz Bay.

The question of deciduousness within this vegetation is of interest. Although the gymnosperms will have been evergreen species, it is possible that some or all of the *Nothofagus* species were deciduous because of the cool to cold temperatures and low light levels prevailing during the winter months (cf. Hill and Scriven, 1995). For example, six of the nine species of *Nothofagus* growing in South America are deciduous and most are tolerant of, if not restricted to, cold climates (see Donoso, 1996; Veblen et al., 1996). The only Australian deciduous species, *Nothofagus gunnii,* is restricted to upper subalpine–alpine habitats in Tasmania.

Support for the presence of deciduous *Nothofagus* species in the Tertiary vegetation of Antarctica is provided by a single leaf very similar to *N. gunnii* preserved in Oligocene sediments in the CIROS-1 core hole, McMurdo Sound (Hill, 1989). Evidence has been presented (Hill and

Truswell, 1993; Francis and Hill, 1996) that pollen found in the allegedly Pliocene Sirius Group (*N. lachlaniae* complex) was produced by a deciduous species of *Nothofagus* (*Nothofagus beardmorensis*) growing under harsh climates with mean annual temperatures of ~12°C.

Paleoclimates

The three major factors shaping plant life in Antarctica during the late Eocene would have been mean annual and seasonal distribution of rainfall, mean air temperatures during summer months, and low light levels and temperatures during winter months. Temperatures and rainfall are likely to have been linked to sea-surface temperatures in Prydz Bay; the dark winters will have been a condition under which plant life inhabiting Antarctica must have evolved, possibly since the Paleozoic, given a near-polar position of Antarctica for much of that time.

The relative abundance data demonstrate that the vegetation growing on the foreshore and along channels in Prydz Bay during the late Eocene was dominated by temperate rainforest species, chiefly *Nothofagus,* Araucariaceae (*Araucaria, Agathis,* and *Wollemia*), Podocarpaceae (*Dacrycarpus, Dacrydium, Lagarostrobus, Microcachrys,* and *Phyllocladus*), *Podocarpus–Prumnopitys, Podosporites,* and, less certainly, Cupressaceae.

The nearest living equivalents of these taxa are confined to wet to very wet climates (1200–2500 mm/yr) with year-round high humidity, and there is no reason to doubt that similar uniformly humid (temperate) conditions prevailed during the late Eocene. Mean temperatures are less easily reconstructed since all genera include species whose habit can range from low shrubs to tall trees depending on local conditions.

Three observations hint that the vegetation was likely to be a rainforest scrub growing under microtherm (cool–cold temperatures): (1) except for *Nothofagus,* the diversity of angiosperms is very low, (2) ferns and other cryptogams are rare, and (3) one fossil species (*P. hexaporus*) previously has only been found in cool to cold climate floras in Tasmania. Ice rafting of clasts to the site would imply that temperatures fell below 0°C during the dark seasons of winter and early spring.

Contamination and Recycling

Modern Pollen

All assemblages included low numbers of modern pollen, in particular *Eucalyptus* and Poaceae (grasses). Modern contaminants are most abundant in low-yielding samples and are assumed to come from drilling equipment.

Downhole Contamination

The absence of commonly occurring Neogene–Quaternary dinoflagellate cysts such as *Lingulodinium macherophorum, Nematosphaeropsis labrynthius,* and *Operculodinium centrocarpum* indicates that downhole contamination is negligible.

Recycling

All samples included low to significant numbers of recycled Permian pollen and, less abundantly, spores. Except for monosaccate and taeniate genera, for example, *Protohaploxypinus* and *Striatopodocarpidites,* bisaccate Permian and Triassic forms are difficult to distinguish from Cretaceous and Tertiary podocarpaceous genera.

The cryptogam component may also contain recycled spores. Species of *Cicatricosisporites, Appendicisporites, Retitriletes,* and *Polypodiisporites* are typically most common in Early Cretaceous sediments, and at least some of the forms recovered from the Eocene may be recycled.

The majority of assemblages also include low numbers of angiosperms that typically occur within the Late Cretaceous–Paleocene in southeastern Australia, for example, *Australopollis obscurus, B. sectilis, F. longus, F. sabulosus, Gambierina* spp., and *Peninsulapollis* sp cf. *Peninsulapollis gillii* (*Tricolpites* sp. cf. *Tricolpites fissilus* of Truswell, 1983). It is uncertain whether these forms are recycled or whether their presence represents an extension of their ranges as known in southeastern Australia. The latter seems more likely, as these pollen grains showed no consistent color differences such as might be expected if they were significantly older.

MESOZOIC

The lower unit in the sequence at this site appears to have been deposited during the Late Cretaceous or, more precisely, Turonian to possibly Santonian (see Table **T3**). An unconformity representing the Campanian–early Eocene is inferred to occur at ~267 mbsf. This record is an important one, given that sediments of Turonian–Santonian age have not previously been reported from Antarctica. Samples below 267 mbsf yielded very low frequencies of marine dinocysts and low to medium recoveries of spores and pollen. The microfloras support close floristic (both marine and terrestrial) links with southeastern Australia during the Late Cretaceous. Detailed distribution of the taxa recovered is given in Table **T6.**

Age Control

Dinocysts

A reference framework for age control is provided by the time distribution of species in southeastern Australia (Stover and Partridge, 1973, 1982; Helby et al., 1987; Marshall, 1988, 1989; A.D. Partridge and M.K. Macphail, unpubl. data) and by regional comparisons with sequences in West Antarctica and adjacent offshore regions (Truswell et al., 1999).

Most samples between 296.06 and 343.00 mbsf preserve fragments of the long-ranging Late Cretaceous species *Heterosphaeridium heterocanthum* (Pl. **P8,** fig. 1) and chitinous material lining the internal chambers of planktonic foraminifers (trochospiral test linings). Index species of Late Cretaceous dinoflagellate zones established by Helby et al. (1987) are generally absent. Exceptions are (1) *Isabelidinium variable,* described from ?Santonian (*Tricolporites apoxyexinus* Zone) dredge samples from the Gippsland Basin (Marshall, 1988), and (2) a dinocyst closely resembling *Wuroia corrugata,* recorded in the *P. mawsonii* Zone in the Gippsland and Bass Basins (Marshall, 1989; M.K. Macphail and A.D. Partridge, unpubl. data) (Pl. **P8,** figs. 2–4).

Spores and Pollen

Microfloras in this interval are wholly dominated by gymnosperms (average = 88%) and cryptogams (average = 11%). Frequent to common taxa include (with modern equivalents in parentheses) *Baculatisporites* (Osmundaceae), *Cyathidites* (Cyatheaceae), *Araucariacites australis* (Araucariaceae), *Cupressacites* (Cupressaceae, Taxodiaceae), *Dilwynites* (*Agathis/Wollemia*), *Microcachryidites antarcticus* (*Microcachrys*), *P. mawsonii* (*Lagarostrobus*), *Podocarpidites* (*Podocarpus–Prumnopitys*), and *T. subgranulosus* (?*Microcachrys*) (Pl. **P10,** figs. 1–14). The only angiosperm type that is constantly recorded is *A. obscurus,* a species whose nearest living relative is the freshwater aquatic herb *Callitriche.* Peat-forming mosses such as *Stereisporites* (*Sphagnum*) are rare.

The miospore component indicates that the maximum age is the Turonian *P. mawsonii* Zone equivalent, based on the indicator species, *P. mawsonii,* which is present to frequent in all samples. It is also notable that two long-ranging species, *Cupressacites* and *Dilwynites* sp. A, which reach their maximum relative abundances in the *P. mawsonii* Zone in the Gippsland Basin (A.D. Partidge, unpubl. data), attain values of 15% and 4%, respectively, in this interval.

The minimum age is less certain because of the persistent presence of species which (1) are confined to the *P. mawsonii* Zone (e.g., *Laevigatosporites* sp. A and *Verrucosisporites* sp. A), or (2) typically first appear in the ?Santonian *T. apoxyexinus* Zone in southeast Australia (e.g., *C. bullatus, Dacrycarpites australiensis,* and *Lygistepollenites florinii*).

Unless better evidence for a *T. apoxyexinus* Zone equivalent age is found, for example, the presence of *Ornamentifera sentosa, Latrobosporites amplus, Forcipites stipulatus, Tricolpites confessus,* and *T. apoxyexinus,* we prefer to correlate the interval with the *P. mawsonii* Zone but broaden the age limits to encompass Turonian–?Santonian time. The lowest sample, at 362.03 mbsf, cannot be dated. It should be noted that some samples assigned to the *P. mawsonii* Zone equivalent in Prydz Bay include taxa whose ranges rarely or never overlap in the Gippsland Basin, for example, *C. bullatus, Laevigatosporites* sp. A, and *D. australiensis.* We have pointed out (M.K. Macphail and E.M. Truswell, unpubl. data) that some degree of diachronism is expected because of environmental contrasts between the two regions. For the same reason, the *P. mawsonii* Zone equivalent should be considered provisional, although the Turonian–?Santonian age range is considered to be reliable.

Depositional Environments

The sparse yield of dinoflagellate cysts (or their absence, as in the interval between 288.26 and 276.60 mbsf) suggests a limited marine influence. The combined data indicate that the interval between 276 and 343 mbsf accumulated in a marginal basin with a diminishing influence of the sea. Whether this was due to falling relative sea levels (regression) or progradation of the shoreline during a marine high stand is unknown. A summary of depositional environments is presented in Table **T4.**

Parent Vegetation and Paleoclimates

Relative abundance data point to the coastal plain vegetation being dominated by conifers. Ferns formed a diverse understorey or perhaps heathland in open areas. Physiological constraints imposed by low light during winter months imply that trees and taller shrubs will have been widely spaced to form a woodland rather than forest (Jefferson, 1982; Specht et al., 1992; del Valle et al., 1997). Two woody species (*P. mawsonii* and *T. subgranulosus* complex) indicate the presence of freshwater swamps, but both are uncommon relative to dry land gymnosperms.

The suggested vegetation formation is termed Austral Conifer Woodland or heath because of its broad resemblance to modern boreal communities growing close to the limits of forest tree growth in the Northern Hemisphere (Table T4). The presence of gymnosperms points to year-round moderate humidity and temperatures that were mild relative to the present day. The low relative abundance of probable or suspected hydrophytes such as *Stereisporites, Podosporites,* and *Phyllocladidites* indicates conditions were not sufficiently cold or uniformly wet to sustain extensive freshwater swamps or raised peat bogs.

COMPARISON WITH OTHER ANTARCTIC MICROFLORAS

Numerous palynological assemblages from Late Cretaceous–Neogene deepwater to shallow-marine sediments have been recovered from the continental margins of Antarctica, from adjacent elevated seafloor areas such as the Kerguelen Plateau and South Tasman Rise in the Southern Ocean, and from the Falkland Plateau in the Southwest Atlantic (Webb, 1990; Truswell, 1997).

Many taxa are found recycled (Truswell, 1983; Truswell and Drewry, 1984), but sections likely to include in situ assemblages range in age from Paleozoic to late Quaternary. Key references are Permian (Kemp et al., 1977; Dibner, 1975; Playford, 1990; Farabee et al., 1991; Francis et al., 1993; Lindstrom, 1994, 1995a, 1995b; Larson et al., 1990; Askin, 1997), Triassic (Farabee et al., 1989; Foster et al., 1994), Jurassic–Cretaceous (Askin, 1983, 1989; Domack et al., 1980; Dettmann and Thompson, 1987; Dettmann, 1989; Askin, 1990a, 1990b; Askin et al., 1991; Duane, 1994; Truswell et al., 1999), Paleogene (Cranwell et al., 1960; McIntyre and Wilson, 1966; Wilson, 1967a, 1975; Haskell and Wilson, 1975; Harris, 1976; Hall, 1977; Brady and Martin, 1979; Goodman and Ford, 1983; Mildenhall, 1989; Wrenn and Hart, 1988; Askin, 1990a, 1990b, 2000; Askin et al., 1991; Truswell, 1990, 1991, 1997; Harris et al., 1996; Levy and Harwood, 2000), and Neogene–Quaternary (Mildenhall, 1989; Harris et al., 1996; Raine, 1998). A review of the paleobotanical evidence for angiosperm-dominated plant communities in Antarctica during the Cretaceous and Tertiary was presented by Hill and Scriven (1995). An overview of the Paleocene–Eocene biostratigraphy (including palynology) of the Mac.Robertson Shelf and the western sector of Prydz Bay was provided by Quilty et al. (1999).

Data from the above works provide a regional chronostratigraphy and phytogeographic framework against which the Prydz Bay microfloras can be assessed in three contexts:

1. Age limits: The absence of taxa in Paleocene–middle Eocene intervals elsewhere in the Southern Ocean and Antarctic margins heightens the probability that assemblages found at Site 1166 are in situ and therefore the ages are reliable. For example, the majority of distinctive dinoflagellates found in Paleocene–early Eocene sections in New Zealand (Wilson, 1967b, 1988) and

the South Atlantic (Harris, 1976) are absent, as are most of a suite of related *Tritonites* species found in early–middle Eocene sequences on the South Tasman Rise (Truswell, 1997) and in correlative sequences in the Gippsland and Otway Basins in southeast Australia (Marshall and Partridge, 1988). The interval 142.5–220.85 mbsf, however, preserves at least two specimens of the latest middle–late Eocene indicator species *T. spinosus*.

2. Endemism: There is strong evidence of regional differences in contemporaneous floras around the Antarctic continent. This is apparent in comparisons between the Prydz Bay assemblages and correlative palynofloras from the Ross Sea/McMurdo Sound, Antarctic Peninsula, South Atlantic, and South Tasman Rise.
3. Provenance: Recycled palynomorphs provide a means for establishing the location of eroding sedimentary sequences within the ice-covered catchment (see Kemp, 1972; Truswell, 1983; Truswell and Drewry, 1984). Changes in the composition and relative abundance of recycled taxa have the potential to provide a broad-brush history of erosion, including unroofing of areas undergoing tectonic uplift.

"Transantarctic Flora"

This dinocyst flora was first identified from glacial erratics in the Ross Sea region (Wilson, 1967a, 1967b). The distinctive high-latitude suite is centered around occurrences of the late early Eocene–Oligocene species *A. antarcticum*. The flora tends to be dominated by morphologically variable species of *Deflandrea,* which historically have been grouped around broadly defined taxa such as *D. antarctica* and related species such as *Deflandrea obeisfieldensis*. The Prydz Bay species informally named *D. "prydzensis"* is part of the same complex.

Although knowledge of the geographic and, more importantly, stratigraphic distribution of this flora remains uncertain (see reviews by Wrenn and Hart [1988] and Truswell [1997]), recent reevaluations of both the marine and terrestrial microfloras from the McMurdo glacial erratics have contributed toward understanding the age constraints. Levy and Harwood (2000) reviewed biostratigraphic controls by comparing species ranges for dinocysts with calcareous nannofossil datums from southern high-latitude sites, including Deep Sea Drilling Project (DSDP) sites toward the South Tasman Rise (Sites 280, 281, 282, and 283) and in the Weddell Sea (Site 696B) and South Atlantic (Sites 511 and 513). They noted that among the McMurdo erratics, the best-known, and relatively diverse, dinocyst assemblages appear to be confined to the middle and late Eocene; assemblages considered to be early Oligocene in age are very restricted in their diversity.

It is becoming increasingly apparent that the flora is subject to geographic variation in terms of taxonomic differentiation and species composition. For example, confusion surrounds the taxonomic limits of morphotypes within the broadly defined *D. antarctica* complex and assemblages from East Antarctica appear to be generally less diverse than those from the Ross and Weddell Sea regions.

Prydz Bay and Mac. Robertson Shelf

From four sites drilled across the center of Prydz Bay during Leg 119, Truswell (1991) identified three major groups of palynomorphs, namely, Permian bisaccate gymnosperms, long-ranging Cretaceous–Paleogene spores and pollen, and Eocene–early Oligocene dinocysts.

Site 742, drilled in 410 m of water in the middle of Prydz Bay, yielded essentially the same assemblage of dinocysts as that from 142.5–220.85 mbsf at Site 1166, including diverse *Nothofagidites, Deflandrea* spp., *E. partridgei,* and *Vozzhenikovia apertura*. Recovery was, however, sparse; recycled Permian forms were common, and Truswell (1991) was careful to point out that recycling of the whole assemblage remains a possibility.

At the same site, 742A, Core 34 yielded what were described as nonmarine floras of Late Cretaceous age that may be correlative with the Late Cretaceous at Site 1166. Abundant spores and pollen were recovered, including *P. mawsonii, Cicatricosisporites australiensis, C. bullatus, M. antarcticus, Kraeuselisporites majus, Podocarpidites* spp., and *Retitriletes* spp. An age of Turonian or younger was suggested on the basis of the miospore evidence (Truswell, 1991), but further processing and reexamination is required to provide a more precise correlation with Site 1166.

Eocene dinocyst assemblages similar to those from Site 1166 are preserved in samples taken from elongate troughs running at right angles to the coast across Mac.Robertson Shelf, west of Prydz Bay, although the diversity is higher and the sequences appear to be slightly older (see Quilty et al., 1999). For example, Site 149/GC47, at the seaward end of Iceberg Alley, contains *Tritonites pandus,* a species that is restricted to late middle Eocene sediments in the Gippsland Basin. The same species is present in samples from site GC10 from the wall of the Neilsen Basin, a depression that is floored by Late Jurassic–Early Cretaceous sediments (see Truswell et al., 1999).

McMurdo Sound/Ross Ice Shelf

The "Transantarctic Flora" has been recorded from the glacial erratics at Black Island and Minna Bluff in McMurdo Sound (see above and Cranwell et al., 1960; McIntyre and Wilson, 1966; Wilson, 1967a, 1967b; Askin, 2000; Levy and Harwood, 2000). It has also been reported from suggested Oligocene and Neogene intervals drilled off the Victoria Land coast in the MSSTS-1, CIROS-1, and CRP-1 core holes (Truswell, 1986; Wilson, 1989; Mildenhall, 1989; Raine, 1998).

Among sites drilled in the Ross Sea region during DSDP Leg 28 (1972–1973), Site 270 yielded abundant palynomorphs (Kemp, 1975; Kemp and Barrett, 1975). At that site, an apparent glaciomarine sequence, lithologically described as a pebbly silty claystone, overlies glauconites dated as 26 Ma. Sediments at the base of the glaciomarine sequence (Subunit 2J) are rich in pollen and spores and also contain much degraded plant tissue. The spore and pollen assemblage is dominated by *Nothofagidites;* there are four or five species of Proteaceae, some Myrtaceae, *Podocarpus,* and rare cyatheaceous fern spores. This assemblage was suggested to be in situ (Kemp and Barrett, 1975) and to represent a coastal vegetation that persisted into the region into the late Oligocene. However, all palynomorphs identified within it are long-ranging, so the possibility remains that this suite was recycled from older sediments during the Oligocene (see Truswell, 1990).

Of particular significance to the dating and ecological interpretation of the Prydz Bay microfloras is CIROS-1, which records two periods of sedimentation on the margin of an intracontinental rift basin—from latest Eocene or earliest Oligocene (702–366 mbsf) and early late Oligocene–early Miocene (360–0 mbsf) (see Harwood et al, 1989).

Importantly, striated pebbles are found throughout the core, although occurrences are less common near the base (Hambrey et al., 1989). These show that glaciers accumulating on the tectonically rising Transantarctic Mountains extended to the coast by earliest Oligocene time.

The composition of dinocyst floras recovered between 697 and 473 mbsf in CIROS-l is closely similar to those at the Prydz Bay Site 1166 (except for the absence of the manuscript species *D. "prydzensis"* and the presence of *A. antarcticum*). The assemblages are dominated by *V. apertura* and include *Alterbidinium (Deflandrea) asymmetricum, A. antarcticum, D. antarctica, E. partridgei, Hystrichosphaeridium tubiferum* (Pl. **P3,** fig. 4)*, Lejeunocystia* sp., *Spinidinium macmurdoense, Turbiosphaera filosa,* and *Vozzhenikovia rotundum.*

Additional work is required to determine whether other less distinctive dinocysts found in CIROS-1 are present at Site 1166 (e.g., *Deflandrea granulata, Phthanoperidium* spp., and *Tectatodinium* cf. *pellitum*). Dinocyst floras above 473 mbsf are depauperate and lack *D. antarctica, E. partridgei, H. tubiferum, Lejeunocysta* sp., and *T. filosa* but include *A. asymmetricum, S. macmurdoense,* and *V. rotundum.*

If similar time distributions apply in Prydz Bay, then the minimum age of samples at 142.5–148.36 mbsf is early early Oligocene, irrespective of known later occurrences of *E. partridgei.*

Species composition and relative abundance of spores and pollen in the CIROS-1 sequence also closely resemble the Site 1166 microflora (see plates 1–3 in Mildenhall, 1989). For example, the assemblages include essentially the same recycled Permian elements, whereas the component believed to be in situ is dominated by species belonging to the *N. flemingii* and *N. lachlaniae* complexes.

Assuming that trace records of Asteraceae and Myrtaceae are contaminants, then the chief differences between the Prydz Bay and Ross Sea microfloral sequences are (1) the Ross Sea lacks, at present, any evidence for a diverse Late Cretaceous suite as found at Site 1166; (2) the CIROS-1 Tertiary suite contains Casuarinaceae (which has also been reported from MSSTS-1, CRP-1, and as a recycled element in surficial Ross Sea sediments); and (3) the CIROS-1 assemblages include two taxa (*Chenopodipollis chenopodiaceoides* and *Corsinipollis epilobioides*) that first appear in the early Oligocene in southern Australia (see Macphail and Truswell, 1989). It is noted that it is difficult to distinguish subrecent *C. chenopodiaceoides* from modern Chenopodiaceae pollen contaminants (present in the Prydz Bay samples), whereas *C. epilobioides* first appears as early as the middle–late Eocene in New Zealand (D. Pocknall, cited in Mildenhall, 1989).

Another form reported from CIROS-1 that was not observed in Prydz Bay is a tricolpate grain referred to as *Perfotricolpites digitatus*. This is approximately one-half the size of specimens from southeastern Australia (see Macphail, 1999). The presence of *P. digitatus* in Antarctica is ecologically anomalous, since (1) the closest living equivalent is pollen produced by the now wholly tropical genus *Merrimia* (Convulvulaceae) and (2) although *P. digitatus* first appears in the Murray Basin in the late Eocene, the species has not been recorded eastward in the Gippsland Basin or in Tasmania. The same form, however, was reported from Sirius Group sediments in the Transantarctic Mountains (Askin and Markgraf, 1986), where it occurs within a *Nothofagus* community. There, affinities with Labiatae or Polygonaceae were suggested. The species has also been figured as *Tricolpites* sp. A in lower Miocene sediments penetrated during the drilling of the Cape Roberts (CRP-1) borehole in the Ross Sea (Raine, 1998, fig. 2a) and occurs too as a recycled element in Ross Sea sediments (see Truswell, 1983, pl. 3, figs. 23, 24).

Numerous modern examples exist of rainforest growing adjacent to coastal glaciers, for example, in Tierra del Fuego. Mildenhall (1989) argued that the CIROS-1 microfloras represent gymnosperm *Nothofagus* rainforest surviving in coastal refugia, not rainforest scrublands or scrub. His reasons included the high diversity of *Nothofagus* relative to existing cold-climate shrublands in South America. The presence in the core of *Nothofagus* pollen clumps, representing whole anthers and therefore local sources, suggests nearby vegetation. Also recovered was a leaf related to *N. gunnii,* a winter-deciduous small to tall shrub growing in subalpine to alpine habitats in Tasmania. This interpretation can be challenged on the grounds that pollen does not indicate plant habit per se (*Nothofagus* species flower profusely irrespective of size), whereas *N. gunnii* can extend below the timberline along cold-air drainage lines.

Drilling from annual sea ice at Cape Roberts penetrated Tertiary sequences considered to range in age from early Miocene to late Eocene with biostratigraphically useful palynomorph assemblages being recovered from early Oligocene and early Miocene intervals (Raine, 1998; Askin and Raine, 2000; Raine and Askin, 2000). In the oldest core, CRP-3, early Oligocene floras are of generally low diversity and are dominated by *Nothofagidites,* with common podocarpaceous conifers, a low diversity of other angiosperms, and rare cryptogams. The main elements of the floras are similar to those from the Prydz Bay Eocene, but there are differences in the minor components (e.g., in the presence of ?Stylidiaceae and Casuarinaceae). Raine and Askin (2000) suggested comparisons between the parent vegetation and low-diversity *Nothofagus* forests growing now in the magellanic region of southern South America, where low forests give way to *Nothofagus* scrubland above the altitudinal treeline.

Antarctic Peninsula

Unlike East Antarctica, microfloras recovered from outcrops on the Antarctic Peninsula are likely to be in situ and incorporate relatively few recycled taxa. As such these provide the nearest equivalent of a continuous record for Cretaceous–Eocene time in Antarctica. Three areas that preserve diverse elements of the Transantarctic dinocyst floras are Cockburn Island (Hall, 1977), James Ross Island (Dettmann and Thompson, 1987), and Seymour Island (Wrenn and Hart, 1988; Askin, 1990a, 1990b; Askin et al., 1991). Many of the Eocene assemblages include recycled Late Cretaceous and Paleocene dinoflagellates not recorded at Prydz Bay.

The youngest diverse dinocyst floras come from the La Meseta Formation of Seymour Island. These late early to late middle–late Eocene assemblages (fig. 10 in Wrenn and Hart, 1988) provide further information regarding circum-Antarctic endemism and the age of the Prydz Bay assemblages in several ways: (1) a number of characteristic species, including *A. antarcticum, D. antarctica,* and *E. partridgei* are restricted to the late early Eocene interval; (2) none of the illustrated *Deflandrea* specimens appear to be *D. "prydzensis;"* and (3) *Lejeunocysta* and *Octodinium* spp. are restricted to the late middle–late Eocene interval.

Terrestrial palynofloras from Cockburn Island closely resemble the Prydz Bay microfloras in being dominated by gymnosperms (chiefly *P. mawsonii, Podocarpidites* spp., and *Nothofagidites* spp.). Other angiosperms make up ~5% of the microflora, but individual taxa, including *Proteacidites,* are uncommon to rare, as are cryptogams.

For the Cretaceous, diverse microfloras of that age are preserved on Dundee, James Ross, Seymour, and Vega Islands near the tip of the Antarctic Peninsula and on Seymour Island (Askin, 1988, 1990a, 1990b; Dettmann and Thompson, 1987; Askin et al., 1991). These range in age from Barremian to Maastrichtian and include many of the dinocysts used as zonal indices in southern Australia by Helby et al. (1987).

Comparison with the Cretaceous sequence at Site 1166 is hindered by the apparent absence of fossiliferous Turonian–Santonian material (see fig. 2 in Dettmann and Thompson, 1987) and the fact that most of the taxa that are shared are long-ranging spore species. Conversely, age-diagnostic dinocysts and pollen taxa found on the Antarctic Peninsula are absent from Prydz Bay or are present only as recycled elements. It may be that correlative sediments (i.e., of late Campanian age) do not occur in subcrop in the Prydz Bay catchment.

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Figure F1. Locality map showing position of Site 1166 and other Leg 188 sites. Sites 739–742 are from Barron, Larson, et al. (1989).

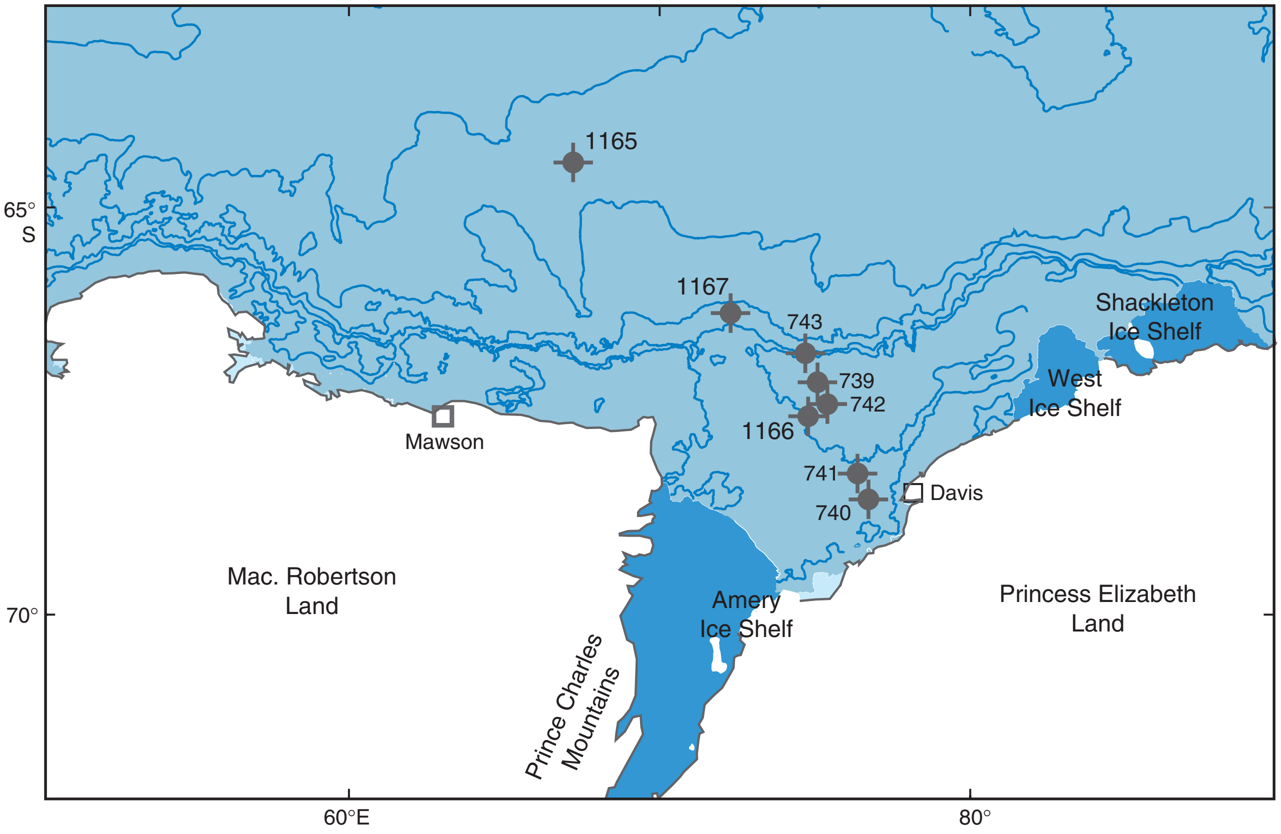


Figure F2. Stratigraphic sequence in Hole 1166A, showing cored intervals, lithology, and biostratigraphic units (from O'Brien, Cooper, Richter, et al., 2001). Zones shown in the "Palynology" column are those of the Gippsland Basin in southeastern Australia (Stover and Partridge, 1973). LWD = logging while drilling. RHOM = logging formation density.

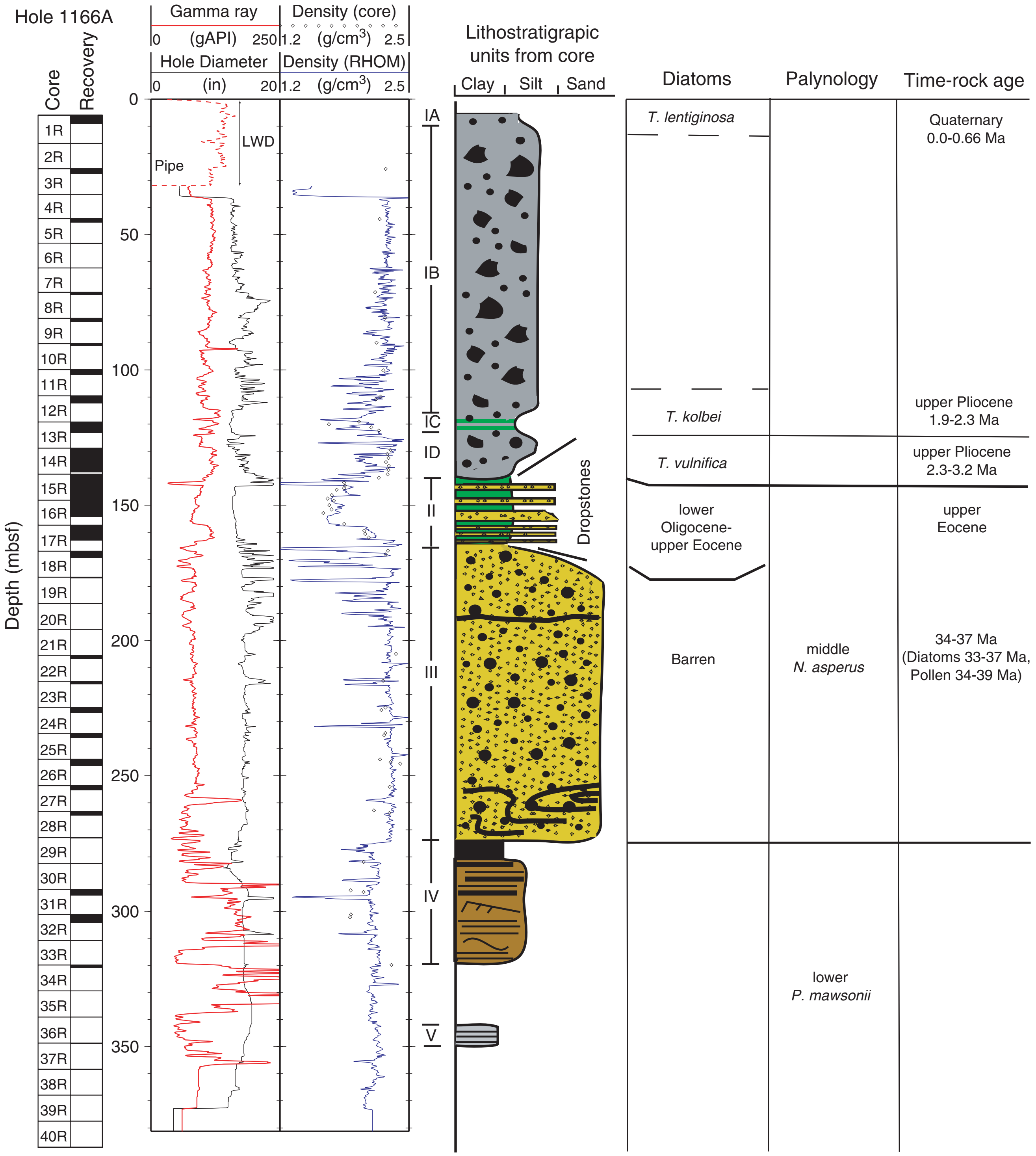


Table T1. Zonal summary.

Depth (mbsf)	Zone (Gippsland Basin equivalent)	Age	Environment
142.5–148.36	Middle *Nothofagidites asperus*	late Eocene	Open marine
156.99–220.85	Middle *Nothofagidites asperus*	middle?–late Eocene	Marginal marine
240.36	Lower–middle *Nothofagidites asperus* Zone	middle?–late Eocene	Marginal marine
249.42	*****Reworked *Phyllocladidites mawsonii* Zone clast*****		Nonmarine
258.72–267.18	Mixed *Nothofagidites asperus*/ *Phyllocladidtes mawsonii* Zone	middle–late Eocene?	Marginal marine
~267.18	*****Unconformity surface*****		
276.60–288.26	*Phyllocladidites mawsonii* Zone	Turonian–?Santonian	Fluvial
296.06–343.00	*Phyllocladidites mawsonii* Zone	Turonian–?Santonian	Marginal marine
362.03	Indeterminate	Unknown	Nonmarine

Table T2. Basic core sample data.

Depth (mbsf)	Yield		Preservation		Comment
	Dinocysts	Spore–pollen	Dinocysts	Spore–Pollen	
142.50	Very high	Low	Good	Good	Dinocysts fragmented
148.36	Very high	Low	Good	Good	Dinocysts fragmented
156.99	Low	High	Good	Good	Estuarine dinocysts
170.98	Very low	Medium	Good	Good	Estuarine dinocysts
180.40	Medium	High	Good	Good	Crustacean remains?
200.67	Very low	Very Low	Good	Poor	Estuarine dinocysts
220.85	Low	Medium	Good	Good	Brackish water algae
240.36	Very low	Low	Medium	Good	Dinocysts fragmented
249.36	—	Very low	—	Medium	Reworked assemblage
258.72	Very low	High	Medium	Good	Mixed-age palynoflora
267.18	—	Trace	—	Medium	Contaminants?
288.26	—	Very low	—	Poor	Zircons present
296.06	Trace	Medium	Poor	Poor	
297.01	Trace	High	Medium	Medium	Grains crumpled/torn
304.95	Trace	Very low	Medium	Medium	TAI ~3–3.5
314.45	Low	Medium	Medium	Medium	
314.96	Trace	Medium	Medium	Medium	
343.00	Trace	Low	Medium	Good	
362.03	—	Trace	—	Poor	

Note: TAI = thermal alteration index.

Table T3. Age determinations.

Depth (mbsf)	Age	Confidence rating	Key taxa
142.50	late Eocene	High	*Tritonites spinosus, Enneadocysta partridgei, Corrudinium* cf. *incompositum*
148.36	late Eocene	Medium	*Enneadocysta partridgei, Corrudinium* cf. *incompositum, Fischeripollis* sp. A
156.99	middle?–late Eocene	Medium	*Periporopollenites hexaporus, G. goniatus, Enneadocysta partridgei*
170.98	middle?–late Eocene	Medium	*Fischeripollis, Nothofagidites goniatus*
180.40	middle?–late Eocene	Low	*Periporopollenites spinosus* ms., Nothofagidites *goniatus, Enneadocysta partridgei*
200.67	Indeterminate	—	[very low yielding sample]
210.18	middle?–late Eocene	Medium	*Enneadocysta partridgei, Svalbardella hampdenensis, Nothofagidites goniatus*
220.85	middle?–late Eocene	Medium	*Tritonites spinosus, Enneadocysta partridgei, Nothofagidites goniatus*
240.36	middle?–late Eocene	Medium	*Enneadocysta partridgei, Nothofagidites goniatus, Integricorpus* sp. A
249.36	[Turonian–?Santonian]	High	[*Laevigatosporites* sp. A, *Phyllocladidites mawsonii*]
258.72	middle?–late Eocene?	Low	*Deflandrea prydzensis, Nothofagidites goniatus*
267.18	middle?–late Eocene?	Low	*Nothofagidites goniatus*
276.60	Turonian–?Santonian	Medium	*Coptospora* sp. A, *Australopollis obscurus, Phyllocladidites mawsonii*
288.26	Turonian–?Santonian	Medium	*Phyllocladidites mawsonii, Dilwynites* sp. A, *Australopollis obscurus*
296.06	Turonian–?Santonian	Medium	*Phyllocladidites mawsonii, Dilwynites granulatus, Australopollis obscurus*
297.01	Turonian–?Santonian	Medium	*Phyllocladidites mawsonii, Dilwynites* sp. A, *Australopollis obscurus*
304.95	Turonian–?Santonian	High	*Isabelidinium variable, Phyllocladidites mawsonii, Dilwynites granulatus*
314.45	Turonian–?Santonian	High	*Isabelidinium variable, Wuroia corrugata, Laevigatosporites* sp. A.
314.96	Turonian–?Santonian	Medium	*Phyllocladidites mawsonii, Dilwynites* sp. A, *Australopollis obscurus*
343.00	Turonian–?Santonian	Medium	*Phyllocladidites mawsonii, Dilwynites granulatus*
362.03	Indeterminate	—	—

Table T4. Paleoenvironments.

Depth (mbsf)	Source vegetation	Depositional environment
142.50	Cool–cold temperate rainforest scrub	Open marine
148.36	Cool–cold temperate rainforest scrub	Open marine
156.99	Cool–cold temperate rainforest scrub	Fluvio-deltaic
170.98	Cool–cold temperate rainforest scrub	Tidal channel
180.40	Cool–cold temperate rainforest scrub	Tidal channel
200.67	Cool–cold temperate rainforest scrub	Tidal channel
210.18	Cool–cold temperate rainforest scrub	Tidal channel
220.85	Cool–cold temperate rainforest scrub	Tidal channel
240.36	*Nothofagus* rainforest scrub	Tidal channel
249.36	[Austral Conifer Woodland]	[Rafted clast]
258.72	*Nothofagus* rainforest scrub	Tidal channel
267.18	*Nothofagus* rainforest scrub?	Indeterminate
276.60	Austral Conifer Woodland	Fluvio-deltaic
288.26	Austral Conifer Woodland	Fluvio-deltaic
296.06	Austral Conifer Woodland	Marginal marine?
297.01	Austral Conifer Woodland	Marginal marine
297.01	Austral Conifer Woodland	Marginal marine
304.95	Austral Conifer Woodland	Marginal marine
314.45	Austral Conifer Woodland	Marginal marine
314.96	Austral Conifer Woodland	Marginal marine
343.00	Austral Conifer Woodland	Marginal marine
362.03	Indeterminate	Indeterminate

Table T5. Relative abundance of Eocene plant microfossil taxa, 142.5–267.18 mbsf. (**See table notes.** Continued on next two pages.)

	Depth (mbsf)											
Fossil taxon	142.50	148.36	156.99	170.98	180.40	200.67	210.18	220.85	240.36	249.36	258.72	267.18
Nonmarine algae												
Botryococcus	–	–	–	–	–	–	–	–	–	–	–	–
Marine dinoflagellates												
Achomosphaera sp. cf. *A. ramosa*	+	+	–	–	–	–	+	+	–	–	–	–
Corrudinium cf. *incompositum*	+	+	–	–	+	–	–	–	–	–	–	–
Cyclopsiella sp.	+	+	–	–	+	–	+	–	–	–	–	–
Deflandrea cf. *asymmetrica*	+	+	+	–	–	–	–	–	–	–	–	–
Spinidinium macmurdoense	+	–	+	+	+	–	+	+	–	–	–	–
Deflandrea antarctica–prydzensis complex	7%	19%	+	2%	2%	–3%	2%	2%	–	–	+	+
Enneadocysta partridgei	+	+	+	–	+	+	+	+	+	–	–	–
cf. *Homotryblium tasmaniense*	+	+	+	–	–	–	+	–	–	–	–	–
Hystrichosphaeridium tubiferum		–	–	–	–	–	–	–	–	–	–	–
Impagidinium sp. cf. *I. victorianum*	+	+	–	+	+	–	+	–	–	–	–	–
Impagidinium spp.	2%	+	–	–	–	–	1%	–	–	–	–	–
Lejeunecysta spp.	+	+	+	+	–	–	+	–	–	–	–	–
Octodinium sp.	–	+	–	–	–	–	–	–	–	–	–	–
Operculodinium spp.	2%	+	–	–	+	–	+	–	–	–	+	–
Schematophora sp. cf. *S. obscura*	+	+	+	–	+	–	+	–	–	–	–	–
Selenopemphix nephroides complex	+	5%	+	–	+	+	–	+	–	–	–	–
Spiniferites spp.	+	1%	–	+	+	–	–	–	–	–	–	–
Spinidinium rotundum	+	+	+	+	–	–	+	+	–	–	–	–
Spinidinium sp. A	+	+	+	+	+	–	+	+	1%	–	+	–
Spinidinium spp.	19%	2%	+	4%	2%	–4%	3%	1%				
Svalbardella sp. cf. *S. hampdenensis*	–	–	–	–	+	–	–	–	–	–	–	–
Thalassiphora sp. cf. *T. pelagica*	–	–	–	–	–	–	–	+	–	–	–	–
Tritonites spinosus	+	–	–	–	–	–	–	+	–	–	–	–
Turbiosphaera cf. *filosa*	+	4%	–	+	–	–	+	+	–	–	–	–
Vozzhenikovia sp. cf. *V. apertura*	–	–	–	–	–	–	–	+	–	–	–	–
Vozzhenikovia cf. *Gippslandica extensa*	+	+	+	+	2%	–	+	1%				
Undifferentiated microplankton	38%	28%	4%	11%	9%	–13%	10%	9%	3%	–	+	–
Total dinocysts	70%	78%	6%	15%	16%	–21%	17%	14%	5%	–	2%	+
Fungi												
Fungal spores + hyphae	1%	1%	+	1%	1%	–	1%	+	6%	+	+	–
Cryptogams												
Aequitriradites spinulosus	–	–	–	–	–	–	–	–	–	–	+	–
Appendicisporites sp.	–	–	–	–	+	–	–	–	–	–	+	–
Baculatisporites spp.	–	–	2%	–	+	–3%	+	+	1%	4%	1%	–
Ceratosporites equalis	–	–	–	–	–	–	–	–	–	–	+	–
Cicatricosisporites australiensis	+	+	+	+	+	–	–	+	–	2%	+	–
Cicatricosisporites ludbrookiae	+	–	–	–	–	–	–	–	–	–	–	–
Clavifera triplex	–	–	+	–	+	–	–	–	–	+	–	–
Coptospora sp. A	–	–	–	–	–	–	–	–	–	2%	+	–
Cyathidites minor/australis	+	+	2%	+	+	–	1%	+	4%	3%	3%	+
Cyathidites paleospora	–	–	–	–	–	–	+	+	–	–	–	–
Dictyophyllidites arcuatus	–	–	+	–	–	–	–	–	–	–	+	–
Foraminisporis asymmetricus	–	–	–	–	–	–	–	–	–	–	+	–
Gleicheniidites sp. A	–	–	+	–	+	–	–	–	–	+	+	–
Gleicheniidites spp.	–	–	+	–	–	–	–	+	–	+	1%	–
Herkosporites elliottii	–	–	+	–	–	–	–	–	–	–	–	–
Laevigatosporites ovatus/major	+	–	+	–	3%	–	2%	2%	–	+	+	–
Laevigatosporites sp. A	–	–	–	–	–	–	–	–	–	+	+	–
Latrobosporites cf. *crassus*	+	+	+	–	–	–	+	–	–	–	–	–
Latrobosporites spp.	–	–	–	–	–	–	–	–	+	+	+	–
Leptolepidites verrucatus	–	–	+	–	–	–	–	–	–	–	+	–
Osmundacidites	–	–	–	–	–	–	–	–	–	+	–	–
Polypodiisporites spp.	–	+	+	–	–	–	–	–	–	–	–	–
Retitriletes australoclavatidites	+	–	+	–	+	–	+	+	+	1%	+	–
Ricciaesporites kawaraensis	–	–	–	+	–	–	+	–	–	–	–	–
Stereisporites antiquisporites	+	–	+	+	+	–	–	+	–	1%	+	–
Stereisporites australis	–	–	+	+	+	–	+	+				
Stereisporites sp. A	–	–	–	–	–	–	–	–	–	+	–	–
Stereisporites sp. B	–	–	–	–	+	–	–	–	–	–	–	–
Trilobosporites trioreticulatus	–	+	–	–	+	–	–	–				
Triporoletes reticulatus	–	–	–	–	–	–	–	–	–	+	–	–
Undifferentiated trilete spores	–	–	–	–	–	–	–	–	+	+	+	–
Total cryptogams	3%	+	6%	4%	5%	–3%	6%	5%	6%	37%	6%	NA

Table T5 (continued).

	Depth (mbsf)											
Fossil taxon	142.50	148.36	156.99	170.98	180.40	200.67	210.18	220.85	240.36	249.36	258.72	267.18
Gymnosperms												
Alisporites grandis	–	+	–	–	–	–	–	–	–	–	–	–
Araucariacites australis	+	+	5%	2%	3%	–3%	3%	8%	3%	11%	16%	–
Balmeiopsis limbata	–	–	+	–	–	–	–	–	–	+	+	–
Corollina spp.	–	–	+	–	–	–	–	–	–	–	–	–
Cupressacites	–	–	+	–	+	–	+	2%	–	15%	5%	–
Dacrycarpites australiensis	–	+	+	+	+	–	+	+	+	–	+	–
Dilwynites granulatus	–	+	+	+	1%	–3%	+	2%	–	+	+	–
Dilwynites sp. A (microgranulate)	–	–	–	–	–	–	–	–	–	+	+	–
Dilwynites sp. A (microechinate)	–	–	–	–	–	–	–	–	–	+	–	–
Lygistepollenites florinii	–	–	+	1%	+	–	+	1%	–	–	+	–
Microalatidites palaeogenicus	–	+	+	–	+	–	+	+	–	–	–	–
Microcachrydites antarcticus	+	+	+	+	1%	–	1%	+	+	+	3%	–
Parvisaccites catastus	–	–	–	–	–	–	–	–	–	–	+	–
Phyllocladidites mawsonii	+	1%	+	3%	+	–6%	2%	2%	3%	1%	3%	+
Phyllocladidites reticulosaccatus	–	+	+	+	+	–	+	–	+	+	–	–
Phyllocladidites verrucosus	–	–	–	–	–	–	–	–	–	–	+	–
Podocarpidites spp.	6%	4%	14%	13%	14%	–13%	13%	12%	10%	17%	22%	+
Trichotomosulcites subgranulosus complex	4%	1%	3%	3%	1%	–3%	4%	3%	4%	7%	13%	–
Vitreisporites spp.	–	–	+	–	–	–	–	–	–	+	–	–
Total gymnosperms	10%	8%	24%	25%	25%	–31%	26%	30%	20%	57%	63%	+
Angiosperms												
Arecipites spp.	–	–	+	–	–	–	–	–	–	–	–	–
Australopollis obscurus	–	–	+	+	+	–	+	–	–	+	+	–
Battenipollis sectilis	+	+	+	–	–	–	+	+	–	–	–	–
Beaupreaidites elegansiformis	+	–	–	–	+	–	–	+	–	–	–	–
Clavatipollenites hughesii	–	–	–	–	–	–	–	–	–	+	+	–
Cupanieidites sp. cf. *C. orthoteichus*	–	–	+	+	+	–	–	–	–	–	–	–
Fischeripollis sp. A	+	+	–	+	–	–	–	–	–	–	–	–
Forcipites longus	–	+	–	–	–	–	–	–	–	–	–	–
Forcipites sabulosus	–	+	–	+	–	–	–	–	–	–	–	–
Gambierina edwardsii	–	+	+	+	–	–	+	–	–	–	+	–
Gambierina sp. cf. *G. edwardsii*	–	–	+	–	–	–	+	+	–	–	–	–
Gambierina rudata	+	+	+	+	+	–	+	+	–	–	+	–
Integricorpus sp. A	–	–	+	+	–	–	–	–	+	–	–	–
Ilexpollenites spp.	+	+	–	–	–	–	–	+	–	–	–	–
Liliacidites spp.	+	–	–	–	–	–	–	–	–	–	–	–
Malvacipollis diversus	+	–	–	–	–	–	–	–	–	–	–	–
Malvacipollis subtilis	+	–	+	+	–	–	+	+	–	–	–	–
Malvacipollis spp.	–	+	+	+	+	–	–	+	–	–	–	–
Nothofagidites emarcidus complex	–	–	+	+	+	–	+	+	+	–	–	–
Nothofagidites asperus complex	+	1%	4%	8%	3%	–3%	6%	8%	3%	–	2%	–
Nothofagidites brachyspinulosus complex	+	+	11%	6%	15%	–13%	18%	11%	2%	–	5%	–
Nothofagidites flemingii complex	3%	1%	8%	8%	10%	–12%	5%	+	13%	–	4%	–
Nothofagidites goniatus	+	+	+	+	2%	–	+	2%	4%	–	+	+
Nothofagidites lachlaniae complex	11%	6%	33%	26%	16%	–16%	15%	24%	41%	–	16%	–
Total *Nothofagus* count	16%	8%	57%	50%	46%	–41%	46%	46%	66%	–	27%	+
Peninsulapollis cf. *gillii* (= *T.* cf. *fissilis*)	+	–	+	+	+	–	–	+	+	–	–	–
Peninsulapollis truswelliae	–	–	–	+	–	–	–	–	–	–	–	–
Periporopollenites hexaporus	–	–	+	–	–	–	–	–	–	–	–	–
Periporopollenites polyoratus	–	–	+	–	–	–	–	–	–	–	–	–
Periporopollenites sp. A (apiculate)	–	–	–	–	+	–	–	–	–	–	–	–
Periporopollenites vesicus	–	–	–	+	–	–	+	–	–	–	–	–
Proteacidites angulatus	–	–	–	+	–	–	–	–	–	–	–	–
Proteacidites kopiensis	–	–	+	+	–	–	–	+	–	–	–	–
Proteacidites sp. cf. *obscurus*	+	–	+	+	+	–	+	+	–	–	–	–
Proteacidites sp. cf. *sinulatus* (reticulate)	–	–	–	+	–	–	–	–	–	–	–	–
Proteacidites scaboratus	–	+	+	+	+	–	+	+	–	–	–	–
Unattributed *Proteacidites* spp.	–	+	2%	2%	2%	–	2%	2%	+	–	1%	–
Retimonocolpites peroreticulatus	–	–	–	–	–	–	–	–	–	+	–	–
Rhoipites/Tricolporites spp.	–	+	+	1%	+	–	1%	2%	+	6%	–	+
Tricolpites confessus		–		–	–	–	+	–	–	–	–	–
Tricolpites spp.	+	–	+	–	–	–	–	–	+	2%	+	–
Tetracolporites verrucosus	–	+	–	–	–	–	–	–	–	–	–	–
Tricolpites sp. cf. *T. trioblatus*	–	–	–	+	–	–	+	+	–	–	–	–
Tricolporites cf. *apoxyexinus*	–	+	–	–	–	–	–	–	–	–	–	–
Tetradopollis sp.	+	+	+	+	–	–	–	–	–	–	+	–
Total angiosperms	16%	10%	63%	56%	50%	–47%	50%	52%	68%	8%	29%	+

Table T5 (continued).

Fossil taxon	Depth (mbsf)											
	142.50	148.36	156.99	170.98	180.40	200.67	210.18	220.85	240.36	249.36	258.72	267.18
Reworked permo-Triassic	4%	4%	3%	4%	4%	(+)	4%	45	15%	+	+	–
Modern contaminants	+	+	+	+	+	+	+	+	6%	–	+	+
Pollen sum (excluding reworked spp.)	188	283	295	371	301	–32	285	337	156	169	368	NA

Notes: + = value < 1%, – = fossil taxon not recorded. NA = not applicable.

Table T6. Relative abundance of Late Cretaceous plant microfossil taxa, 276.60–362.03 mbsf. (See table notes. Continued on next page.)

Fossil taxon	Depth (mbsf)								
	276.60	288.26	296.06	297.01	304.95	314.45	314.96	343.00	362.03
Nonmarine algae									
Botryococcus	–	–	–	–	2%	–	–	–	–
Marine dinoflagellates									
Cribroperidinium sp.	–	–	–	–	+	–	–	–	–
Heterosphaeridium heterocanthum	–	–	+	+	+	+	+	+	–
Isabelidinium variabile	–	–	–	–	+	+	+	–	–
Spiniferites spp.	–	–	–		+				
Wuroia corrugata	–	–	–	–	–	+	–	–	–
Trochospiral liners	–	–	–	+	+	+	–	–	–
Undifferentiated microplankton	–	–	–	–	2%	–	+	–	–
Total dinocysts	–	–	+	+	5%	+	1%	+	–
Fungi									
Spores + hyphae	1%	9%	4%	4%	+	4%	1%	+	–
Cryptogams									
Aequitriradites spp.	–	–	–	–	–	–	–	+	–
Appendicisporites sp.	–	–	–	+	–	–	–	–	–
Baculatisporites spp.	4%	+	1%	+	+	1%	2%	–	–
Biretisporites spp.	+	+	+	+	+	+	+	+	–
Camarozonosporites australiensis	+	–	–	+	–	–	–	–	–
Ceratosporites equalis	+	–	+	+	+	–	+	–	–
Cicatricosisporites australiensis	+	+	+	+	2%	+	+	–	–
Cicatricosisporites ludbrookiae	+	–	–	–	–	–	–	–	–
Coptospora sp. A	+	–	+	+	–	–	+	–	–
Cyathidites spp.	4%	15%	2%	2%	4%	2%	2%	2%	–
Dictyophyllidites spp.	–	–	–	–	+	+	–	–	–
Foraminisporis asymmetricus	–	–	–	+	–	–	–	–	–
Gleicheniidites sp. A	+	+	–	+	–	+	+	+	–
Gleicheniidites spp.	+	–	–	–	+	+	1%	8%	–
Kraeuselisporites spp.	+	–	+	–	–	–	–	–	–
Laevigatosporites ovatus/major	2%	+	4%	1%	+	+	+	–	–
Laevigatosporites sp. A	–	–	–	–	–	+	–	–	–
Leptolepidites spp.	–	–	+	–	–	–	–	–	–
Nevesisporites dailyii	+	+	+	–	–	–	–	–	–
Osmundacidites	+	–	+	–	–	+	–	–	–
Retitriletes australoclavatidites	2%	–	+	–	+	–	+	2%	–
Retitriletes eminulus	+	–	–	–	–	–	–	–	–
Retitriletes nodosus	–	–	–	+	–	–	–	–	–
Stereisporites antiquisporites	+	–	–	–	+	–	1%	+	–
Stereisporites sp. A	–	–	–	–	–	–	+	–	–
Triporoletes reticulatus	+	–	–	–	–	–	–	–	–
Verrucatosporites sp. A	+	–	–	–	–	–	–	+	–
Undifferentiated trilete spores	+	–	3%	4%	–	+	1%	4%	–
Total cryptogams	16%	20%	8%	7%	6%	6%	10%	16%	–
Gymnosperms									
Alisporites grandis	–	–	+	–	–	+	+	–	–
Araucariacites australis	20%	7%	28%	19%	11%	33%	24%	16%	–
Balmeiopsis limbata	–	–	+	–	–	+	+	–	–
Cupressacites	1%	1%	3%	1%	4%	5%	2%	6%	–
Dilwynites granulatus	4%	–	3%	4%	2%	4%	4%	6%	–
Dilwynites sp. A (microgranulate)	4%	1%	2%	2%	–	7%	1%	–	–
Dilwynites sp. B (microechinate)	–	–	–	+	–	–	–	–	–
Exesipollenites tumulus	–	+	–	–	–	–	+	–	–
Lygistepollenites florinii	–	–	–	–	?	–	–	–	–
Microcachrydites antarcticus	5%	12%	2%	1%	2%	2%	4%	8%	–
Phyllocladidites mawsonii	1%	3%	1%	+	5%	1%	1%	+	–
Phyllocladidites reticulosaccatus	+	–	+	–	4%	–	+	–	–
Podocarpidites spp.	35%	39%	45%	42%	55%	33%	50%	46%	+
Trichotomosulcites subgranulosus complex	12%	14%	4%	25%	6%	5%	1%	2%	+
Trisaccites spp.	–	–	–	+	–	1%	–	–	–
Vitreisporites spp.	–	–	–	–	–	–	+	–	–
Undifferentiated gymnosperms	+	+	1%	–	–	–	+	4%	–
Total gymnosperms	82%	–80%	90%	92%	92%	91%	88%	88%	+
Angiosperms									
Australopollis obscurus	1%	1%	+	+	2%	+	+	–	–
Erdtmanipollis sp.	+	–							

Table T6 (continued).

Fossil taxon	Depth (mbsf)								
	276.60	288.26	296.06	297.01	304.95	314.45	314.96	343.00	362.03
Rhoipites/Tricolporites spp.	–	–	+	–	+	+	–	–	–
Tricolpites spp.	–	–	+	–	–	–	–	–	–
Total angiosperms	2%	1%	2%	+	2%	+	+	–	–
Reworked permo-Triassic	+	+	–	–	1%	+	+	–	–
Modern contaminants	–	+	–	+	–	–	–	35%	+
Pollen sum (excluding reworked spp.)	245	60	188	133	167	282	276	52	NA

Note: + = value < 1%, – = fossil taxon not recorded. NA = not applicable.

Plate P1. 1–4. Sample 188-1166A-16R-CC, 26–36 cm; 148.36 mbsf (500×); (1, 2) *Deflandrea "prydzensis"* ms; (3, 4) *Deflandrea antarctica* complex. **5–7.** Sample 188-1166A-15R-CC, 3–5 cm; 142.50 mbsf; (5, 6) *Deflandrea* sp. cf. *Deflandrea asymmetrica* (788×); (7) *Tritonites spinosus* (1250×).

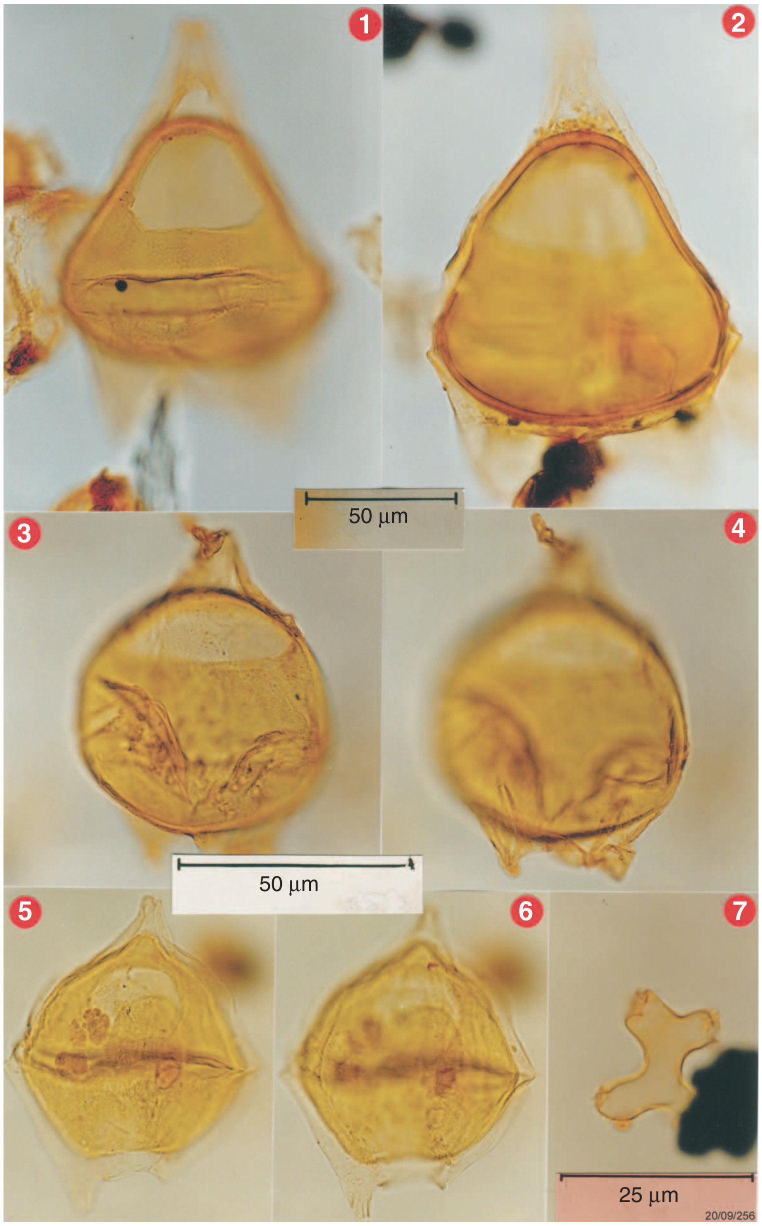


Plate P2. 1–3. *Vozzhenikovia* sp. cf. *Gippslandia extensa;* 180.40 mbsf (Sample 188-1166A-20R-CC, 30–40 cm) (788×). **4–7.** Sample 188-1166A-16R-CC. 26–36 cm; 148.36 mbsf; (4, 5) *Enneadocysta partridgei* (788×); (6, 7) *Turbiosphaera* sp. cf. *Turbiosphaera filosa* (500×).

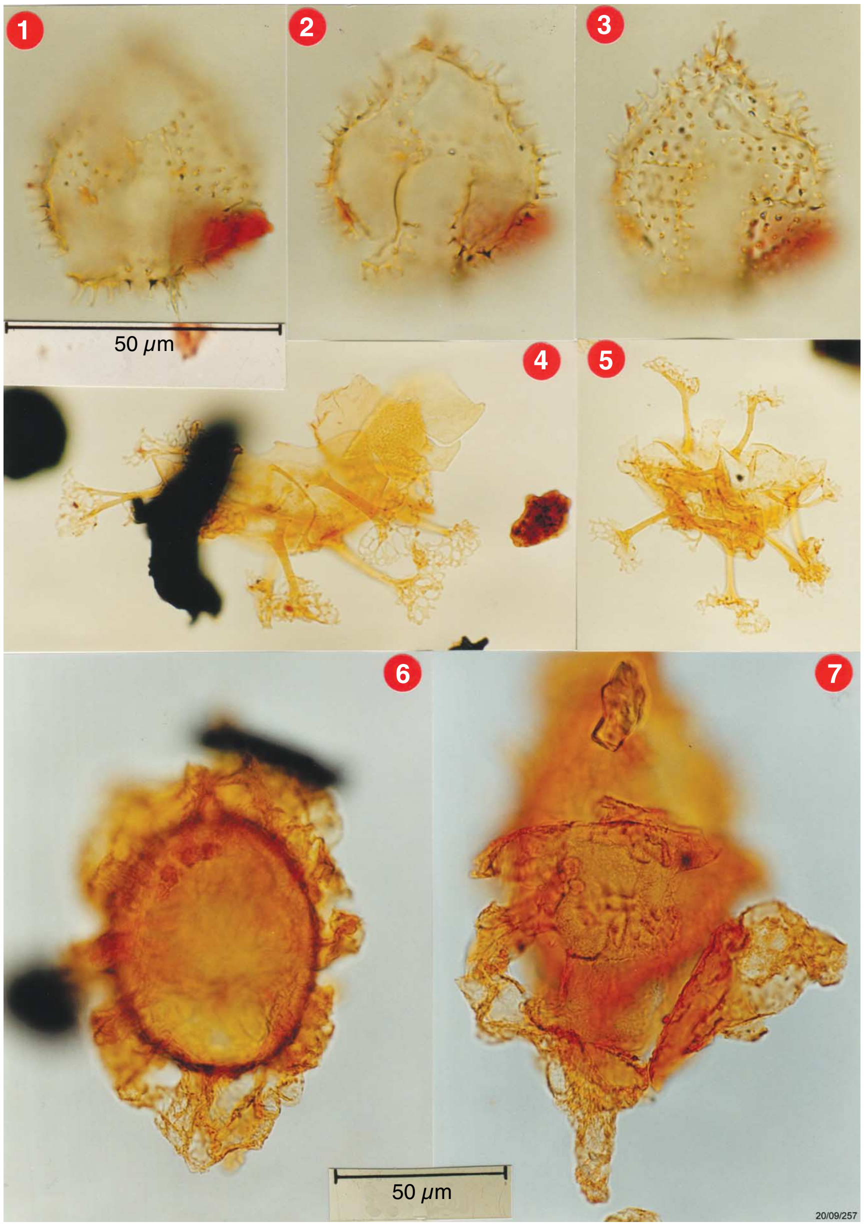


Plate P3. **1.** *Spinidinium macmurdoense;* 142.50 mbsf (Sample 188-1166A-15R-CC, 3–5 cm) (788×). **2.** *Spinidinium rotundum;* 156.99 mbsf (Sample 188-1166A-17R-CC, 84–99 cm) (788×). **3–5.** Sample 188-1166A-16R-CC, 26–36 cm; 148.36 mbsf (788×); (3) unidentified dinoflagellate cf. *Hemicystodinium zoharyi;* (4) *Hystrichosphaeridium tubiferum;* (5) *Schematophora* sp. cf. *obscura*. **6.** cf. *Adnatosphaeridium reticulense;* 142.5 mbsf (Sample 188-1166A-15R-CC, 3–5 cm) (500×). **7.** *Thalassiophora* sp. cf. *Thalassiophora pelagica;* 220.85 mbsf (Sample 188-1166A-24R-CC, 85 cm) (125×).

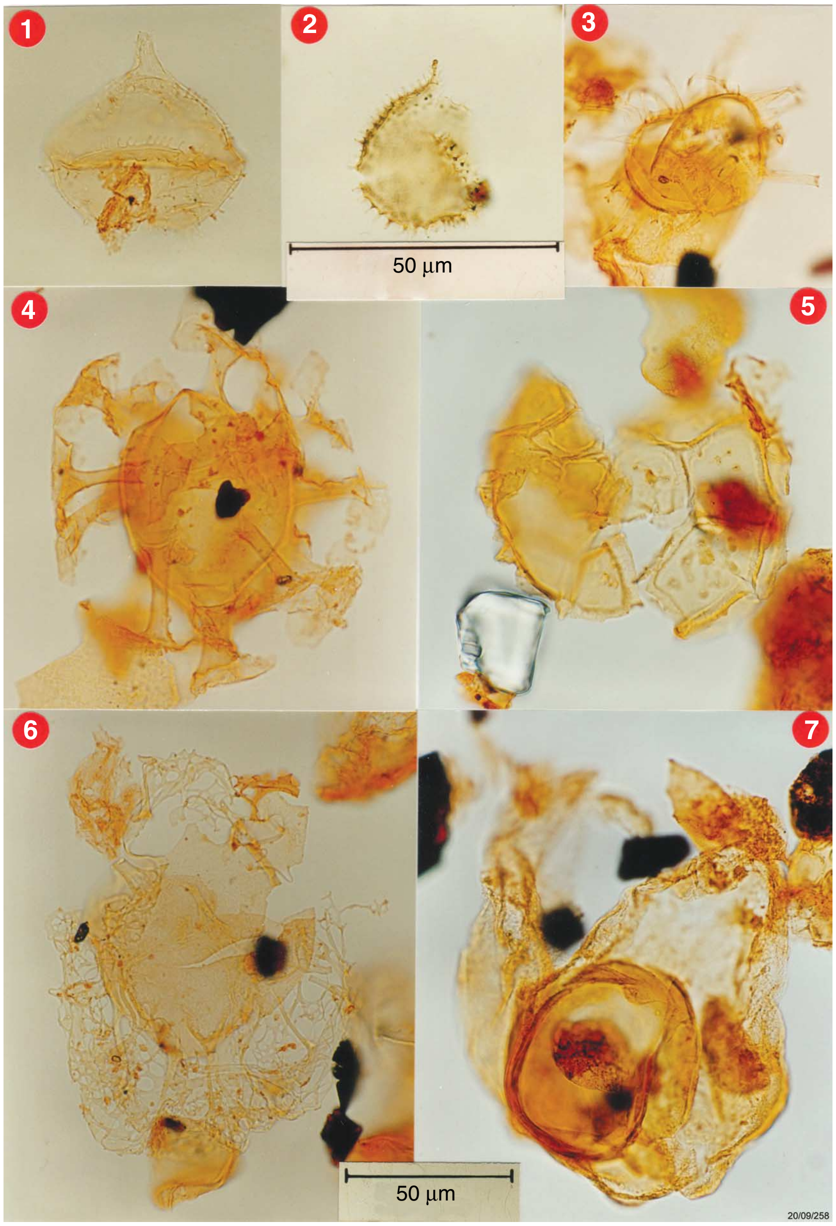


Plate P4. **1.** *Impagidinium* sp. cf. *Impagidinium victorianum;* 142.50 mbsf (Sample 188-1166A-15R-CC, 3–5 cm) (500×). **2.** *Spinidinium* sp. cf. *Vozzhenikovia apertura;* 148.36 mbsf (Sample 188-1166A-16R-CC, 26–36 cm) (788×). **3.** *Cyclopsiella* sp.; 210.18 mbsf (Sample 188-1166A-23R-CC, 8–18 cm) (788×). **4.** *Lejeunecysta* sp.; 148.36 mbsf (Sample 188-1166A-16R-CC, 26–36 cm) (788×). **5.** cf. *Selenopemphix* sp.; 142.50 mbsf (Sample 188-1166A-15R-CC, 3–5 cm) (788×). **6, 7.** *Fischeripollis* sp. A; 148.36 mbsf (Sample 188-1166A-16R-CC, 26–36 cm) (788×).

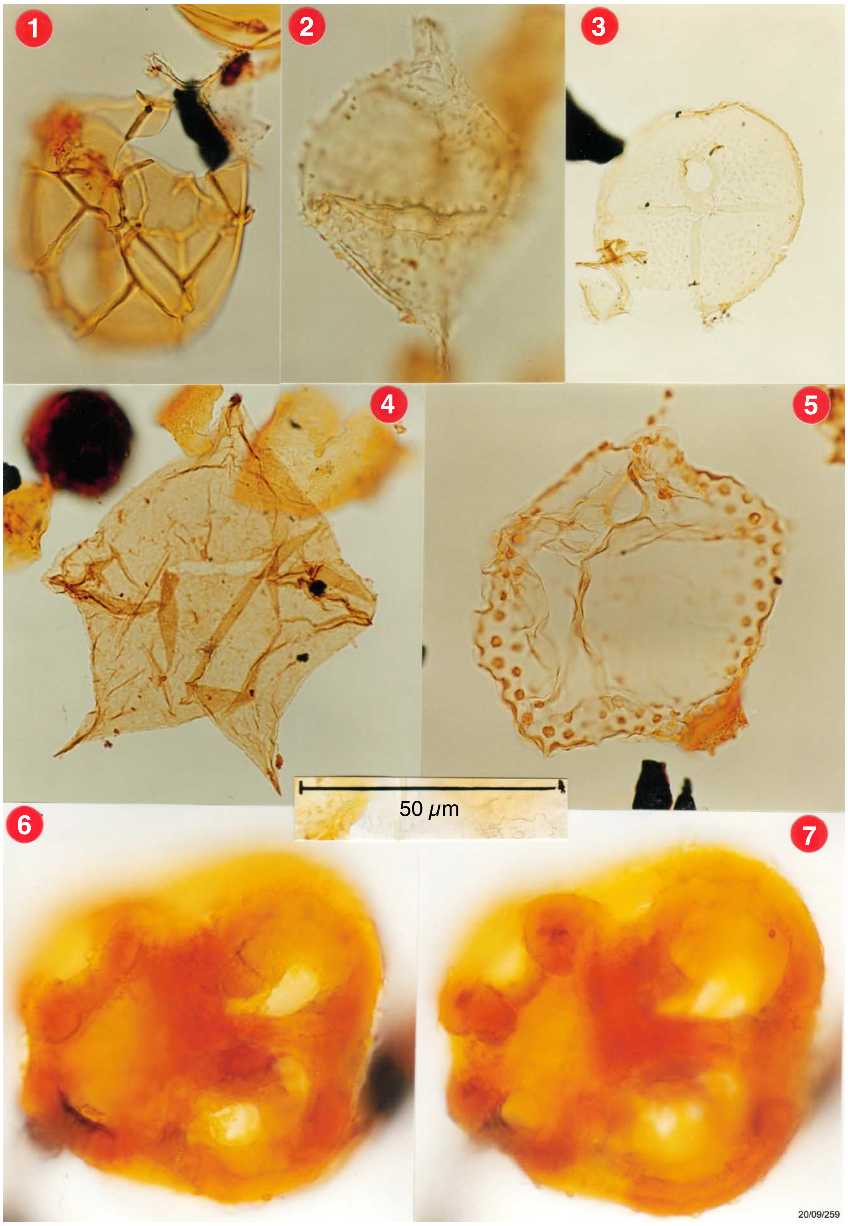


Plate P5. Photomicrographs taken at 788× magnification. **1.** *Fischeripollis* sp. (fragment); 148.36 mbsf (Sample 188-1166A-16R-CC, 26–36 cm). **2–5.** *Fischeripollis* sp. A; 142.50 mbsf (Sample 188-1166A-16R-CC, 26–36 cm). **6–8.** Sample 188-1166A-17R-CC, 84–99 cm; 156.99 mbsf; (6) *Nothofagidites goniatus*; (7, 8) *Integricorpus* sp. **9**, **10.** *Periporopollenites "spinosus"* ms.; 180.40 mbsf (Sample 188-1166A-20R-CC, 30–40 cm). **11**, **12.** *Peroporopollenites hexaporus;* 156.99 mbsf (Sample 188-1166A-17R-CC, 84–99 cm. **13–15.** *Stereisporites "stellus"* ms.; 180.4 mbsf (Sample 188-1166A-20R-CC, 30–40 cm). **16.** *Corrudinium* sp. cf. *incompositum;* 142.50 mbsf (Sample 188-1166A-16R-CC, 26–36 cm).

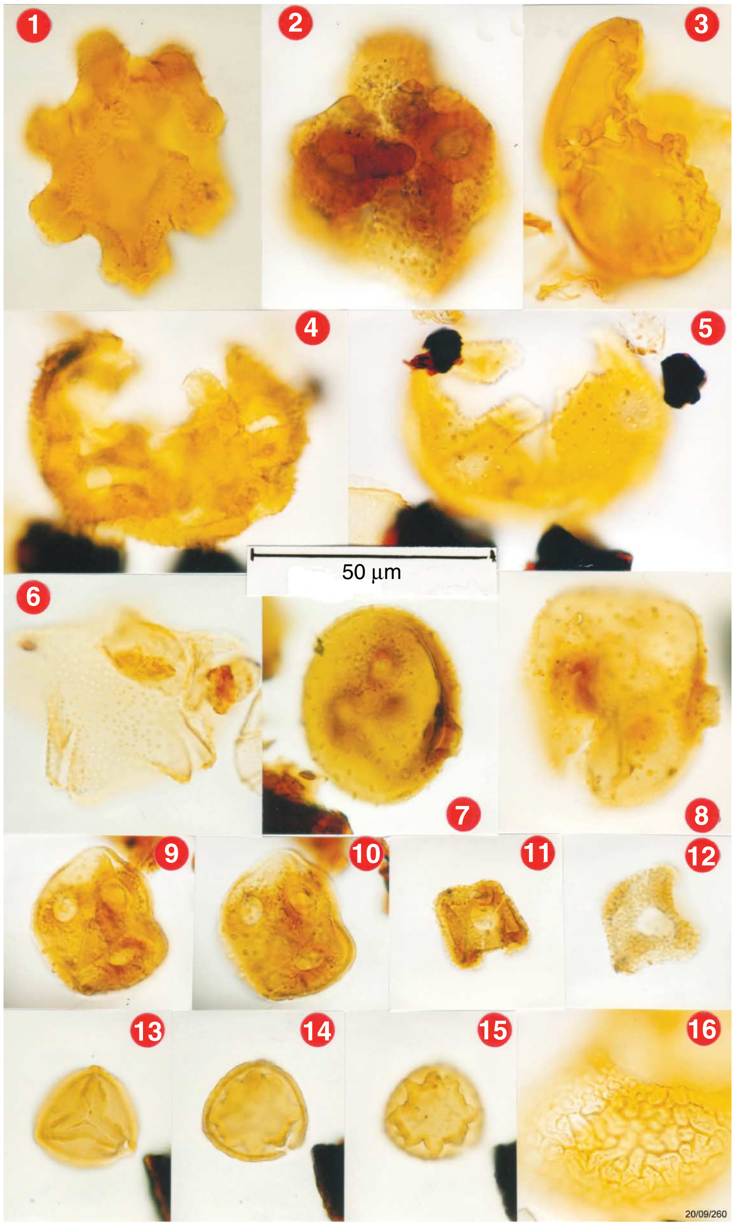


Plate P6. Photomicrographs taken at 788× magnification. **1, 2.** Sample 188-1166A-17R-CC, 84–99 cm; 156.99 mbsf; (1) *Nothofagidites flemingii* complex; (2) *Nothofagidites brachyspinulosus* complex. **3, 4.** Sample 188-1166A-16R-CC, 26–36 cm; 148.36 mbsf; (3) *Ilexpollenites* sp. (clavae in crotonoid arrangement); (4) Tricolporate sp. cf. *Tricolporites apoxyexinus*. **5.** *Tetradites* sp.; 156.99 mbsf (Sample 188-1166A-17R-CC, 84–99 cm). **6.** *Liliacidites* sp. cf. *Lilium;* 142.50 mbsf (Sample 188-1166A-16R-CC, 26–36 cm). **7.** Var. of *Forcipites longus;* 148.36 mbsf (Sample 188-1166A-16R-CC, 26–36 cm). **8.** Var. of *Gambierina edwardsii;* 156.99 mbsf (Sample 188-1166A-17R-CC, 84–99 cm). **9.** *Beaupreadites elegansiformis;* 180.40 mbsf (Sample 188-1166A-20R-CC, 30–40 cm). **10, 11.** Sample 188-1166A-16R-CC, 26–36 cm; 148.36 mbsf; (10) var. of *Forcipites sabulosus;* (11) *Tetracolporites verrucosus*. **12–15.** Sample 188-1166A-17R-CC, 84–99 cm; 156.99 mbsf; (12, 13) *Proteacidites* sp. cf. *kopiensis;* (14, 15) *Proteacidites "lapis"* ms. **16, 17.** Var. of *Proteacidites angulatus;* 170.98 mbsf (Sample 188-1166A-19R-1, 98 cm). **18.** *Lygistepollenites* sp. cf. *Lygistepollenites balmei;* 142.50 mbsf (Sample 188-1166A-16R-CC, 26–36 cm). **19.** *Octodinium askinae;* 148.36 mbsf (Sample 188-1166A-16R-CC, 26–36 cm).

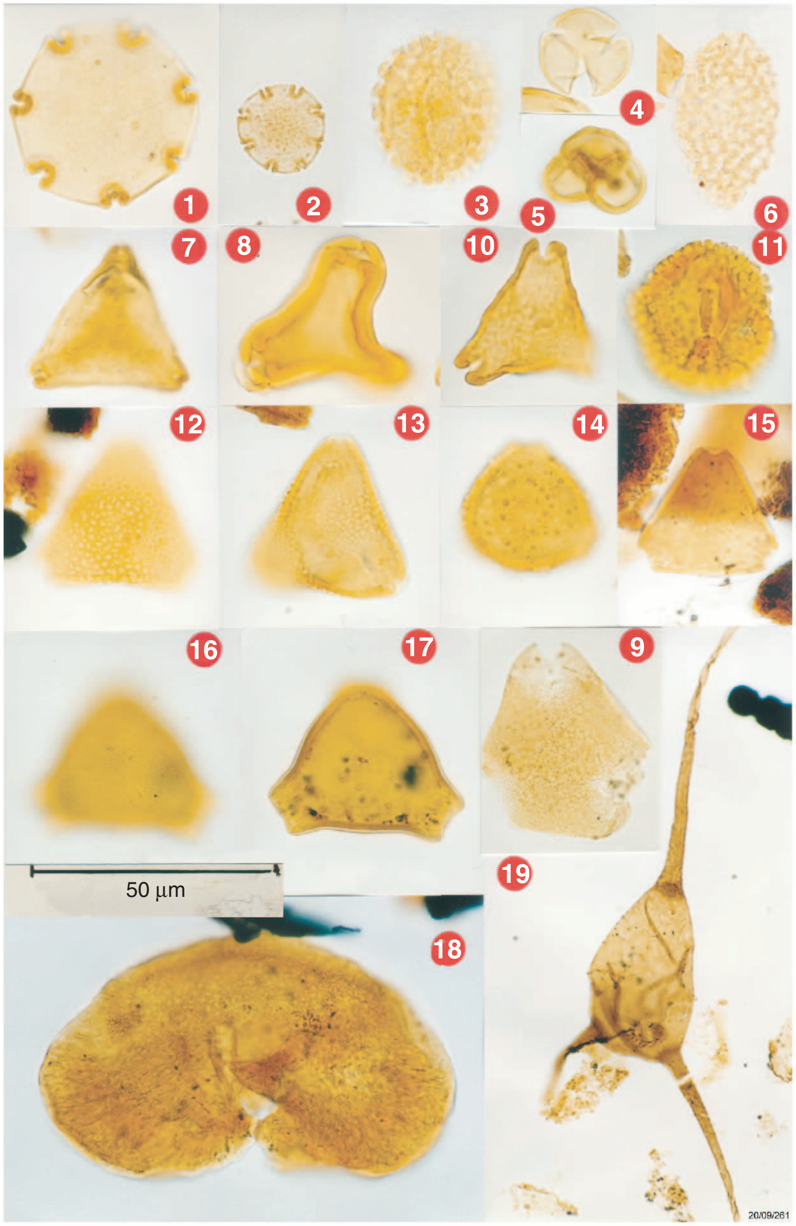


Plate P7. Photomicrographs taken at 788× magnification. **1.** Unidentified megaspore (?Devonian); 276.60 mbsf (Sample 188-1166A-30R-1, 20 cm). **2, 3.** Sample 188-1166A-31R-CC; 288.26 mbsf; (2) unidentified megaspore (?Devonian); (3) unidentified foveolate spore (Permian). **4, 5.** Sample 188-1199A-32R-1, 26 cm; 296.06 mbsf; (4) Trochospiral lining of an unidentified foraminifer; (5) unidentified sporomorph. **6–8.** Sample 188-1166A-31R-CC; 288.26 mbsf. (6, 8) *Exesipollenites tumulus* (the specimen in fig. 6 appears to be encapsulated within a *Corollina* pollen); (7) *Microbaculispora tentula* (Permian).

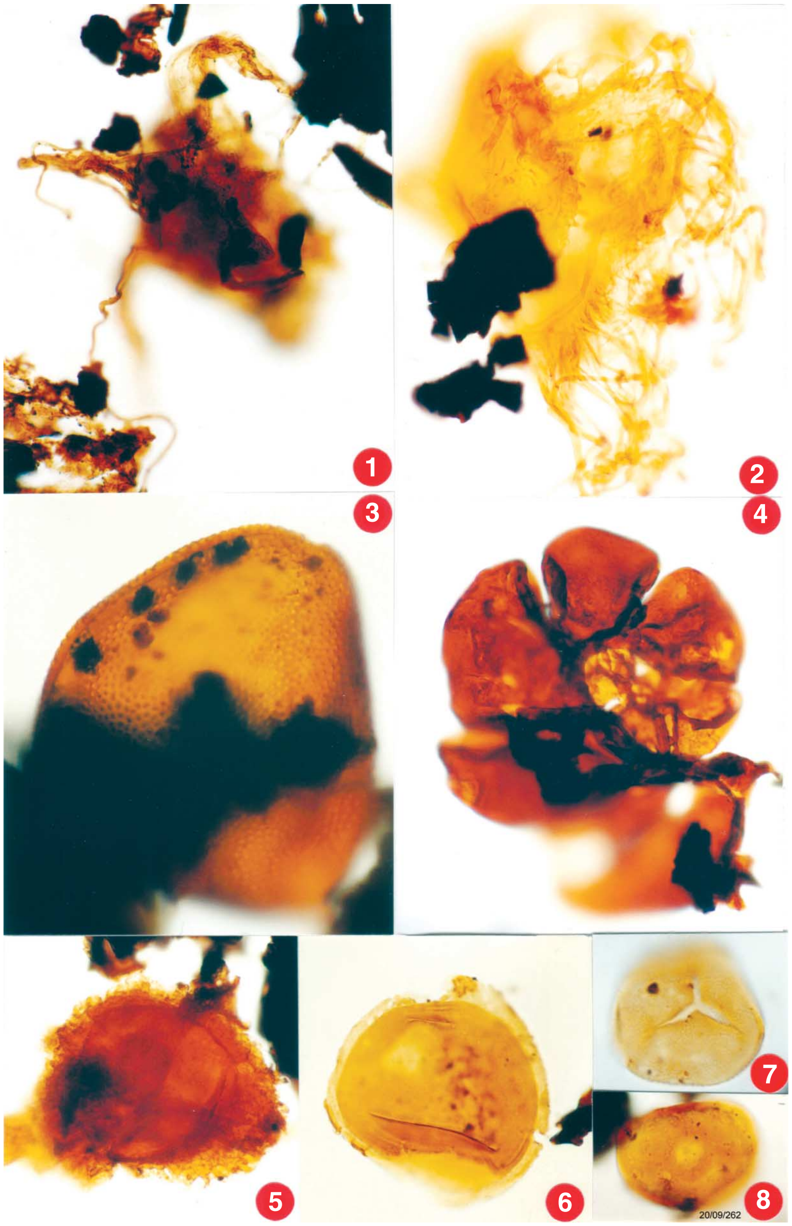
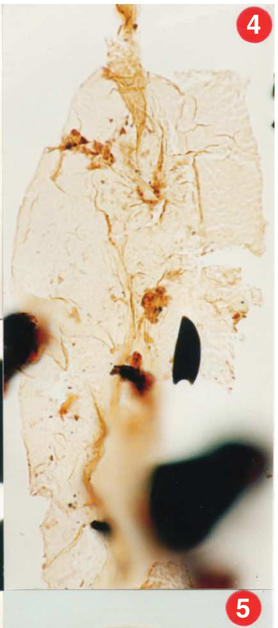
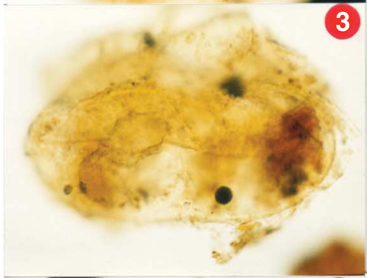


Plate P8. Photomicrographs taken at 788× magnification. **1.** *Heterosphaeridium heterocanthum*; 298.09 mbsf (Sample 188-1166A-32R-CC). **2, 3.** Sample 188-1166A-33R-CC, 95 cm; 304.95 mbsf. (2) *Isabelidinium variable* (apical horn and archeopyle); (3) *Isabelidinium variable* (weakly developed antapical horns). **4.** *Wuroia corrugata;* 314.95 mbsf (Sample 188-1166A-34R-CC, 55 cm). **5, 6.** Sample 188-1166A-30R-1, 20 cm; 276.60 mbsf. (5) *Osmundacidites* sp. cf. *Osmundacidites wellmanii;* (6) *Kraeuselisporites majus*. **7.** *Dictyophyllidites* sp.?; 258.72 mbsf (Sample 188-1166A-28R-CC). **8, 9.** *Ceratosporites* sp. cf. *equalis* (proximal and equatorial views); 296.06 mbsf (Sample 188-1166A-32R-1, 26 cm).





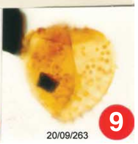


Plate P9. Photomicrographs taken at 788× magnification. **1–6.** Sample 188-1166A-27R-CC; 249.42 mbsf; (1, 2) *Laevigatosporites* sp. A; (3, 4) *Coptospora* sp. A; (5) *Camarazonosporites bullatus* var. (proximal view); (6) *Camarozonosporites bullatus* var. (distal view showing hilum). **7.** *Dilwynites* sp. A (microgranulate); 276.60 mbsf (Sample 188-1166A-30R-1, 20 cm). **8.** *Dilwynites* sp. B (microechinate); 249.42 mbsf (Sample 188-1166A-27R-CC). **9.** *Gleicheniidites* sp. A; 304.95 mbsf (Sample 188-1166A-33R-CC, 95 cm). **10, 11.** Sample 188-1166A-30R-1, 20 cm; 276.60 mbsf; (10) *Dilwynites granulatus;* (11) *Dilwynites* sp. cf. *Dilwynites tuberculatus*.

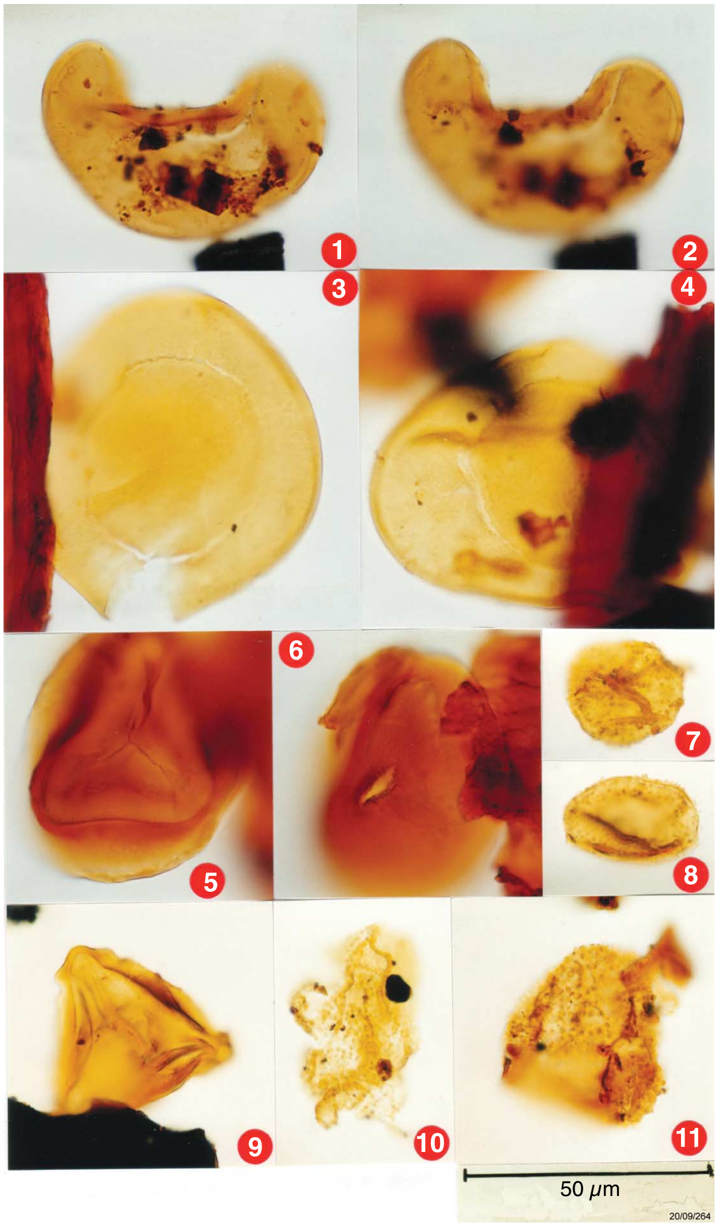


Plate P10. Photomicrographs taken at 788× magnification. **1–3.** *Dilwynites* sp. A (microgranulate); 276.60 mbsf (Sample 188-1166A-30R-1, 20 cm). **4.** *Dilwynites* sp. B (microechinate); 249.42 mbsf (Sample 188-1166A-27R-CC). **5.** *Araucariacites australis;* 304.95 mbsf (Sample 188-1166A-33R-CC, 95 cm). **6, 7.** Sample 188-1166A-27R-CC; 249.42 mbsf; (6) *Phyllocladidites reticulosaccatus* var.; (7) *Cupressacites* sp. **8.** *Trichotomosulcites subgranulosus* var.; 296.06 mbsf (Sample 188-1166A-32R-1, 26 cm). **9, 10.** *Microcachryidites antarcticus* var.; 249.42 mbsf (Sample 188-1166A-27R-CC). **11–14.** *Phyllocladidites mawsonii* vars.; 276.60 mbsf (Sample 188-1166A-30R-1, 20 cm). **15, 16.** Sample 188-1166A-32R-1, 26 cm; 296.06 mbsf; (15) *Australopollis obscurus;* (16) cf. *Australopollis obscurus*. **17.** *Periporopollenites* sp. cf. *Periporopollenites polyoratus;* 276.60 mbsf (Sample 188-1166A-30R-1, 20 cm). **18.** *Retimonocolpites peroreticulatus;* 249.42 mbsf (Sample 188-1166A-27R-CC). **19.** *Proteacidites* aff. *Proteacidites polymorphus;* 276.60 mbsf (Sample 188-1166A-30R-1, 20 cm). **20, 21.** *Ailanthipites* sp. cf. sp. *Ailanthipites paenestriatus* (modern contaminant?); 249.42 mbsf (Sample 188-1166A-27R-CC). **22.** *Stereisporites* sp. cf. *Stereisporites australis;* 343.00 mbsf (Sample 188-1166A-37R–CC, 2 cm).