

Oligocene and Early Miocene Terrestrial Palynology of the Cape Roberts Drillhole CRP-2/2A, Victoria Land Basin, Antarctica

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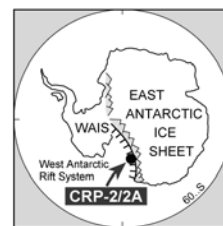
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Abstract - Sparse terrestrial palynomorphs (spores and pollen) were recovered from glaciogene Lower Miocene and Oligocene core samples from the Cape Roberts Project (CRP) drillhole CRP-2/2A, Victoria Land Basin, Antarctica. Rarity of palynomorphs probably results from the sparse periglacial vegetation in the surrounding landscape at the time of deposition, as well as dilution from rapid sediment accumulation. The Miocene and Late Oligocene vegetation is interpreted as including herb-moss tundra with low-growing woody plants (including *Nothofagus* and podocarp conifers) in more protected areas, similar to that encountered in the Miocene of CRP-1. Species richness and numbers of specimens increase downhole, a trend that begins very gradually below ~307 mbsf, and increases below ~443 mbsf through the Early Oligocene. These lower assemblages reflect low diversity woody vegetation dominated by several species of *Nothofagus* and podocarps, growing in somewhat milder conditions, though still cold temperate to periglacial in the Early Oligocene. The CRP-2/2A core provides new biostratigraphical information, such as the First Appearance Datums (FADs) of *Tricolpites* sp.a near the Oligocene/Miocene boundary, and Marchantiaceae in the Early/Late Oligocene transition: these are taxa that along with *N. lachlaniae*, *Coptospora* spp. and *Podocarpidites* sp.b characterize assemblages recovered from outcrops of the Pliocene Sirius Group in the Transantarctic Mountains. Some elements of the extremely hardy periglacial tundra vegetation that survived in Antarctica into the Pliocene had their origin in the Oligocene during a time of deteriorating (colder, drier) climatic conditions. The CRP results highlight the long persistence of this tundra vegetation, through approximately 30 million years of dynamically changing climatic conditions. Rare Jurassic and more common Permian-Triassic spores and pollen occur sporadically throughout the core. These are derived from Jurassic Ferrar Group sediments, and from the Permian-Triassic Victoria Group, upper Beacon Supergroup. Higher frequencies of reworked Beacon palynomorphs and coaly organic matter below ~307 mbsf indicate greater erosion of the Beacon Supergroup for this lower part of the core. A color range from black, severely metamorphosed specimens, to light-colored, yellow (indicating low thermal alteration), reworked Permian palynomorphs, indicates local provenance in the dolerite-intruded Beacon strata of the Transantarctic Mountains, as well as areas (now sub-ice) of Beacon strata with little or no associated dolerite well inland (cratonwards) of the present Transantarctic Mountains.



INTRODUCTION

Until recent drilling projects in the Ross Sea area, the middle Cenozoic vegetational history of this part of Antarctica has remained somewhat of a mystery. Typically, because of the widely accepted notion of a post-Eocene glaciated landscape, post-Eocene vegetation in the areas adjacent to the Ross Sea had been largely discounted. The Cape Roberts drillholes CRP-1 and CRP-2/2A provide a sedimentary record that spans the Early Oligocene to Early Miocene, albeit with many unconformities, and terrestrial palynomorphs recovered from these cores enable reconstruction of at least part of the contemporaneous vegetation (Cape Roberts Science Team [CRST], 1998, 1999; Raine, 1998).

Cape Roberts Project CRP-2/2A was sited 14.2 km offshore from Cape Roberts on the annual sea-ice in the Victoria Land Basin, Ross Sea, at a water depth of 177.94 m, at 77.006° S and 163.719° E (see location map),

and was cored from 16 October to 25 November, 1998, to a total depth of 624.15 metres below sea floor (mbsf). The uppermost 27 mbsf of CRP-2/2A include Quaternary and Pliocene sediments, while the strata below 27 mbsf (Fig. 1) are of Early Miocene and Oligocene age (CRST, 1999; McIntosh, this volume; Scherer et al., this volume; Watkins & Villa, this volume; Wilson et al., Chronostratigraphy, this volume). The Miocene and Oligocene sediments carry a distinct glaciogene imprint throughout and comprise cyclic glaciomarine nearshore to offshore sediments, with a range of lithologies from diamictites and conglomerates to laminated mudstones (CRST, 1999).

This paper discusses terrestrial palynomorphs from the Miocene and Oligocene portion of CRP-2/2A. Samples were processed for palynology at McMurdo Station as described in the Initial Reports (CRST, 1998, 1999) and Simes & Wrenn (1998): 183 samples were collected for palynological analysis and 123 of these were processed and examined for spores and pollen (collectively termed

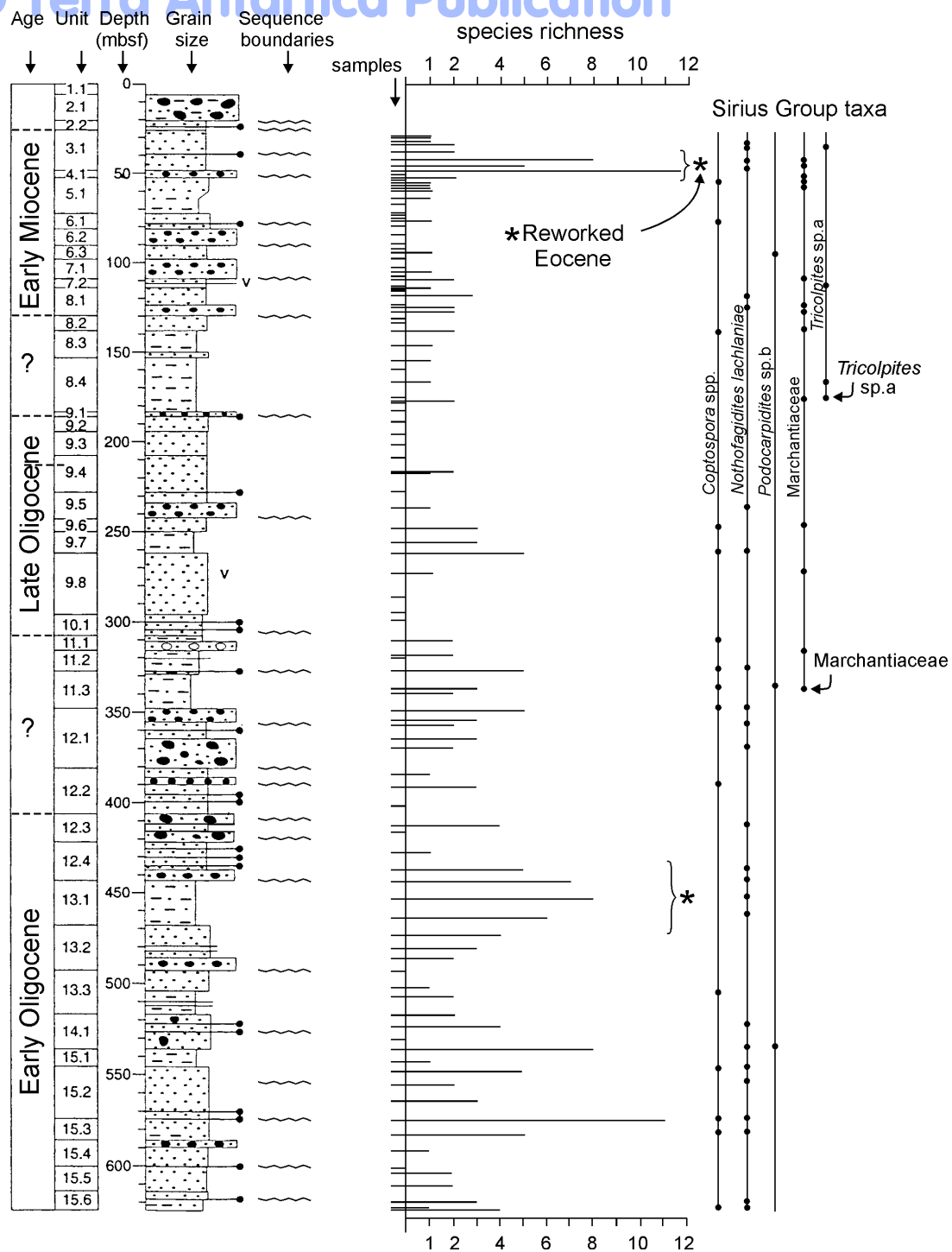


Fig. 1 - Species richness (diversity) of Cenozoic miospores, expressed as numbers of taxa. Intervals in which redeposited Eocene taxa are relatively abundant are indicated by stars. The right-hand side of the diagram shows distribution of taxa also known from outcrops of the Sirius Group (see text) and the FADs of two of the taxa. Columns on the left include the lithostratigraphic units (eg. 1.1), lithologic column and sequence boundaries as described in CRST 1999.

miospores). All prepared microscope slides were completely scanned to maximize recovery of the few preserved miospores. Marine palynomorphs, in contrast, are abundant in most samples and are discussed in CRST (1999) and Hannah, Wilson & Wrenn (this volume).

The overall impression when working with these samples is the extremely low abundance of miospores. This was also true for the CRP-1 samples (Raine, 1998) and for other Cenozoic drillhole and outcrop material

from the vicinity (e.g. Brady & Martin, 1979; Truswell, 1986; Mildenhall, 1989; Askin & Ashworth, 1998). For the CRP-2/2A material, the sparseness is interpreted (CRST, 1999) as resulting from both sparse contemporaneous vegetation in the surrounding landscape, and dilution by rapid sediment accumulation. Raine (1998) noted the inherent problems for interpretation associated with sparse miospore assemblages: the low numbers of miospores are not an adequate reflection of the vegetation, and

reworked specimens may form a significant proportion of the assemblage. Modern contaminants are not an important factor in CRP-2/2A. Differentiation of the contemporaneous miospore assemblage from reworked specimens, however, remains a problem for the Cape Roberts material, especially as there is little independent evidence on stratigraphic ranges for many miospore species in this region of Antarctica, and small amounts of burial have resulted in both contemporaneous and most reworked Cenozoic specimens being of similar light color (yellow) and similar autofluorescence. In previous studies, interpretation of Antarctic Neogene assemblages in particular have been plagued by ambiguities in recognizing reworked material, as discussed by Raine (1998) and Askin (2000).

CRP-2/2A OLIGOCENE – EARLY MIOCENE ASSEMBLAGES

The Oligocene – Early Miocene miospore assemblages of CRP-2/2A are notably species and specimen poor (Tab. 1; Fig. 1). Sample details and composition of organic residues and miospore assemblages of CRP-2/2A are presented in the Initial Report (CRST, 1999); selected taxa are illustrated in figure 2 (see also figs. 5.10 and 5.11 of CRST 1999). Figure 1 plots species richness (diversity) of Cenozoic miospores. Total numbers of Cenozoic specimens for each sample are not plotted in figure 1, as these values almost exactly mirror the diversity plots. Total counts per sample are usually less than 10, and the highest frequency of specimens counted was 64 at 575.36–575.37 mbsf, notably much higher than all other samples, and almost twice that of the second highest, 34 at 40.54–40.55 mbsf. Intervals of higher species (and specimen) richness tend to coincide with intervals with noticeably increased occurrences of reworked Eocene dinoflagellate cysts (for dinocyst distribution data, see CRST, 1999), though this is not true for sample 575.36–575.37 mbsf. Two such intervals are bracketed and marked with a star on figure 1 as probably also including a significant proportion of reworked Eocene miospores, including for example in samples between 40.54 and 47.54 mbsf various species of *Nothofagidites*, plus *Osmundacidites wellmanii*, and conifers *Microcachrydites antarcticus* and *Trichotomosulcites subgranulatus*. This same argument for a reworked Paleogene origin for miospores found in Neogene sediments (because of association with reworked Eocene dinoflagellate cysts) has been used in the past (e.g. Wrenn, 1981; Truswell, 1986), but for the entire miospore assemblage.

The Miocene and Upper Oligocene sections of CRP-2/2A are similar, the main discernible variation being an increase in numbers of species and specimens below about 307 mbsf. This trend continues more markedly down through the Lower Oligocene strata below 443 mbsf. Miocene–Upper Oligocene strata are characterized by mostly single specimen occurrences, excluding the 40.54 to 47.54 mbsf interval where most of the miospores are probably reworked from older (?Eocene) sediments.

Figures 1 and 3 include the lithostratigraphic units,

lithologic column and sequence boundaries (as outlined in CRST 1999). Although specimen and species richness of contemporaneous miospores are generally greater in the finer-grained samples, as might be expected for deposition of silt-grade particles, we can discern no regular relationship between sequences (or parts of sequences) and composition of palynological assemblages. We believe that the numbers of preserved miospores (both contemporaneous and reworked) are too few for meaningful environmental interpretation at the individual sequence or cycle level. Statistically significant numbers of specimens (at least several hundred per sample) are desired for such interpretations, whereas only single or a few (64 at best) specimens were recovered from CRP-2/2A samples.

The upper part (Miocene) of CRP-2/2A repeats in part the Miocene succession recovered from CRP-1 (CRST, 1998; Raine, 1998). Like CRP-1, the Miocene and Late Oligocene successions of CRP-2/2A include spores of Bryophyta, listed in table 1 as Marchantiaceae and *Coptospora* spp. Modern affinities of these liverwort and moss spores are discussed in Raine (1998). Marchantiaceae and *Coptospora* spp. are important parts of the Sirius Group vegetation (see below), as are pollen of *Nothofagidites lachlaniae*, *Tricolpites* sp.a and *Podocarpidites* sp.b. All these miospores are believed to be contemporaneous with deposition. It is difficult to determine with certainty which of the other miospores are also contemporaneous and which are reworked. One of the more useful outcomes of the Cape Roberts Project, however, is the additional distribution data it provides, through much of the Oligocene and Early Miocene, allowing the beginnings of a Cenozoic spore and pollen biostratigraphy for the McMurdo Sound area.

It is likely that some of the other *Nothofagidites* species besides *N. lachlaniae* are derived from the nearby vegetation at time of deposition, especially during the Early Oligocene. Examples of these might include some of the *Nothofagidites* undifferentiated *fusca* group which occur consistently though rarely throughout the core and show a noticeable increase in frequency downhole in the Early Oligocene, and some of the *Nothofagidites flemingii* and *N. cf. flemingii* (a smaller form), which are consistently though rarely present throughout, and also occur in CRP-1. This is likely also true for most of the podocarp conifer species of *Podocarpidites*.

Miospores previously described from various outcrops of the (?)Pliocene Sirius Group in the Transantarctic Mountains comprise very low diversity assemblages of *Coptospora* (at least three species) and Marchantiaceae spores, and pollen of *Nothofagidites lachlaniae*, *Tricolpites* sp.a and *Podocarpidites* sp.b (though some have been reported under different names, Askin & Markgraf, 1986; Hill & Truswell, 1993; Askin & Ashworth, 1998; Wilson et al., 1998). These taxa are all important elements of the CRP Oligocene and Miocene, and their occurrences in the CRP-2/2A core are plotted in figure 1 under Sirius Group taxa. *Nothofagidites lachlaniae* and *Coptospora* spp. occur throughout the sampled core. The woody *Nothofagus* plant that produced pollen of *Nothofagidites lachlaniae* (Hill & Truswell, 1993) and leaves of *Nothofagus beardmorensis* (Hill et al., 1996) was interpreted, largely from its wood anatomy, as being a prostrate tundra plant in Sirius Group

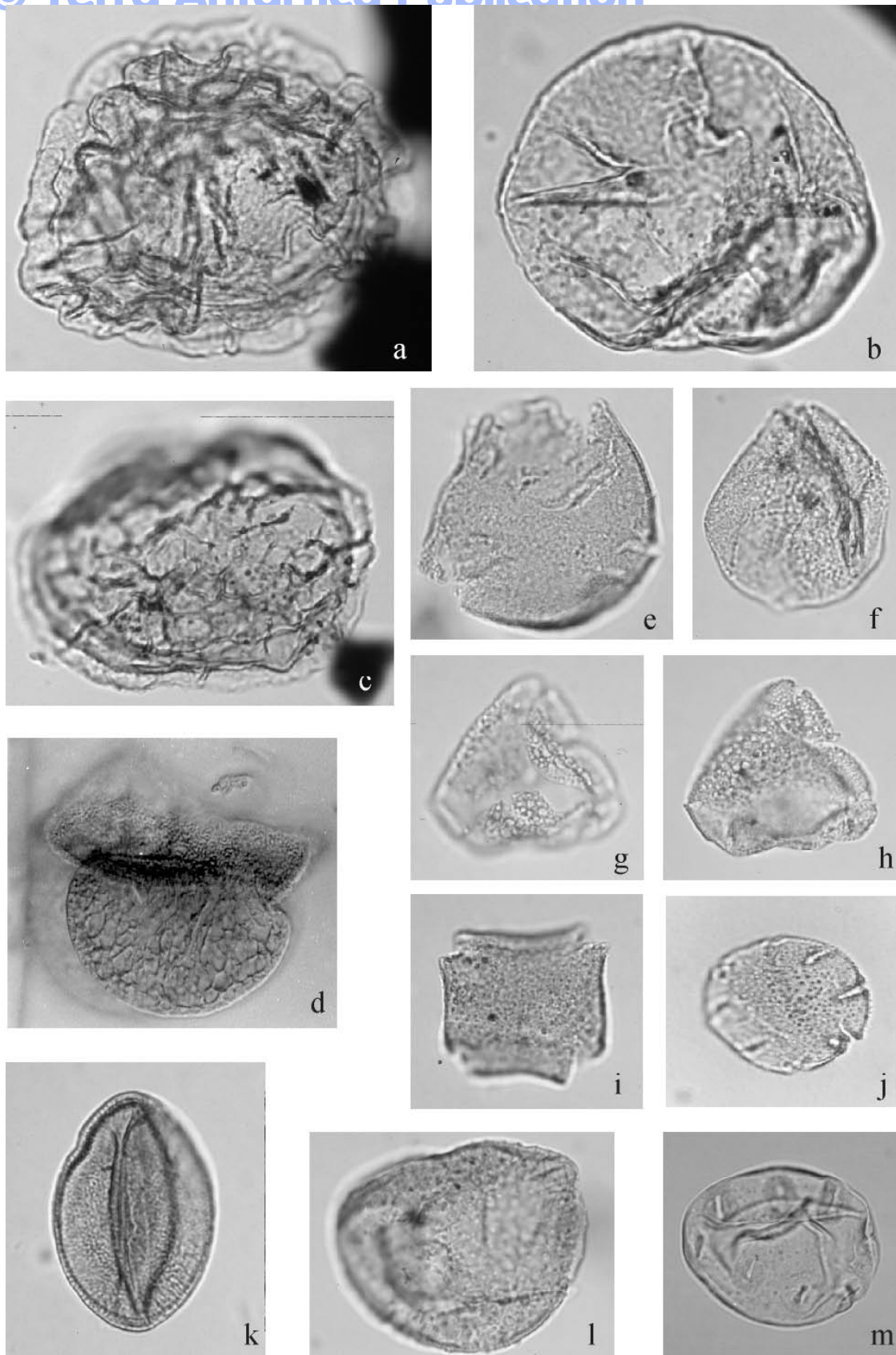


Fig. 2 – Photomicrographs of selected spores and pollen from CRP-2/2A, all at magnification approximately x1000. All are Cenozoic taxa. a) Marchantiaceae, depth 44.08–44.09 mbsf, P67/1, England Finder coordinates E49/3, maximum dimension 74 μm ; b) *Coptospora* sp., 575.36–575.37 mbsf, P174/3, L54/0, 71 μm ; c) *Ricciaesporites* sp., 575.36–575.37 mbsf, P174/2, M42/0, 67 μm ; d) *Podocarpidites* sp.b, 22.33–22.34 mbsf, P72/1, F56/2; e) *Assamiapollenites* cf. *incognitus* Pocknall & Mildenhall, 215.49–215.52 mbsf, P113/2, K43/2, 44 μm ; f) *Cyperaceapollis* sp., 444.76–444.78 mbsf, P146/2, O35/1, 39 μm ; g, h) *Phormium* sp., proximal and distal focus levels respectively, 346.12–346.13 mbsf, P144/1, P43/3, 34 μm ; i) ?*Stylidiaceae*, 47.41–47.54 mbsf, P57/1, W50/0, 31 μm ; j) *Nothofagidites lachlaniae* (Couper) Pocknall & Mildenhall, 556.06–556.07 mbsf, P173/4, C29/0, 31 μm ; k) *Tricolpites* sp.a, 21.02–21.03 mbsf, P63/1, N52/3, 45 μm ; l) ?*Ranunculaceae*, 453.26–453.27 mbsf, P159/3, V54/0, 47 μm ; m) *Nothofagidites flemingii* (Couper) Potonié, 47.41–47.54 mbsf, P57/2, C36/2, 37 μm .

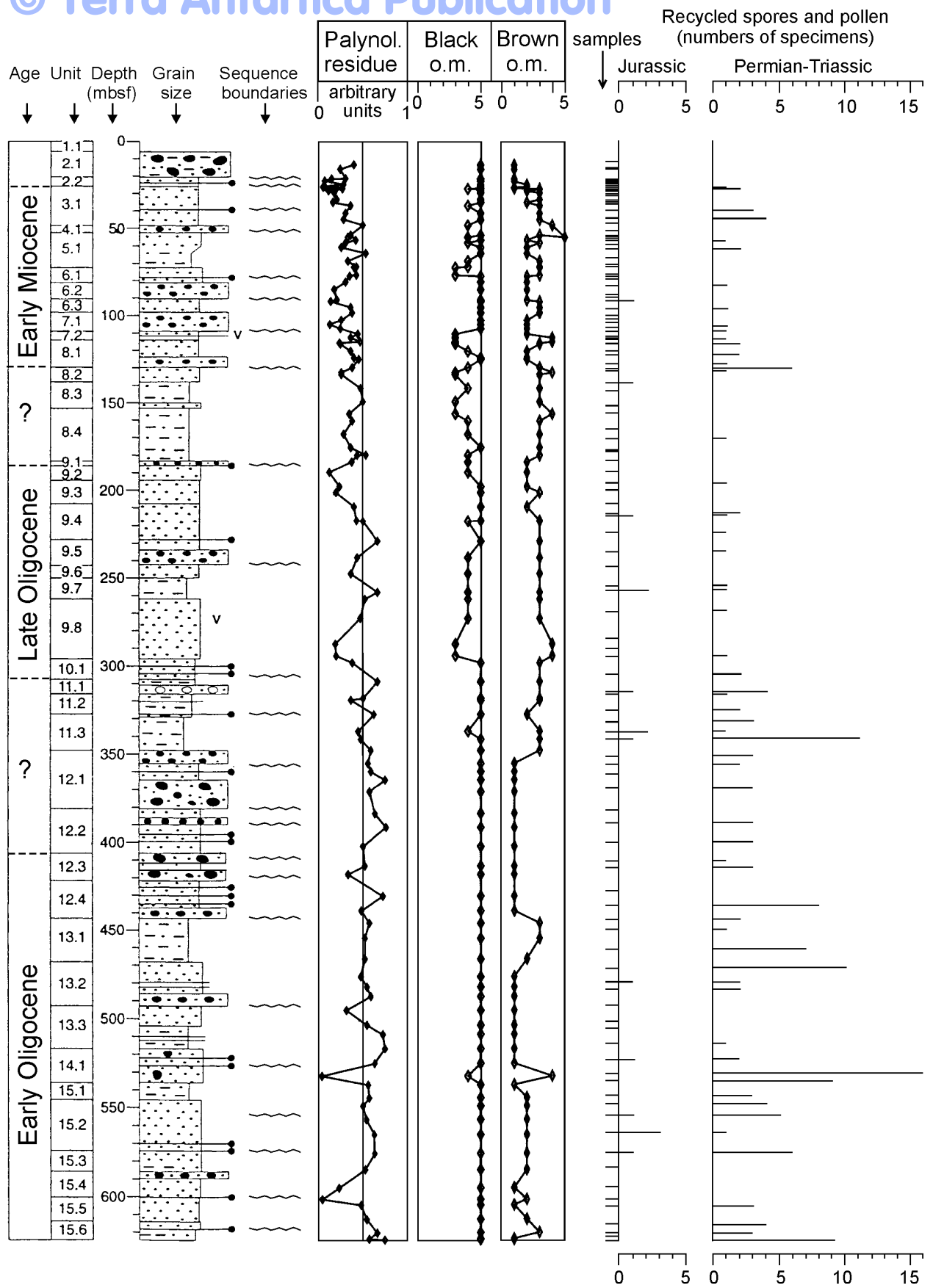


Fig. 3 – Abundance of redeposited Jurassic-Cretaceous and Permian-Triassic spores and pollen, expressed as numbers of observed specimens (taxa and distribution data from CRST, 1999, table 5.9). Also shown is the relative abundance of total organic particulate material (palynological residue) per unit weight of sediment, and relative abundance of the black coaly and brown tissue components of this residue, ranked by visual estimation [0 = absent, 5 = prolific]. See also CRST, 1999 for a summary of the palynofacies and organic components.

Proteaceae shrub occupying warmer sites, for example on mid-slopes, and herbaceous or mossy tundra in colder sites at higher elevations and on valley floors. Summer temperatures for the Miocene (erroneously given as “July”, rather than January temperatures in Raine, 1998) were likely similar to those of islands in the vicinity of the Antarctic Convergence today. Temperatures may have been somewhat similar, though probably slightly warmer during the Late Oligocene, as attested to by the slightly more diverse miospore assemblages.

Conditions in the Early Oligocene were somewhat more favorable to plant growth, judging from the miospore record. A discernible trend, even with the small numbers of miospores recovered, is the increase downhole in species richness and numbers of specimens (Tab. 1, Fig. 1), a trend that begins very gradually below about 307 mbsf, and increases downhole below ~443 mbsf. The Early Oligocene landscape included more diverse woody vegetation growing in somewhat milder climates than in the Late Oligocene and Miocene, although the sedimentological evidence indicates the climates were still largely glacial (CRST, 1999). The Early Oligocene miospore assemblages near the base of CRP-2/2A never reach the richness in species diversity and abundance seen in the Eocene McMurdo Sound erratics (Cranwell et al., 1960; Cranwell, 1969; McIntyre & Wilson, 1966; Wilson, 1967; Askin, 2000) or in the Eocene assemblages recovered from the lower part of the CIROS-1 drillhole (Mildenhall, 1989, and Raine, unpublished data). In those Eocene assemblages, which reflect moist temperate climates, there is a greater variety of angiosperm taxa, including Proteaceae and representatives of other families not encountered here, and a greater variety of gymnosperms and cryptogams. The vegetation represented by the CRP-2/2A miospore assemblages reflects a time of deteriorating climatic conditions that post-dates the onset of glacial conditions in the Eocene in the McMurdo Sound area.

An important observation from these Cape Roberts results is the long-lived nature of the tundra vegetation, which evidently persisted throughout much of the Oligocene and the Miocene to perhaps the middle Pliocene, surviving through approximately 30 million years of dynamically changing climate conditions.

There are some notable occurrences for Antarctica amongst the CRP-2/2A assemblages. These are mainly herbaceous taxa and include a possible specimen of Stylidiaceae (the trigger plant family, austral and mostly subalpine herbs and cushion plants) at 47.41–47.54 mbsf, *Assamiapollenites* cf. *incognitus* (a biostratigraphically important New Zealand Miocene angiosperm of unknown affinity, probably monocotyledonous) at 215.49–215.52 mbsf, *Phormium* sp. (Agavaceae, related to New Zealand flax) at 346.12–346.13 mbsf, *Cyperaceae* sp. (Cyperaceae, the sedge family) at 444.76–444.78 mbsf, *Ranunculaceae* (buttercup family) at 453.26–435.27 mbsf, and *Ricciaesporites* sp. (Ricciaceae, a thallose liverwort family) at 575.36–575.37 mbsf. All these taxa add to the known floristic diversity of the McMurdo Sound area, and may be useful biostratigraphic markers in the future.

PALAEOZOIC AND MESOZOIC REWORKED ASSEMBLAGES

Reworked Palaeozoic and Mesozoic spores and pollen occur sporadically throughout the CRP-2/2A core. Two broad age groupings are recognized: Jurassic-Cretaceous and Permian-Triassic. Numbers of these reworked specimens are plotted in figure 2 (taxa and distribution data from CRST, 1999, table 5.9). These reworked assemblages are derived from erosion of sedimentary strata in (or beyond, see below) the current Transantarctic Mountains belt, and transport and redeposition by the proto-Mackay Glacier.

Very rare single specimens typical of Jurassic-Lower Cretaceous strata (such as *Corollina* sp. and *Callialasporites segmentatus*) occur in CRP-2/2A. The likely source of these specimens is the Lower-Middle Jurassic Ferrar Group. Ferrar Group sediments, including palynomorph-bearing lacustrine beds, have been reported (e.g. Tasch & Lammons, 1978) from Carapace Nunatak, which is located upstream and slightly to the north of Mackay Glacier.

Permian-Triassic spores and pollen found throughout CRP-2/2A are derived from erosion of the Permian-Triassic coal measures and fluvial sediments of the Victoria Group, Beacon Supergroup. Victoria Group strata, which are intruded by Ferrar dolerite sills, crop out in the Transantarctic Mountains through which the Mackay Glacier flows. There is a significant increase in frequency of Permian-Triassic reworked specimens and black coaly material (“black o.m.”) below ~307 mbsf (Fig. 3; see also CRST, 1999, for summary of the palynofacies and organic components). This suggests greater amounts of erosion of Beacon strata during the Early Oligocene as compared with the subsequent interval in CRP-2/2A. This is consistent with clast and grain studies that show increased quantities of dolerite, coal and rounded quartz grains from dolerite-intruded Beacon strata in the lower part of the core (CRST, 1999; Talarico et al., this volume).

Heating associated with dolerite intrusion and basalt extrusion of the Jurassic Ferrar Group has thermally metamorphosed the organic matter of the Beacon Supergroup to varying degrees. Palynomorphs reflect amount of heating by exine (wall) color changes from light yellow, through orange, red-brown, dark brown to black before their eventual destruction (which occurs at about the equivalent transition from anthracitic coal to meta-anthracite, vitrinite reflectance R_o 4.0%). The Permian-Triassic reworked assemblage includes well-preserved yellow-orange specimens to barely recognizable black corroded remnants. Most notable are the occasional well-preserved Permian spores and pollen that exhibit relatively low thermal alteration. Examples are the specimen of *Protohaploxylinus* sp. (CRST, 1999, fig. 5.11.j) at 44.08–44.09 mbsf which is yellow in color, and the orange-brown specimen of *Pseudoreticulatispora pseudoreticulata* (CRST, 1999, fig. 5.11.m) at 57.32–57.42 mbsf. These have a provenance from Permian sediments that have not been severely metamorphosed, and certainly not to the extent observed in the presently exposed Permian sediments. Palynomorphs recovered from outcrop samples

of the Permian Weller Coal Measures in southern Victoria Land (e.g. Kyle, 1977) are poorly preserved and dark brownish black to black and corroded. It was suggested by Askin (1998) that light-colored Triassic palynomorphs, reworked into Sirius Group beds on Mount Feather, were derived from Triassic Victoria Group strata with little or no associated dolerite, inland of the current Transantarctic Mountains. A similar provenance is envisaged for some of the reworked Beacon palynomorphs recovered in the CRP-2/2A cores: the dark-colored specimens probably had a more local derivation from the present dolerite-intruded Transantarctic Mountains, but the light-colored specimens have been eroded and carried by the proto-Mackay Glacier from some distance inland. As with the reworked Feather palynomorphs, these provide good, albeit indirect, evidence for the lack of dolerite cratonwards of the Transantarctic Mountains.

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