

## 5 - Palaeontology

### INTRODUCTION

Six groups of fossils were examined during the preliminary investigation of the CRP-2/2A pre-Pliocene sequence: diatoms, calcareous nannofossils, foraminifers, marine palynomorphs, terrestrial palynomorphs, and marine invertebrate macrofossils. Each of these fossil groups provides important biostratigraphical and palaeo-environmental data for the analysis of the recovered sequence. Marine diatoms provide the principal data for biostratigraphically dating the core material. Calcareous nannofossils and marine palynomorphs provide additional biostratigraphical control. Biostratigraphical dating provides age control for the sedimentary rock sequence in CRP-2/2A, allows regional correlation to other sections in the Victoria Land Basin and the Southern Ocean, and helps constrain the calculation of sediment accumulation rates.

All six fossil groups provide valuable information on the palaeoenvironment of the Ross Sea and surrounding continental areas near Cape Roberts. Planktic diatoms and marine palynomorphs are important monitors of neritic or mesotrophic surface water conditions in the geological past, while calcareous nannofossils indicate when oligotrophic oceanic waters invaded the site. In consequence, these planktic microfossil groups provide information on relative water depth, nutrient availability, turbidity, and water temperature. Benthic foraminifers and invertebrate macrofossils indicate past seafloor conditions including temperature and substrate character. Terrestrial palynomorphs yield a record of the vegetation on the continent adjacent to the site of CRP-2/2A, as well as indicate the age of existing sedimentary rocks that are being eroded on the mainland.

Changes in fossil assemblages through time may be the result of evolutionary changes in the organisms, environmental changes that force ecological restructuring of the biota, or shifts in preservational regime. All of these factors are clearly at work in the fossil succession in CRP-2/2A. A sequence of formal or informal zones for each microfossil group is illustrated in figure 5.1, and a brief introduction to the fossil groups is given below.

Diatoms are the most abundant fossil group in CRP-2/2A sediments. In certain intervals, diatoms constitute as much as 30% of the sedimentary rock. However, in most samples, diatom abundance is not more than about 5% of the silt and sand-dominated sediment, and some intervals are barren of diatoms. High sediment accumulation rates and generally good diatom preservation provide the opportunity to develop a detailed biostatigraphy for the late Palaeogene-early Miocene period for the Ross Sea, although several major disconformities are present. CRP-2/2A diatom assemblages are dominated by planktic assemblages, which

are better biostratigraphical markers than benthic taxa. The diatom assemblages, however, are dominated by neritic taxa, rather than open-ocean pelagic taxa, which form the basis of Southern Ocean deep-sea biostratigraphy. Diatoms provide ages of *c.* 20 Ma below the Plio-Pleistocene/Miocene unconformity at *c.* 26 mbsf. The base of the Miocene cannot be confidently identified based on diatoms, but is suggested to be at *c.* 130 mbsf and is associated with an unconformity. Similarly, the upper/lower Oligocene boundary is probably within a barren interval between *c.* 300 and 412 mbsf. Lower Oligocene sediments are recognized, based on diatom assemblages, from *c.* 412 mbsf down to at least *c.* 484 mbsf. Diatom assemblages below 484 mbsf cannot be confidently assigned to either Lower Oligocene or uppermost Eocene at present.

Foraminifera, representing 28 genera and 45 species, occur in 73 of the 135 samples examined from the upper

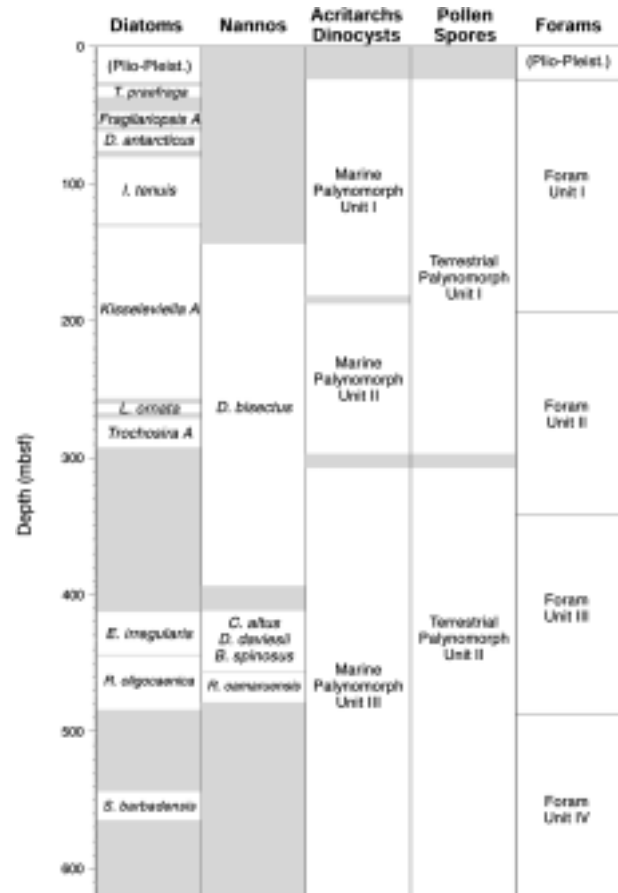


Fig. 5.1 - Summary diagram of tentative CRP-2/2A zonation schemes from diatom, calcareous nannofossil, marine palynomorph, terrestrial palynomorph, and foraminifer stratigraphy. Shaded areas represent intervals of poor preservation, barren samples, or gaps in sample spacing.

Palaeogene through Lower Miocene section of CRP-2/2A from *c.* 34 to *c.* 624 mbsf. All assemblages contain only calcareous benthic taxa, and neither planktic nor agglutinated benthic forms were observed. Four major foraminiferal units were delineated for the succession, and ascribed to local biofacies shifts. The units may reflect long-term bathymetric changes from inshore environments in early Oligocene to mid or outer shelf and then outer shelf or upper bathyal in early late Oligocene. Inshore conditions apparently returned during the late Oligocene-early Miocene.

Calcareous nannofossils in the CRP-2A succession record episodes of hemipelagic sedimentation marking times when open oceanic surface waters penetrated into the Victoria Land Basin. One major, and several minor, pulses of oceanic surface water invasion are indicated during the Upper Oligocene *Dictyococcites bisectus* Zone from *c.* 144 to 397 mbsf. Another episode of oceanic incursion is evidenced by nannofossil assemblages from *c.* 412 to 481 mbsf, where at least two upper biostratigraphical zones are represented. A long barren interval, from *c.* 482 to 613 mbsf, overlies two nannofossil-bearing samples just above the base of the hole.

Well-preserved marine palynomorphs were recovered from most samples from the upper Palaeogene through Miocene section. Species richness is moderate to high. The majority of specimens are considered to be *in situ* and many have not been described formally. Three marine palynological units are recognized (Fig. 5.1). Unit I is dominated by prasinophyte algae, mainly *Leiospheres* and *Sigmopollis*, and represents an extension of the assemblage recovered from below 99.01 mbsf. Marine palynomorphs Unit II is marked by the presence of the dinoflagellate *Lejeunecysta* sp 1. Unit III assemblages are characterized by the acritarch *Leiofusa*, the dinoflagellate *Pyxidinopsis* sp. and several species of *Lejeunecysta*. These units probably reflect changes in the palaeoenvironment. The assemblages recovered from CRP-2/2A continue to fill in a gap in the knowledge of marine palynomorph biostratigraphy between the well-established Palaeogene Transantarctic flora and the Recent. Several species of dinoflagellates, notably *Lejeunecysta* spp., may provide several biostratigraphical datums for the Ross Sea area.

Terrestrial palynomorphs are very rare throughout the upper part of the core, above *c.* 306 mbsf. This is interpreted as the result of both sparse contemporaneous vegetation in the surrounding landscape and dilution by rapid sediment accumulation. The rare spores and pollen reflect a long-lived tundra vegetation that survived in coastal lowlands in harsh periglacial conditions. Below 306 mbsf, palynomorphs are relatively more diverse and common, although total numbers remain very low. They reflect a low diversity woody vegetation that included several species of *Nothofagus* and podocarpaceous conifers, along with other angiosperm taxa and cryptogams. The assemblages in lowermost CRP-2A never reach the species richness and abundance seen in the Eocene sedimentary rocks documented from the lower part of CIROS-1 or the McMurdo Sound erratics. Recycled palynomorphs, of

probable Eocene, Jurassic-Cretaceous, and Permian-Triassic age, are also recognized. Permian-Triassic palynomorphs derived from the Beacon Supergroup are most abundant below 306 mbsf.

## SILICEOUS MICROFOSSILS

### INTRODUCTION

Diatoms provide one of the primary biostratigraphical and palaeoenvironmental tools for interpreting the CRP-2/2A core. In addition to diatoms, silicoflagellates and ebridians (both siliceous flagellates), and a chrysophyte cyst provide supporting biostratigraphical information. Upper Palaeogene through Lower Miocene diatom assemblages are recognized from *c.* 28 mbsf to the bottom of the hole at 624.15 mbsf, and this interval is divided into 10 tentative biostratigraphical zones. A large number of taxa in this interval are previously unknown or undescribed, many of which have been informally recognized in Ross Sea cores. Three undescribed, but taxonomically distinct, taxa provide tentative zonal boundaries. The CRP-2/2A core will provide age constraints on these and other taxa for the Ross Sea, which will permit age calibration of previously-drilled Antarctic cores.

### METHODS

All samples were prepared for siliceous microfossils as strewn slides of raw sediment, following standard procedures. As necessary, selected samples were reacted in H<sub>2</sub>O<sub>2</sub> and/or HCl to help remove organic and carbonate cements, respectively. Additional samples were prepared further by separating the >10 µm fraction using nylon screens. Several samples were sieved with 20 µm and 25 µm stainless steel mesh sieves, and diatoms in about 15 samples were prepared with density separation techniques, using a sodium polytungstate solution prepared at 2.2 specific gravity. Relative diatom abundance, represented graphically on figure 5.2 and in table 5.1, was determined from strewn slides of unsieved material. Stratigraphical occurrence and abundance data are based on detailed analysis of more than 50 diatom-bearing samples, plus cursory examination of 250 additional samples.

### RESULTS

Siliceous microfossils occur in variable abundance through the recovered stratigraphical succession of CRP-2/2A (Fig. 5.2). Diatoms are most abundant in fine-grained lithologies, except in intervals that have undergone significant diagenesis. More than 150 diatom species and species groups, plus 11 silicoflagellates, 7 ebridians, 2 endoskeletal dinoflagellates, and one biostratigraphically-useful chrysophyte cyst are recognized in the initial examination of CRP-2/2A samples. Radiolarians were not observed in the recovered sequence.

CRP-2/2A Initial Report siliceous microfossil data (Fig. 5.3) include many informal taxonomic designations.

Tab. 5.1 - CRP-2/2A relative diatom abundance data.

Top	Bottom	Abund.	Top	Bottom	Abund.	Top	Bottom	Abund.	Top	Bottom	Abund.
25.25	25.26	T	147.07	147.08	T	288.00	288.01	R	468.52	468.53	C
26.48	26.49	F	148.19	148.20	T	292.08	292.10	F	470.79	470.80	C
26.78	26.79	R	148.72	148.73	T	296.39	296.40	T	474.90	474.91	A
27.70	27.71	R	149.65	149.66	T	298.07	298.08	R	476.30	476.31	F
29.06	29.08	R	150.70	150.71	T	302.65	302.66	T	479.71	479.72	F
31.71	31.72	F	152.40	152.41	T	306.95	306.96	T	480.82	480.83	R
33.84	33.85	F	153.70	153.71	T	307.70	307.71	B	483.92	483.93	F
36.24	36.25	F	155.20	155.21	R	309.88	309.89	T	484.55	484.56	B
36.40	36.41	F	156.07	156.08	R	311.56	311.57	T	486.28	486.30	B
37.44	37.45	F	158.50	158.51	R	316.48	316.50	T	486.76	486.77	B
39.82	39.83	R	159.81	159.82	T	317.27	317.28	T	494.38	494.39	B
40.24	40.25	R	160.29	160.30	T	318.85	318.68	T	495.62	495.63	B
41.19	41.20	T	162.42	162.43	T	320.05	320.06	T	496.90	496.91	B
45.12	45.13	R	164.50	164.51	R	322.00	322.01	T	499.65	499.66	B
47.41	47.54	T	166.34	166.35	R	324.54	324.55	T	500.26	500.27	B
47.82	47.83	T	168.79	168.80	R	326.07	326.08	T	501.05	501.06	B
50.82	50.83	T	169.58	169.59	R	328.08	328.09	R	503.90	503.91	B
52.47	52.48	T	171.49	171.50	R	330.08	330.09	T	506.22	506.23	B
54.36	54.37	R	173.46	173.47	R	332.76	332.77	T	507.86	507.88	B
56.10	56.11	R	174.38	174.39	R	334.14	334.15	T	510.13	510.14	B
57.32	57.42	F	176.29	176.30	A	336.51	336.52	R	511.75	511.76	B
<b>CRP-2A</b>			177.89	177.90	C	338.45	338.46	T	514.04	514.05	B
53.19	53.20	T	179.93	179.94	C	339.80	339.82	T	516.08	516.09	B
55.81	55.82	T	181.32	181.33	C	341.72	341.73	T	520.12	520.13	B
58.15	58.16	R	183.58	183.59	T	342.46	342.47	T	523.04	523.05	B
59.96	59.97	R	185.76	185.77	B	343.26	343.27	R	524.39	524.41	B
61.50	61.51	T	186.70	186.71	T	345.58	345.59	R	526.01	526.02	B
64.60	64.61	R	187.67	187.68	R	347.31	347.32	R	528.22	528.23	B
66.24	66.25	R	188.57	188.58	R	350.89	350.90	R	529.33	529.34	T
67.84	67.85	T	191.36	191.37	R	352.15	352.16	R	532.34	532.35	B
69.47	69.48	R	193.99	194.00	R	354.23	354.24	B	533.43	533.44	B
71.13	71.13	R	195.70	195.72	R	356.44	356.45	R	537.25	537.26	R
71.70	71.71	F	197.12	197.13	F	358.22	358.24	T	538.46	538.47	R
73.94	73.95	C	198.52	198.53	F	360.27	360.28	T	540.73	540.74	F
75.52	75.56	F	199.08	199.09	R	362.91	362.92	T	542.04	542.05	F
79.48	79.49	R	200.16	200.17	R	364.27	364.28	B	543.81	543.83	F
80.79	80.80	F	202.85	202.86	R	369.73	369.74	T	545.18	545.19	T
85.57	85.58	B	204.58	204.59	R	376.54	376.55	B	548.57	548.58	R
87.58	87.59	T	206.81	206.82	R	379.03	379.04	B	551.29	551.30	R
89.72	89.73	B	208.76	208.77	F	382.02	382.03	B	554.70	554.71	F
90.77	90.78	T	210.58	210.59	F	382.81	382.82	T	556.60	556.61	R
91.19	91.20	F	212.61	212.62	F	384.28	384.29	T	557.85	557.86	R
93.04	93.05	R	215.33	215.34	F	390.01	390.02	T	560.33	560.34	R
95.61	95.62	R	215.72	215.74	F	390.19	390.21	T	562.31	562.32	R
96.84	96.85	R	218.80	218.81	F	394.48	394.49	R	564.63	564.66	R
98.30	98.31	T	226.94	226.95	F	400.22	400.23	B	565.50	565.51	R
101.17	101.18	T	229.70	229.71	F	405.37	405.38	T	565.98	565.99	F
103.28	103.29	T	231.49	231.50	F	405.58	405.59	B	567.50	567.51	T
106.77	106.78	T	233.00	233.01	F	412.27	412.29	T	570.02	570.03	T
108.18	108.19	T	234.70	234.71	F	413.05	413.06	R	575.15	575.16	B
109.12	109.13	F	236.25	236.26	F	414.79	414.80	R	577.67	577.68	B
111.05	111.06	F	237.87	237.88	R	424.10	424.11	T	580.53	580.54	B
111.53	111.54	T	241.89	241.90	R	426.49	426.50	B	583.51	583.52	T
112.90	112.91	F	243.63	243.64	F	429.38	429.39	B	584.54	584.57	T
113.51	113.52	C	245.54	245.55	R	434.66	434.67	T	585.58	585.59	R
114.43	114.44	F	247.08	247.09	F	436.72	436.73	T	585.84	585.85	T
116.15	116.16	C	249.07	249.08	C	437.68	437.69	T	592.23	592.24	B
119.65	119.66	C	250.93	250.94	C	441.85	441.86	R	595.72	595.73	B
120.33	120.34	F	252.46	252.47	C	443.89	443.90	F	597.44	597.45	B
122.56	122.57	F	254.43	254.44	A	444.25	444.26	F	599.25	599.26	B
123.32	123.33	R	256.91	256.92	A	444.96	444.98	F	601.35	601.36	B
128.52	128.53	T	259.20	259.21	A	446.55	446.56	C	603.14	603.15	B
130.32	130.33	R	260.02	260.04	A	447.68	447.69	C	604.40	604.42	B
130.90	130.93	F	261.60	261.61	A	448.73	448.74	C	604.92	604.93	B
131.67	131.68	F	263.20	263.21	A	450.06	450.07	C	605.66	605.67	T
132.34	132.35	F	264.38	264.39	C	453.19	452.20	C	609.07	609.08	B
134.74	134.75	F	266.38	266.39	C	456.83	456.84	C	611.10	611.11	B
135.09	135.10	C	268.31	268.32	C	459.70	459.71	C	613.35	613.36	B
137.46	137.47	C	271.02	271.04	C	459.90	459.91	C	614.03	614.04	T
138.83	138.84	F	273.50	273.51	F	460.13	460.14	C	619.19	619.20	T
139.90	139.91	R	275.48	275.49	F	461.65	461.66	C	620.50	620.51	T
141.26	141.27	R	275.90	275.91	F	463.53	463.54	C	622.31	622.32	B
143.69	143.70	T	280.12	280.13	R	464.98	465.00	C	623.03	623.04	B
145.14	145.15	T	282.42	282.43	F	466.27	466.28	C	623.76	623.79	B
145.58	145.59	T	287.07	287.08	R	467.85	467.86	C	624.03	624.04	T

Note: all depths are in metres below sea floor (mbsf).

Samples 25.25 through 57.32 mbsf, above the solid line, are from hole CRP-2.

Samples from 53.19 through 624.03 mbsf, below the solid line, are from hole CRP-2A.

“Top” refers to upper depth of sample interval, and “Bottom” refers to lower depth of sample interval (in mbsf).

B = barren, T = trace, R = rare, F = few, C = common, and A = abundant.

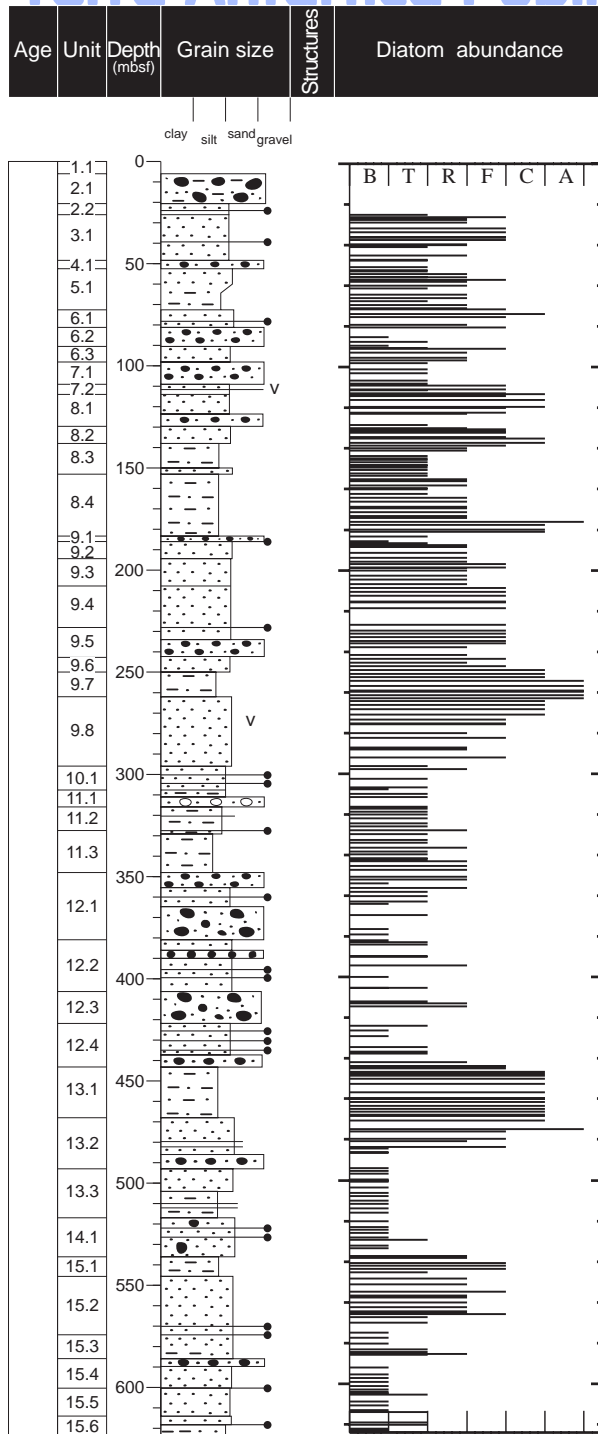


Fig. 5.2 - Diatom abundance in Lower Miocene-upper Palaeogene sediments, CRP-2/2A, plotted against the lithological summary log. Abundance categories (B = barren; T = trace; R = rare; F = few; C = common; A = abundant) are based on analysis of strewn slides of unsieved material. Intervals containing abundant diatoms contain the highest proportion of pelagic species.

These designations are internal to CRP-2/2A unless specific reference is made to published works (e.g. *Hemiaulus* sp. A (MSSTS-1)). Age assignments and diatom taxonomy are based on a large body of literature, but primary sources of information are reports from Southern Ocean drilling, notably Harwood & Maruyama (1992), Baldauf & Barron (1991), Gombos & Ciesielski (1983), Gombos (1977), Hajós (1976), and Schrader (1976). Useful diatom reports

from Antarctic continental shelf drilling and piston coring include Harwood et al. (1998), Harwood et al. (1989b), Harwood (1989), Harwood (1986), Barron & Mahood (1993), and Mahood et al. (1993). Several reports from stratigraphical sections outside of the Antarctic region also contribute useful information, including Yanagisawa & Akiba (1998), Scherer & Koç (1996), Gladenkov & Barron (1995), Akiba et al. (1993), and Schrader & Fenner (1976).

#### TENTATIVE DIATOM ZONATION

The nearly 600 m of Miocene and upper Palaeogene sediment recovered include significant diatom floral overturn, allowing subdivision into 10 tentative diatom range or partial range biozones, based on first and/or last occurrences of more than 50 taxa (Fig. 5.3, Tab. 5.2). Most other taxa are either long-ranging, or too sporadic in their abundance or distribution for reliable biostratigraphical utility. Biozones proposed in this report are not formally defined and, as such, should not be considered beyond the present context. This working zonal scheme will be updated and formally defined in the CRP-2/2A Scientific Results volume.

The *Thalassiosira praeфрага* Zone is a total range zone recognized from the first occurrence (FO) of *T. praeфрага* at 36.25 mbsf to the top of the Lower Miocene section at c. 28 mbsf (Tab. 5.2, Fig. 5.3). Diatoms in this interval are moderately preserved, which suggests the FO of *T. praeфрага* is not truncated. Harwood et al. (1998) defined this zone in the CRP-1 core based on the total range of *T. praeфрага*. The last occurrence (LO) of *T. praeфрага*, however, is not represented in CRP-2/2A due to an unconformity at c. 28 mbsf, which separates Lower Miocene and Plio-Pleistocene sediments.

The *Fragilariopsis* sp. A Zone is a partial range zone defined from the FO of *Fragilariopsis* sp. A (at 57.42 mbsf) up to the FO of *Thalassiosira praeфрага* (at 36.23 mbsf). This interval is characterized by poor to moderate diatom preservation and low abundance. *Fragilariopsis* sp. A is a relatively common component of diatom assemblages within this zone and continues as a common component of assemblages through the *T. praeфрага* Zone. The taxon referred to as *Fragilariopsis* sp. A in the present study has been previously recognized in several Ross Sea cores, but its FO has not been well documented.

We tentatively define the *Dactyliosolen antarcticus* Zone as a partial range zone from the FO of *Dactyliosolen antarcticus* (at 75.56 mbsf) up to the FO of *Fragilariopsis* sp. A (at 57.42 mbsf). Diatoms are common and moderately preserved from 75.56 to 71.13 mbsf but are poorly preserved and rare above this interval to the base of the overlying zone. *Dactyliosolen antarcticus* is a rare to common component of diatom assemblages within this zone and continues as a component of assemblages through the *T. praeфрага* Zone. A distinctive taxon in the interval from 75.56 to 71.13 mbsf is a small, previously undescribed *Rhizosolenia* sp., which we refer to as *Rhizosolenia* sp. A.

The *Ikebia tenuis* Zone is a partial range zone defined from the LO of *Kisseleviella* sp. A (at 130.90 mbsf) up to the FO of *Dactyliosolen antarcticus* (at 80.65 mbsf). Diatoms are common and well preserved in this interval.

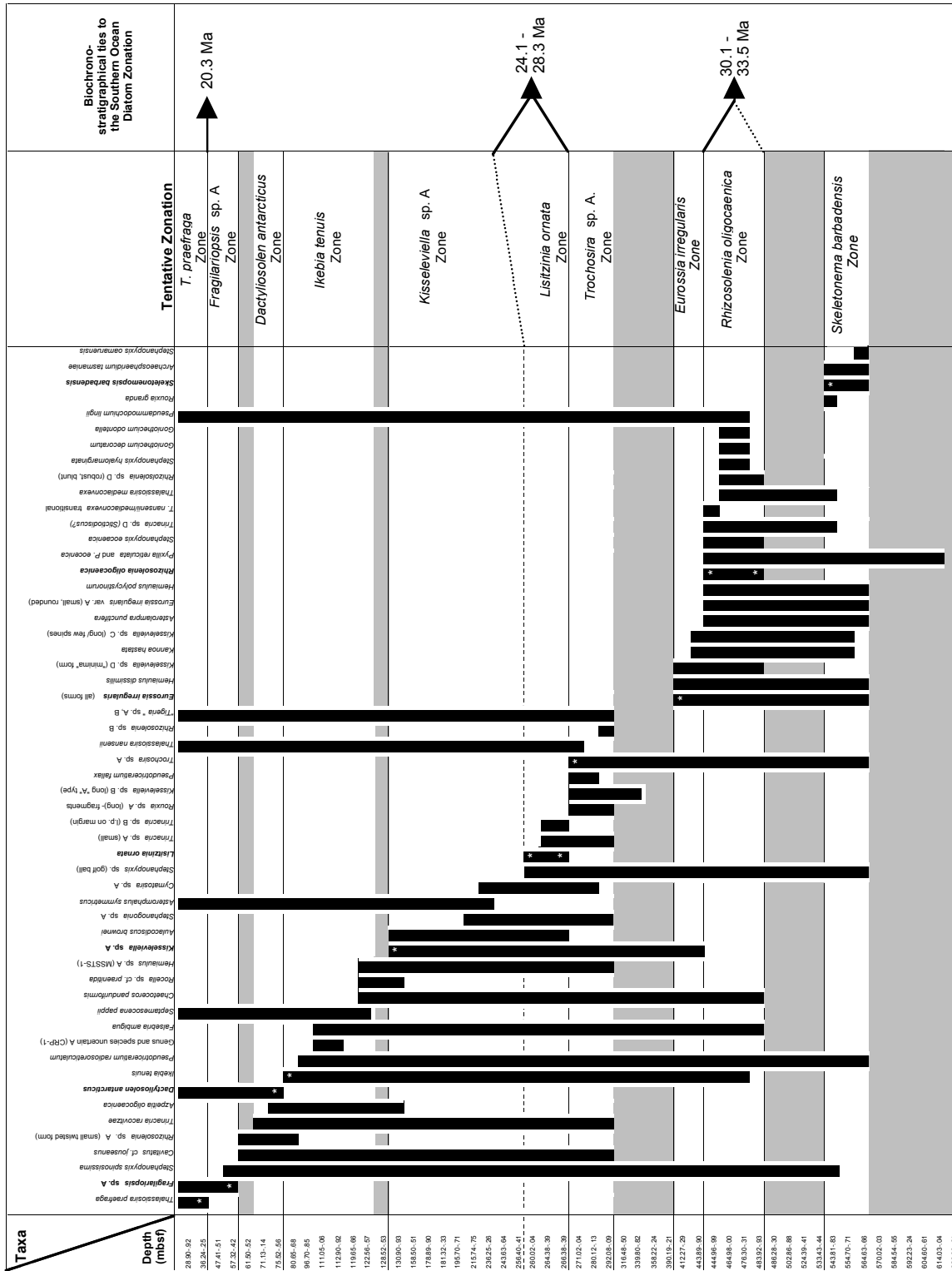


Fig. 5.3 - Stratigraphical ranges of key diatoms and diatom species groups (51), ebridians (2), silicoflagellates (1) and chrysophyte cysts (1) in CRP-2/2A. The chart is a graphical representation of selected taxa from total taxonomic census data, illustrating the first and/or last consistent occurrences of these taxa within CRP-2/2A. These ranges are the foundation for a tentative zonal scheme, including total range and partial range zones. Shaded areas reflect poor biosiliceous preservation.

Tab. 5.2 - Definition of boundaries for tentative diatom zonation of CRP-2/2A and characteristic taxa of each zone.

Zone	Boundaries	CRP-2/2A depth (mbsf)	Characteristic Taxa
<i>Thalassiosira praeфрага</i> Total Range Zone	<b>Top.</b> LO <i>Thalassiosira praeфрага</i> <b>Base.</b> FO <i>Thalassiosira praeфрага</i>	Not represented 36.25	<i>Dactyliosolen antarcticus</i> <i>Fragilariopsis</i> sp. A <i>Thalassiosira nansenii</i> <i>Thalassiosira praeфрага</i>
<i>Fragilariopsis</i> sp. A Partial Range Zone	<b>Top.</b> FO <i>Thalassiosira praeфрага</i> <b>Base.</b> FO <i>Fragilariopsis</i> sp. A	36.25 57.42	<i>Dactyliosolen antarcticus</i> <i>Fragilariopsis</i> sp. A
<i>Dactyliosolen antarcticus</i> Partial Range Zone	<b>Top.</b> FO <i>Fragilariopsis</i> sp. A <b>Base.</b> FO <i>Dactyliosolen antarcticus</i>	57.42 75.56	<i>Dactyliosolen antarcticus</i> <i>Rhizosolenia</i> sp. A
<i>Ikebia tenuis</i> Partial Range Zone	<b>Top.</b> LO <i>Ikebia tenuis</i> <b>Base.</b> LO <i>Kisseleviella</i> sp. A	80.65 130.90	<i>Azpeitia oligocaenica</i> <i>Ikebia tenuis</i> <i>Rocella</i> sp. cf. <i>praenitida</i>
<i>Kisseleviella</i> sp. A Partial Range Zone	<b>Top.</b> LO <i>Kisseleviella</i> sp. A <b>Base.</b> LO <i>Lisitzinia ornata</i>	130.90 259.21	<i>Aulacodiscus brownei</i> <i>Cymatosira</i> sp. A <i>Kisseleviella</i> sp. A <i>Stephanogonia</i> sp. A
<i>Lisitzinia ornata</i> Total Range Zone	<b>Top.</b> LO <i>Lisitzinia ornata</i> <b>Base.</b> FO <i>Lisitzinia ornata</i>	259.21 266.38	<i>Aulacodiscus brownei</i> <i>Cymatosira</i> sp. A <i>Kisseleviella</i> sp. A <i>Stephanogonia</i> sp. A <i>Trinacria</i> sp. A <i>Trinacria</i> sp. B
<i>Trochosira</i> sp. A Partial Range Zone	<b>Top.</b> LO <i>Trochosira</i> sp. A <b>Base.</b> Not defined.	271.02 -	<i>Cymatosira</i> sp. A <i>Kisseleviella</i> sp. A <i>Kisseleviella</i> sp. B <i>Rouxia</i> sp. A <i>Stephanogonia</i> sp. A <i>Trinacria</i> sp. A <i>Trochosira</i> sp. A
<i>Eurossia irregularis</i> Partial Range Zone	<b>Top.</b> LO <i>Eurossia irregularis</i> <b>Base.</b> LO <i>Rhizosolenia oligocaenica</i>	412.27 444.96	<i>Eurossia irregularis</i> <i>Hemiaulus dissimilis</i> <i>Kannoa hastata</i> <i>Kisseleviella</i> sp. C <i>Kisseleviella</i> sp. D
<i>Rhizosolenia oligocaenica</i> Total Range Zone	<b>Top.</b> LO <i>Rhizosolenia oligocaenica</i> <b>Base.</b> FO <i>Rhizosolenia oligocaenica</i>	444.96 483.93	<i>Asterolampra punctifera</i> <i>Eurossia irregularis</i> <i>Goniothecium decoratum</i> <i>Goniothecium odontella</i> <i>Hemiaulus dissimilis</i> <i>Hemiaulus polycystinorum</i> <i>Kannoa hastata</i> <i>Kisseleviella</i> sp. C <i>Kisseleviella</i> sp. D <i>Rhizosolenia</i> sp. D <i>Pyxilla reticulata</i> <i>Rhizosolenia oligocaenica</i> <i>Stephanopyxis eocenica</i> <i>Thalassiosira nansenii/medianaconvexa</i>
<i>Skeletonemopsis barbadensis</i> Partial Range Zone	<b>Top.</b> LO <i>Skeletonemopsis barbadensis</i> <b>Base.</b> Not defined.	543.81 -	<i>Archaeosphaeridium tasmaniae</i> <i>Asterolampra punctifera</i> <i>Eurossia irregularis</i> <i>Hemiaulus dissimilis</i> <i>Hemiaulus polycystinorum</i> <i>Kannoa hastata</i> <i>Kisseleviella</i> sp. C <i>Pyxilla reticulata</i> <i>Rouxia granda</i> <i>Skeletonemopsis barbadensis</i>

Note: FO = first occurrence, and LO = last occurrence.

*Ikebia tenuis* is not abundant in this interval, but is consistently present through the *Ikebia tenuis* Zone. This stratigraphical interval also contains several, distinct ash beds, of varying thickness. No significant diatom assemblage changes were noted through the ash-bearing section. Diatoms are well-preserved within the volcanic

glass-bearing interval (114.2 to 109.1 mbsf), probably due to the high silica availability in the sediments, which may have buffered pore waters and reduced the dissolution rate of diatom frustules.

The *Kisseleviella* sp. A Zone is a partial range zone defined from the LO of *Lisitzinia ornata* (at 259.21 mbsf)

up to the LO of *Kisseleviella* sp. A (at 130.90 mbsf). The assemblages in this interval are characterized by variable diatom abundance and preservation. *Kisseleviella* sp. A, however, is present in all samples containing rare to abundant diatoms and comprises a significant component of the assemblages. The LO of *Stephanogonia* sp. A is noted within this zone and may provide a datum to further subdivide this zone.

*Kisseleviella* sp. A is an undescribed taxon which occurs in CRP-2/2A, MSSTS-1, and CIROS-1. Illustrated specimens, designated as *Kisseleviella carina* by Harwood (1986, p. 86, Pl. 6, Figs. 12-15) from several intervals in the MSSTS-1 have a similar lanceolate form to what we have designated as *Kisseleviella* sp. A in this report. We believe that *Kisseleviella* sp. A is taxonomically distinct from morphotypes in the strict definition of *Kisseleviella carina* (see Akiba & Yanagisawa, 1986). A re-examination of several samples from the CIROS-1 core shows that the *Kisseleviella* species above the unconformity at c. 366 mbsf are of the *Kisseleviella* sp. A type (of CRP-2A), whereas another *Kisseleviella* form, more closely related to *K. carina* (*sensu stricto*) occurs in the lowest Oligocene/uppermost Eocene, below the unconformity in CIROS-1.

The *Lisitzinia ornata* Zone is a total range zone that is tentatively defined in the present study from the FO of *Lisitzinia ornata*, at 259.21 mbsf, up to its LO, at 266.38 mbsf. Diatoms are abundant and well-preserved within this short interval, but *Lisitzinia ornata* is rare. Distinctive diatom taxa that also occur in this zone include *Trinacria* sp. A and *Trinacria* sp. B.

The *Lisitzinia ornata* Total Range Zone as defined in the present study differs from the *Lisitzinia ornata* Partial Range Zone proposed by Harwood (1986) and applied in deep-sea sediments on ODP Leg 120 (Harwood & Maruyama, 1992). In these studies, the *Lisitzinia ornata* Partial Range Zone is defined by the FO of *Lisitzinia ornata* at the base and the FO of *Rocella gelida* as the top (Harwood, 1986). *Rocella gelida* was not observed in CRP-2/2A, and, consequently, cannot be used as a zonal marker. We, therefore, use the total range of *L. ornata*.

The top of the *Trochosira* sp. A Partial Range Zone is defined by the LO of *Trochosira* sp. A (at 271.02 mbsf). The base of this zone is not defined due to an underlying thick interval of poor preservation and low diatom abundance from 302.65 to 412.27 mbsf. Distinctive taxa within the *Trochosira* sp. A Zone (271.02 to 292.09 mbsf) include *Kisseleviella* sp. B and *Rouxia* sp. A. The first occurrences of *Hemiaulus* sp. A, *Stephanogonia* sp. A, *Trinacria* sp. A, and “*Tigeria*” spp. A & B occur at 292.08 mbsf, suggesting the presence of an unconformity at or below this depth in the interval of poor preservation.

The *Eurossia irregularis* Partial Range Zone is tentatively defined from the LO *Rhizosolenia oligocaenica* (at 444.96 mbsf) up to the LO of *Eurossia irregularis* (at 412.27 mbsf). Diatoms in this interval are poor to moderately preserved and present in low abundance. The LOs of *Hemiaulus dissimilis* and *Kisseleviella* sp. D occur at the top of this zone at 412.27 mbsf and provide further support for a significant unconformity between c. 300 and 412 mbsf. The diatom assemblage in this zone is similar to that of the underlying *Rhizosolenia oligocaenica* Zone

(see below) but is distinguished by the absence of *R. oligocaenica*

The *Rhizosolenia oligocaenica* Total Range Zone is defined from the FO of *Rhizosolenia oligocaenica* (at 483.93 mbsf) up to the LO of *Rhizosolenia oligocaenica* (at 444.96 mbsf). This interval contains common and well-preserved diatoms. The top of this zone marks the LO of several taxa (see Fig. 5.3) which indicate a possible unconformity between 444.99 and 443.90 mbsf. Alternatively, these last occurrences may be a reflection of poorer preservation in the overlying *Eurossia irregularis* Zone. The assemblage composition, however, is significantly different from that above the level of poor preservation at c. 300 mbsf. The bottom of the *Rhizosolenia oligocaenica* Zone is underlain by a interval of poor preservation from 486.28 to 533.44 mbsf, suggesting the FO of *Rhizosolenia oligocaenica* may be truncated. Distinctive taxa that are stratigraphically limited to the *Rhizosolenia oligocaenica* Zone include *Goniothecium odontella*, *Goniothecium decoratum*, *Rhizosolenia* sp. D, and *Thalassiosira nanseni/mediconvexa* transitional forms.

The *Rhizosolenia oligocaenica* Total Range Zone, as defined in the present study, differs from the *Rhizosolenia oligocaenica* Partial Range Zone, originally proposed by Gombos & Ciesielski (1983) and redefined by Harwood & Maruyama (1992). The *Rhizosolenia oligocaenica* Partial Range Zone is defined by the FO occurrence of *Rhizosolenia oligocaenica* up to the FO of *Cavitatus jouseanus* (Harwood & Maruyama, 1992). The FO of *Cavitatus jouseanus* is not applied as a datum in CRP-2A due to taxonomic uncertainties and discontinuous occurrence.

The top of the *Skeletonemopsis barbadensis* Partial Range Zone is defined by the LO of *Skeletonemopsis barbadensis* at 543.81 mbsf. The base of this zone is not presently defined because of poor preservation below 564.66 mbsf; the lowermost 50 m of core (565.50 to 624.03 mbsf), beneath the *Skeletonemopsis barbadensis* Zone, contains only rare, recrystallized and non-age-diagnostic diatoms. The *Skeletonemopsis barbadensis* zone contains moderately preserved diatoms in low abundance. The assemblage within this interval is of low species richness but is otherwise similar to the that in the *R. oligocaenica* Zone. The assemblage is distinguished by the presence of *Archaeosphaeridium tasmaniae* (a chrysophyte cyst), *Rouxia granda*, and *Skeletonemopsis barbadensis*, which are confined to this interval.

#### AGE AND STRATIGRAPHICAL CORRELATIONS

Correlation of key taxa in CRP-2/2A with palaeomagnetic chrons, and with occurrences in other McMurdo Sound cores is presented in table 5.3. Most of the taxa present in CRP-2/2A are rare in the deep-sea pelagic record, and most open-ocean taxa common in deep-sea sediments are rare in CRP-2/2A. Consequently, few of the zones proposed above can be confidently tied to the magnetostratigraphically-calibrated Southern Ocean diatom records. However, direct correlation with deep-sea diatom datums (Harwood & Maruyama, 1992) is possible

Tab. 5.3 - Deep-sea ranges of selected Oligocene-early Miocene diatom taxa and occurrence in CRP-2/2A and other McMurdo Sound cores.

Species	Age Range (Ma / Chron)	Occurrence in CRP-2/2A (mbsf)	Occurrence in McMurdo Sound Cores (mbsf)	Sources
<i>Thalassiosira praefraga</i>	20.3 <sup>†</sup> (FCAD) to 18.3 <sup>††</sup> (C6r to C5En)	FO at 36.25	FO at 103.39 (CRP-1)	H&M / Y&A / H*
<i>Cavitatus rectus</i>	LO at ~20.5 <sup>†</sup> (C6r)	Not present	LO at 146.79 (CRP-1)	A+ / Y&A
<i>Dactyliosolen antarcticus</i>	26.5 <sup>n</sup> to present (C8n.2n)	FO at 75.56	Ranges through CRP-1 lower Miocene	H&M / H*
<i>Lisitzinia ornata</i>	28.3 <sup>n</sup> to 24.1 <sup>n</sup> (C9r to C6Cr)	266.38 to 259.21	Not present in CRP-1 309.38 (CIROS-1) 222.04 to 187.21 (MSSTS-1)	H / H* / B / H&M
<i>Asteromphalus symmetricus</i>	28.7 <sup>n</sup> to 18.3 <sup>n</sup> (C10n.2n to C5En)	Lowest confirmed occurrence at 236.25	LO at 84.00 (CRP-1) 179.32 to 149.26 (CIROS-1) 222.58 to 61.52 (MSSTS-1)	H / H* / H&M / H+
<i>Cavitatus jouseanus</i>	30.9 <sup>n</sup> to 14.6 <sup>n</sup> (C12n to C5ADr)	292.09 to 71.13	147.69 to 99.02 (CRP-1) 359.63 to 110.26 (CIROS-1) 222.58 to 50.88 (MSSTS-1)	H / H* / B / H&M / Y&A / H+
<i>Asterolampra punctifera</i>	LO at 27.0 <sup>n</sup> (C9n)	Highest confirmed occurrence at 444.96	500.14 to 382.70 (CIROS-1)	H* / H&M
<i>Pyxilla reticulata</i>	LO at 30.1 <sup>n</sup> (C11r)	624.79 to 444.96	661.13 to 366.99 (CIROS-1)	H* / H&M
<i>Rhizosolenia oligocaenica</i>	33.5 <sup>n</sup> to 30.9 <sup>n</sup> (C13n to C12r)	564.63 to 444.96	428.00 to 382.70 (CIROS-1)	H* / B / H&M

Note: Ages are calibrated to the Berggren et al. (1995) time scale. Ages indicated with <sup>n</sup> are datums derived from Southern Ocean cores, and those indicated with <sup>†</sup> are datums derived from North Pacific cores. Information is compiled from the following sources: H = Harwood (1986), H\* = Harwood (1989), B = Baldauf & Barron (1991), H&M = Harwood & Maruyama (1992), A+ = Akiba et al. (1993), Y&A = Yanagisawa & Akiba (1998), and H+ = Harwood et al. (1998).

with at least 10 taxa (Tabs. 5.3 & 5.4). Age calibrations are based on correlation with the magnetostratigraphical records of ODP legs 120 (Harwood & Maruyama, 1992), 119 (Baldauf & Barron, 1991), and several North Pacific cores (Yanagisawa & Akiba, 1998). Many stratigraphically-useful neritic taxa are also known from Northern Hemisphere high-latitude records (Schrader & Fenner, 1976; Scherer & Coş, 1996). We have recalibrated the reported ages of the first and last occurrence datums from these ODP legs to the Berggren et al. (1995) timescale.

Diatoms in the upper part of CRP-2/2A can be correlated with the Lower Miocene section of CRP-1, though not completely. The best datum for correlation between CRP-1 and CRP-2/2A is the First Common Appearance Datum (FCAD) of *Thalassiosira praefraga*, which occurs at 102.24 mbsf in CRP-1 and at 36.24 mbsf in CRP-2. This datum defines the base of the *Thalassiosira praefraga* Zone (Fig. 5.3, Tab. 5.2). In the North Pacific, this datum occurs at 20.3 Ma, in Chron C6r (Yanagisawa & Akiba, 1998). Proposed correlation points between CRP-1 and CRP-2/2A are presented in table 5.4.

*Dactyliosolen antarcticus* is an extant species in the Southern Ocean and has a reported first occurrence in Chron C8n, c. 26.5 Ma (Harwood & Maruyama, 1992). This diatom occurs from 118.56 mbsf to the top of the Miocene section of CRP-1, and occurs from 75.52 mbsf to the top of the Miocene section of CRP-2A. The Southern Ocean calibration for the first occurrence of this taxon provides a maximum age for sediments at c. 75 mbsf and above. *Dactyliosolen antarcticus*, however, probably has a younger first occurrence on the continental shelf

The top of the *Cavitatus rectus* Zone in CRP-1 occurs at 147.48 mbsf (Harwood et al., 1998), but this zone is not recognized in CRP-2/2A, suggesting that a relatively short

disconformity may exist in the lower Miocene section of CRP-2/2A, removing this zone. The duration of the *C. rectus* Zone in the Southern Ocean is currently unknown. The absence of *Ikebia tenuis* in the *C. rectus* Zone in CRP-1 (Harwood et al., 1998) suggests that this unconformity is above 80.65 mbsf in CRP-2/2A. Sediments below 80.65 mbsf in CRP2A are, therefore, interpreted as being older than the base of CRP-1.

The <sup>40</sup>Ar/<sup>39</sup>Ar dates on the ash (21.44±.05 Ma) in the interval from 111.58 to 114.03 mbsf help constrain the age of the proposed *Ikebia tenuis* Zone (80.65 to 130.90 mbsf). Calculation of accumulation rates from an age-depth plot in this interval will enable a precise age determination for the LO of *Ikebia tenuis*.

At present, the position of the Miocene/Oligocene boundary in CRP-2/2A cannot be assigned with confidence based on diatoms. A significant change in the diatom assemblage is recognized below 128.52 mbsf, which appears to mark a significant disconformity. *Kisseleviella* sp. A is common in assemblages below 130.90 mbsf and absent in assemblages above 128.52 mbsf. *Kisseleviella* sp. A occurs in MSSTS-1 from 50.88 mbsf to the base of that core at

Tab. 5.4 - Tentative correlation of CRP-2/2A to CRP-1 based on diatom assemblages.

CRP-2/2A (fast-track sample depth in mbsf)	CRP-1 (interval of possible correlation in mbsf)
36.25 to 26.30	102.25 to 59.58 (LSU 5.8 to 5.2)
47.41-47.51 (poor preservation)	?
57.32-57.42	141.80 to 103.39 (LSU 6.3 to 6.1)
75.56 to 71.13	No correlative assemblage present

222.58 mbsf and in CIROS-1 from c. 366 to 145.15 mbsf. The LO of this taxon in CIROS-1 and in CRP-2/2A may provide a good point of correlation, but its LO may be truncated by disconformities in each hole, thereby limiting its usefulness as a time marker between holes.

The *Lisitzinia ornata* Zone in CRP-2A (259.21 to 266.38 mbsf) represents a strong pulse of biosiliceous sedimentation on the continental shelf, which can be seen in diatom abundance data on figure 5.2. The total range of *L. ornata* in the deep sea is calibrated to the palaeomagnetic time scale, ranging from Chrons C9r to C6r (28.3 to 24.1 Ma). The last occurrence of *L. ornata* is confined to C8n (25.8 Ma) in most cores from the Southern Ocean (Harwood & Maruyama, 1992; Baldauf & Barron, 1991).

*Lisitzinia ornata* is a pelagic species that was probably excluded ecologically from the Antarctic continental shelf, except during intervals of enhanced exchange with pelagic water masses. Consequently, the *L. ornata* Zone in CRP-2A most likely represents only a part of the total range of the taxon in the deep sea. This taxon is known to occur in one sample in CIROS-1 at 309.38 mbsf and may represent a correlative assemblage to that within the *L. ornata* Zone of CRP-2A. *Lisitzinia ornata* also occurs in MSSTS-1, scattered through 100 m of core, from 122.87 to 222.58 mbsf.

The *Trochosira* sp. A Zone is not calibrated with biostratigraphical datums tied to the magnetic polarity time scale. Diatom preservation is poor, and abundance low, in the interval 316.48 mbsf to 390.21 mbsf, preventing biostratigraphical interpretation of the base of the *Trochosira* sp. A Zone and the top of the underlying proposed *Eurossia irregularis* Zone. The *Eurossia irregularis* Zone, which is recognized below 412.27 mbsf, is assigned a stratigraphical position of Lower Oligocene, based on the presence of *Eurossia* spp., *Hemiaulus dissimilis*, and *Kannoa hastata*. These taxa have not been reported in Upper Oligocene sediments in the Southern Ocean.

The Upper/Lower Oligocene boundary cannot be identified with confidence in CRP-2A. The interval between c. 300 and 412 mbsf, which represents a brecciated, microfossil-poor interval. The boundary may lie in the *Trochosira* sp. A Zone or within the underlying diatom-poor interval. A distinct change in lithology at c. 300 mbsf may represent an unconformable boundary between the Upper and Lower Oligocene.

*Rhizosolenia oligocaenica* occurs in CRP-2/2A from 444.96 to 483.96 mbsf in an interval rich in biosiliceous material. The total range of *R. oligocaenica* is widely recognized in the Southern Ocean, with a reported range from 30.1 to 33.5 Ma, in Chrons C12r to C13n. The Southern Ocean first occurrence of this taxon, however, is not well calibrated due to poor diatom preservation and/or poor palaeomagnetic results in most holes, but is not reported to occur below C13n. The first occurrence of *R. oligocaenica* in the Southern Ocean commonly marks the onset of continuous high diatom productivity in the earliest Oligocene.

The lowermost interval with well-preserved diatom assemblages in CRP-2A occurs between 564.66 and

Tab. 5.5 - Siliceous microfossil taxa with ranges restricted to intervals below the unconformity (at ~366 mbsf) in CIROS-1.

<i>Archaeosphaeridium australe</i> *	<i>Parebriopsis fallax</i> *
<i>Archaeosphaeridium tasmaniae</i>	<i>Pseudammodochium dictyoides</i> *
<i>Asterolampra punctifera</i>	<i>Pyxidicula</i> sp. A*
<i>Cotyledon fogedi</i>	<i>Pyxilla eocena</i>
<i>Dictyocha deflandrei</i>	<i>Pyxilla reticulata</i>
<i>Ebrinula paradoxa</i> *	<i>Rhizosolenia oligocaenica</i>
<i>Ebriopsis crenulata</i> (loricate)*	<i>Rocella praenitida</i> *
<i>Ebriopsis crenulata</i> *	<i>Rouxia granda</i>
<i>Eurossia</i> spp.	<i>Sceptroneis lingulatus</i>
<i>Hemiaulus characteristicus</i> *	<i>Sphinctolothus pacificus</i> *
<i>Hemiaulus dissimilis</i>	<i>Stephanopyxis oamaruensis</i>
<i>Kannoa hastata</i> †	<i>Stephanopyxis superba</i> *
<i>Kisseleviella carina</i> s.s.‡*	<i>Stictodiscus kittonianus</i> *

Note: taxa indicated with an asterisk were not observed in CRP-2/2A. Reported late Eocene to earliest Oligocene ranges from CIROS-1 are based on the Wilson et al. (1998) age model.

(†) *Kannoa hastata* was identified as *Ikebia tenuis* in the CIROS-1 core (Harwood, 1989). (‡) *Kisseleviella* forms below 366 mbsf in CIROS-1 (designated as *Kisseleviella carina* by Harwood (1989)) may represent a new species, taxonomically separate from *Kisseleviella carina* Sheshukova-Poretzkaya.

543.83 mbsf and is designated the *Skeletonemopsis barbadensis* Zone. The occurrence of *Rhizosolenia oligocaenica* in this zone is equivocal, due to preservational limitations. *Skeletonemopsis barbadensis* ranges from the Middle Eocene to up to the lower part of the *Rhizosolenia oligocaenica* Zone in the Southern Ocean (Gombos & Ciesielski, 1983). This assemblage is difficult to date biostratigraphically, because of a paucity of well-constrained markers.

The *Rhizosolenia oligocaenica* and *Skeletonemopsis barbadensis* Zones of CRP-2A share some of the floral elements of the diatom assemblage below the unconformity (c. 366 to 500 mbsf) in CIROS-1. However, many taxa characteristic of CIROS-1 (Tab. 5.5; Harwood, 1989) and lowermost Oligocene/uppermost Eocene sediment of Prydz Bay, East Antarctica (Barron & Mahood, 1993) do not occur in CRP-2A. These include, among others, *Hemiaulus characteristicus*, *Sphinctolothus pacificus*, and *Kisseleviella carina* (*sensu* Harwood, 1989, Pl. 4, Figs. 35-37; Barron & Mahood, 1993, Pl. 5, Fig. 11; and Hajós, 1976, Pl. 25, Figs. 5-9). The lowermost assemblages in CRP-2A also lack typical Late Eocene diatoms, such as *Distephanosira architecturalis*. Consequently, we interpret the *R. oligocaenica* Zone in CRP-2A (444.96 to 483.93 mbsf) as Lower Oligocene (Chron C12r), and the *S. barbadensis* Zone (543.81 to 564.66 mbsf) as Lower lower Oligocene or Upper upper Eocene.

## PALAEOENVIRONMENTS

Throughout the interval recovered in CRP-2/2A, the diatom record is strongly dominated by neritic planktic diatoms, with *Stephanopyxis* spp. the most abundant taxa. The diatom record of CRP-2/2A indicates deposition well below sea-level, and almost entirely below the photic zone (>~50m water depth), based on the rare occurrence of benthic diatoms. Fragments and rare whole specimens of large, bottom-dwelling diatoms, such as *Isthmia* and

*Arachnoidiscus*, occur throughout the diatom-bearing intervals in low abundance. We consider these to be allochthonous, as are smaller benthic taxa that occur relatively commonly, including *Cocconeis* spp. and *Rhabdonema* spp.

Benthic diatoms may be *in situ* in the interval 110-112 mbsf, in association with volcanic deposits ( $^{40}\text{Ar}/^{39}\text{Ar}$  dated as 21.44 Ma). Diatom assemblages in these samples include a very large and distinctive diatom, referred to as "Genus and Species uncertain A" in the lower Miocene section of CRP-1 (Harwood et al., 1998). The low abundance of benthic diatoms in CRP-2/2A contrasts with CRP-1 and CIROS-1, both of which include intervals with significant abundance of benthic diatoms, which typically indicate shallow-water deposition (<50 m) (Harwood, 1989; Harwood et al., 1998). An alternative hypothesis worthy of consideration is the possibility that benthic diatoms are excluded from parts of the stratigraphical section due to high sediment input and turbid waters. A high suspended sediment load would have limited light penetration, and a highly mobile bottom may have limited colonization by many benthic diatom taxa.

## SUMMARY

The CRP-2/2A core provides a detailed stratigraphical record for the Antarctic continental shelf, despite numerous disconformities. The diatom assemblages suggest high sediment accumulation rates throughout the recovered successions, especially between *c.* 80 and *c.* 300 mbsf. Several distinct neritic diatom assemblages are identified through the core, and numerous FO and LO datums provide a basis for a detailed diatom biostratigraphical zonation. Major diatom assemblages in CRP-2/2A are confined to distinct stratigraphical intervals and are interpreted as being bounded by unconformities, based on deep-sea ranges of selected taxa. It is not possible to define firm age boundaries at this time, but using the diatom assemblages, we consider the interval from 26.9 mbsf to *c.* 130 mbsf to be Lower Miocene and the interval from *c.* 130 to 300 mbsf to be Upper Oligocene. The interval from *c.* 412 to 483 mbsf is Lower Oligocene, and from 483 mbsf to the base of the hole is considered lowermost Oligocene/Upper Eocene.

## FORAMINIFERA

### INTRODUCTION

A total of 135 samples, including 32 "Fast-track", 99 routine and 4 macrofossil matrix samples, covering the interval from 34.28 to 623.77 mbsf, were selected for foraminiferal study from CRP-2/2A cores and processed and examined at Crary Science and Engineering Center. Seventy-three were found to contain foraminifers, and yielded a fauna of *c.* 28 genera and *c.* 45 species. Specimen preservation was generally good, with test microstructures only slightly altered by leaching or recrystallization, but ranged from very good to poor.

Miocene and Oligocene strata in CRP-2/2A comprise a *c.* 600 m thick sequence of diamictite, muddy sandstone, sandy or silty mudstone and conglomerate, encompassing the interval from 26.79 mbsf (metres below sea-floor) to 624.15 mbsf (Bottom of Hole). Top of the Miocene is placed at the unconformable contact between LSU 2.2 (Pliocene) and 3.1 (26.79 mbsf in CRP-2; 27.14 mbsf in CRP-2A) of the standard lithostratigraphical classification (see Description of Sequence section, chapter 3) for the drill hole. The Oligocene-Miocene boundary is determined to lie at *c.* 130 m, near the base of LSU 8.1, and the Lower Oligocene-Upper Oligocene boundary is at *c.* 440 m, near the base of LSU 12.4 (see Chronology section, chapter 7). Boundary determinations rest primarily on diatom and nannofossil evidence. The Eocene-Oligocene boundary had not been reached upon termination of drilling.

## MATERIAL AND METHODS

Sample selection emphasised fine-grained sediments, mostly sandy or silty mudstones, as the most likely to contain foraminifers. There was no attempt to sample all the lithologies present. Samples, most weighing 50-100 g (undried) and representing *c.* 5 cm of core, were processed using standard techniques, and the resulting residues wet-sieved into >500  $\mu\text{m}$ , >125  $\mu\text{m}$ , >63  $\mu\text{m}$  and <63  $\mu\text{m}$  fractions. After drying, the first three fractions were examined for microfossils, and the last reserved for other non-palaeontological studies. All fossil material, including sponge spicules, diatoms, shell fragments, *etc.*, observed during picking was recorded, but samples lacking foraminifers are referred to here as "non-fossiliferous".

Most foraminifers were found in the 125-500  $\mu\text{m}$  residue, and systematic search therefore focussed on this fraction. Small samples were picked entirely, but for large samples, the >125  $\mu\text{m}$  material was subdivided, using a microsplitter, to provide at least two well-covered picking trays (9 x 5 cm; usually 1/4 to 1/8 of total residue) for examination. This defines the minimum criterion for determining a sample to be non-fossiliferous. In addition, all of the >500  $\mu\text{m}$  - 2 mm residue was scanned for large specimens, and a small portion of >63  $\mu\text{m}$  material was searched for minute species. Some large miliolids (see below) were removed by hand from surrounding matrix.

CRP-2 and CRP-2A samples overlap by about 6 m at the top of LSU 5.1, but all contain similar faunas and are included in a single sample suite.

### BIOSTRATIGRAPHY

Four characteristic foraminiferal assemblages, defined by their taxonomic composition and overall character, occupy successive parts of the CRP-2/2A sequence, and appear in most cases to show a clear relationship to the boundaries of lithostratigraphical units (see Fig. 5.4). These units are considered to reflect changes in biofacies and lithofacies at the CRP-2/2A site, and therefore to be of only local significance. All assemblages comprise only calcareous benthic taxa; neither planktic nor agglutinated species were recorded in the Oligocene- Miocene section

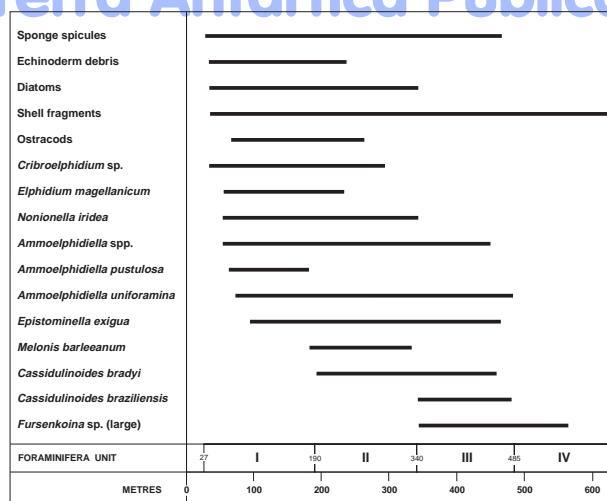


Fig. 5.4 - Distribution of Foraminiferal Units, selected foraminiferal species, and other fossil material in the CRP-2/2A drill hole.

of CRP-2/2A. Figure 5.4 shows the distribution of the faunal units in the CRP-2/2A section, along with the ranges of significant foraminiferal species.

#### Foraminiferal Unit I (26.91-193.75 mbsf)

Samples from this interval, which includes LSU 3.1 to LSU 9.2, generally contain either sparse, low diversity foraminiferal faunas, or are non-fossiliferous. Seventy samples were examined, and 38 contained foraminifera. *Elphidium magellanicum* and *Cribroelphidium* sp. are the most typical and persistent taxa, and appear in most assemblages. Although richer faunas occur at a few levels, typical assemblages contain five or fewer individuals, and three or fewer species. The maximum observed abundance/diversity was 60 specimens/10 species at 71.13 mbsf. *Nonionella iridea* displays a short interval of persistent occurrence between *c.* 56 and *c.* 76 mbsf; and *Epistominella exigua* has scattered occurrences down hole from *c.* 95 mbsf.

Persistently non-fossiliferous intervals occur at *c.* 36-41 mbsf, (LSU 3.1, medium to fine sandstone), and *c.* 107-123 mbsf (LSU 7.1, 7.2 and 8.1; sandstone, diamictite and lapillistone).

The Miocene - Upper Oligocene boundary occurs within Unit I at *c.* 130 mbsf (see Chronology section, chapter 7), but no significant change in foraminiferal assemblages was noted near this level.

#### Foraminiferal Unit II (193.95-342.42 mbsf)

The top of Foraminiferal Unit II, which probably coincides with the boundary between lithostratigraphical LSU 9.2 and 9.3, is marked by the highest occurrences of *Cassidulinoides bradyi* (193.95 mbsf), and *Eponides bradyi* (just below at 195.57 mbsf). Both characterize assemblages down to 342.42 mbsf, where the next faunal change occurs. As compared to the overlying unit, foraminiferal abundance and diversity are higher, and samples are more

consistently fossiliferous (23 of 35 samples). Common species within this interval include *Epistominella exigua*, *Melonis barleeanum*, *Ammoelphidiella* spp. and *Cribroelphidium* sp.

Foraminifera are relatively common down to *c.* 260 mbsf, with typical samples yielding 10-50 specimens, representing 4-9 species. The lower part, from *c.* 260 mbsf to *c.* 340 mbsf has sparser assemblages, commonly with only one or two species. There is a substantial barren interval from *c.* 275 to *c.* 320 mbsf. The lower boundary of Unit II lies near the base of LSU 11.3.

Diatom and calcareous nannofossil data indicate that Foraminiferal Unit II is entirely Late Oligocene in age.

#### Foraminiferal Unit III (342.42 - *c.* 486.19 mbsf)

Highest occurrences of *Cassidulinoides braziliensis* at 342.42 mbsf and a large, unnamed *Fursenkoina* sp., *c.* 3 m below at 345.50 m, mark the top of Foraminiferal Unit III, and the two species are the most common taxa within it. *Epistominella exigua* and *Eponides bradyi* have sporadic occurrences. Eleven of 20 samples contained sparse to moderate foraminiferal assemblages, consisting of three to six species. Isolated, large miliolid individuals were observed in the core at *c.* 345, 460 and 466 mbsf.

The upper part of Foraminiferal Unit III is poorly developed, but more diverse and abundant assemblages occur in its lower third. There is an abrupt increase in abundance and diversity below *c.* 440 mbsf., the level thought to represent the Upper Oligocene-Lower Oligocene boundary (see Chronology section, chapter 7). There is a major barren interval from *c.* 347 to *c.* 435 m, which includes all of LSU 12.1 and 12.2 (diamictite and sandstone). The base of the unit lies *c.* 6 m above the base of LSU 13.2.

#### Foraminiferal Unit IV: Impoverished (486.19-624.15 mbsf)

The top of Foraminiferal Unit IV is placed at a non-fossiliferous sample *c.* 4 m below the lowest occurrence of *Cassidulinoides braziliensis*. The Unit commences near the base of LSU 13.2 and continues to the base of the drilled section in LSU 15.6. Rocks within the Unit are well-indurated and difficult to disaggregate. Only one (564.58 mbsf) of the eight samples examined yielded foraminifers: a single, moderately preserved, specimen of *Fursenkoina* sp. (of Foraminiferal Unit III). Despite the virtual absence of smaller foraminifera, isolated single specimens of large, apparently well preserved, biloculine miliolids (probably *Pyrgo* spp.) were observed in the core at *c.* 599 and 620 mbsf. Their presence may indicate a specialised, perhaps hypersaline, environment unsuitable for other species.

#### PALAEOENVIRONMENT

All of the four Foraminiferal Units described above contain calcareous benthic foraminiferal faunas of moderate to very low diversity, and lack both planktic and

agglutinated benthic foraminifera. These factors suggest that all four assemblages reflect various inshore benthic environments, which were isolated from oceanic circulation and affected by various events and processes, *e.g.* reduced salinity, involving meltwater.

Progressing from Foraminiferal Units IV to II, the faunas suggest a long-term deepening trend, as indicated by increasing foraminiferal abundance and diversity (although with second-order reversals) followed by a return, as reflected by the Unit I fauna, to more inshore environments.

The sparse fauna of Unit IV, with scattered large miliolids, is consistent with a shallow water (hypersaline?) environment, above wave base (*c.* 50 m?), as suggested by sedimentological evidence (see Facies Analysis section, chapter 3). Foraminiferal Unit III assemblages probably reflect increased, mid- to outer- shelf (100-200 m) water depths, especially from *c.* 440-485 mbsf. Still further deepening, to perhaps outer-shelf or upper-slope depths (200-300 m), may indicated by the more consistent and diverse faunas of Unit II. Foraminiferal Unit I marks an abrupt return to low diversity, sparse faunas characterized by the shallow water taxa, *Elphidium* and *Criboelphidium*. A near-shore setting is likely, but apparently there is no sedimentological evidence that the site was above wave base.

#### AGE AND CORRELATION

All foraminifers from CRP-2/2A have either long or poorly known ranges, and no age-diagnostic species were encountered to permit external correlation. Although the CRP-2/2A faunas are less diverse and lack planktic species, they bear a general resemblance to Oligocene and Miocene faunas from lithostratigraphical Unit 2 (especially 2B to 2D) at DSDP Site 270 (Leckie & Webb, 1985). Foraminiferal Units II and III are comparable to the *Globocassidulina-Cassidulinoides-Trochoelphidiella* Assemblage Zone from the lower part of DSDP270, while Foraminiferal Unit I resembles the *Epistominella-Elphidium-Nonionella* Assemblage Zone from the upper part of that drill hole. CRP-2/2A faunas also seem closely related to faunas in Units 5, 7, 8, 9 and 15 in CIROS-1, but significantly, no fauna equivalent to the lowermost CIROS-1 fauna, from Unit 21 (Webb, 1989, p. 105), was encountered in CRP-2/2A.

Only Foraminiferal Unit I assemblages are represented in the nearby CRP-1 drill hole (Cape Roberts Science Team, 1998c).

### CALCAREOUS NANNOFOSSILS

#### INTRODUCTION

Calcareous nannofossils occur throughout the Southern Ocean in pre-Miocene sedimentary rocks deposited in pelagic and hemipelagic settings where the bottom was above the carbonate compensation depth (CCD). Conditions during the Cretaceous through Oligocene were sufficiently different in the Southern Ocean from the

temperate and tropical areas of the world that separate biostratigraphical zonation have been developed. The Southern Ocean biostratigraphical zonation of Wei & Wise (1990) has been adopted to subdivide the Eocene and Oligocene sequence in the Cape Roberts cores. This zonation has the advantage of utilizing several prominent high-latitude species while retaining those biostratigraphical marker species from temperate zonation that penetrate in the high Southern latitudes. Most of the biohorizons used in this zonation have been correlated directly to the palaeomagnetic time scale and, indirectly, to the geochronological time scale.

#### RESULTS

The entire pre-Pliocene sequence from holes CRP-2/2A was sampled and examined for calcareous nannofossils. Samples were chosen preferentially from fine-grained lithologies or at least from sedimentary rocks with fine-grained matrix material. All samples were examined initially by using smear slides of raw sediment. In most cases, no additional sample preparation was done. A few coarser-grained sediments were processed by a gravitational settling technique in which approximately 0.1 cm<sup>3</sup> of sediment was disaggregated and suspended in sufficient purified water to constitute a column of approximately 2 cm height in a small closed vial. This suspension was allowed to settle undisturbed for 60 seconds, at which point an aliquot of the supernatant was withdrawn and mounted on a cover glass. This procedure removed grains larger than approximately 20 microns from the supernatant, and thus concentrated the finer, nannofossil-bearing size fraction.

A total of six samples spanning in the cored interval from 29.70 to 57.32 mbsf in Hole CRP-2 and 179 samples from 54.67 to 624.10 mbsf in CRP-2A drill hole were examined for calcareous nannofossils. All of the pre-Pliocene samples from CRP-2 are barren of calcareous nannofossils. In total, 72 of the 183 samples from CRP-2A contain some nannofossils. This suggests a representation of nannofossils in less than 40% of the cored interval. However, examination of figure 5.5 indicates that the distribution of nannofossil-bearing samples in the section is not uniform, but occur with nannofossiliferous intervals separated by barren intervals. For example, the 25 m from *c.* 144 to 169 mbsf contains nannofossils in 90% of the samples (18 out of 20), whereas the subjacent 25 m from *c.* 169 to 194 mbsf contains nannofossils in only 11% of the samples (one out of nine). These intervals of nannofossil-bearing samples define a set of hemipelagic depositional episodes (see below) that punctuate the Oligocene history of the Ross Sea. These fossiliferous intervals occur generally in the finest-grained mudrocks and correspond to those where other palaeontological indicators of deep water have been found (*e.g.* pteropods).

The highest of these stratigraphical intervals (144.44 to 167.35 mbsf) constitutes an interval of relatively continuous nannofossil occurrence. Excluding the barren samples intercalated within this sequence, the average nannofossil species richness is 3.3 species per sample. The highest richness values occur near the centre of the sequence

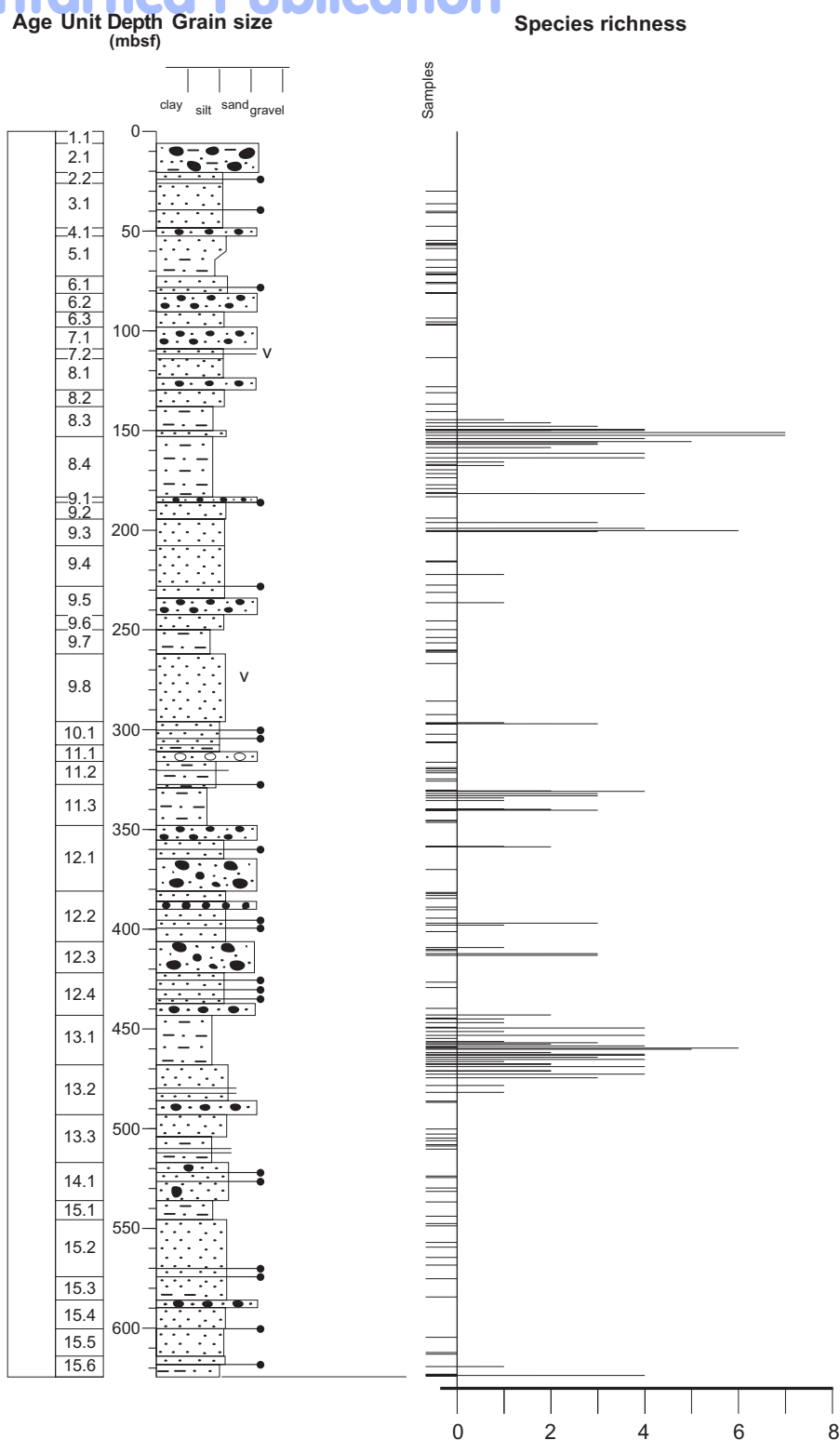


Fig. 5.5 - Species richness of calcareous nanofossil assemblages from CRP-2/2A. Horizontal axis is the number of species identified in a given sample. Those samples with zero (0) species identified are barren samples. Note that the distribution of nanofossil-bearing samples is non-random, defining a set of hemipelagic episodes during deposition of the Oligocene of CRP-2A (see text).

(150.70 to 155.20 mbsf), with two samples having seven species per sample (Tab. 5.6). Specimen abundance and species richness decrease both up-section and down-section from this richness maximum. Taxa present include *Dictyococcites bisectus*, *Dictyococcites productus*, *Reticulofenestra minuta* and *Reticulofenestra minutula*. The presence of *D. bisectus* without *Chiasmolithus altus* is indicative of the *Dictyococcites bisectus* Zone of late

Oligocene age. The last occurrence of *D. bisectus* is well constrained in the Southern Ocean (Wei & Wise, 1992; Berggren et al., 1995) at 23.9 Ma. This datum (identified at 149.28 mbsf) is almost certainly a minimum estimate for the age of this horizon, as this species is only present in this sequence during the interval of highest species richness. The late Oligocene age is corroborated by the presence of *R. minuta*.



The interval from 169.58 to 193.65 mbsf is characterized by samples that are largely barren of calcareous nannofossils. Only one sample, at 181.74 mbsf, contains rare, moderately preserved nannofossils. Species present include *D. bisectus*, *Dictyococcites daviesii*, and *R. minuta*. This assemblage is consistent with the *D. bisectus* Zone, although it might also be a depauperate representative of the underlying *Chiasmolithus altus* Zone.

Calcareous nannofossils occur consistently in samples from the short interval of 195.70 to 200.54 mbsf. All four samples taken from this interval contain rare, moderately preserved assemblages consisting of three to six taxa (Tab. 5.6). The most species-rich sample, from 200.15 mbsf, contains the smaller reticulofenestrads (*R. minuta* and *R. minutula*) as well as the larger dictyococcitids (*D. daviesii*, *D. hesslandii*, and *D. productus*), but significantly lacks *D. bisectus*. In addition, it contains *Thoracosphaera saxae*, a calcareous dinoflagellate. The assemblage is consistent with, but not definitive of, the *D. bisectus* Zone of late Oligocene age.

Below this short interval of nannofossiliferous rock, there is a thick (at least 115 m) sequence of strata that is largely devoid of calcareous nannofossils (Fig. 5.5). From 215.52 to 330.26 mbsf, it yielded only four samples (222.25, 236.25, 296.39, and 296.83 mbsf) that contain very rare, generally poorly preserved nannofossils. Because of the very rare occurrence of these specimens in a thick sequence of otherwise barren sedimentary rock, it is entirely probable that the specimens are reworked. None of the depauperate assemblages are age diagnostic. It is notable, however, that they contain the last down-hole occurrence of *R. minuta* (at 296.83 mbsf).

All nine samples taken from the interval 330.69 to 340.19 mbsf contain calcareous nannofossils, although surrounding rocks immediately above and below are barren. The assemblages are similar to others higher up-section, containing *D. bisectus*, *D. daviesii*, and *D. hesslandii*. In addition, thoracosphaerids occur in samples 330.82 and 340.00 mbsf. Below is another thick (c. 70 m) interval of rock that is largely barren of nannofossils. From 340.28 to 410.94 mbsf, only four samples (358.22, 396.98, 397.92, and 409.38 mbsf; Tab. 5.6) contain nannofossils. The assemblages are generally poorly preserved and contain only very rare nannofossils including *D. daviesii* and *D. hesslandii*. In addition, however, a sample at 358.49 mbsf contains common fragments of *Thoracosphaera heimii* and *Thoracosphaera saxea*, mainly as single platelets, representing thoracosphaerid tests that have been broken. No other nannofossils are present. This thoracosphaerid-rich interval is reminiscent of the thoracosphaerid horizons in the Quaternary of CRP-1 (Cape Roberts Science Team, 1998b) and CRP-2A (this volume). Villa & Wise (1998) related the Quaternary occurrences in CRP-1 to relatively warm intervals during an otherwise glacially dominated climatic regime. However, this deduction may not be applicable directly to the mid-Oligocene occurrence.

The identification of calcareous nannofossil assemblages of the late Oligocene *Dictyococcites bisectus* Zone distinguishes this sequence in CRP-2A from others in the Ross Sea. Direct comparison with others in the Ross

Sea is difficult because of the lack of previous work on upper Oligocene nannofossils. Interest in the CIROS-1 core focused on the Lower Oligocene and Upper Eocene. Neither Edwards & Waghorn (1989) nor Wei (1992) sampled above CIROS-1 Lithostratigraphical Unit 18 (highest samples at 385.77 and 380.00 mbsf, respectively). Monechi & Reale (1997) sampled CIROS-1 Lithological Units 11 (four samples between 214.55 and 228.83 mbsf) and 15 (310.45 and 316.34 mbsf), dated by diatoms as late Oligocene in age (Harwood et al., 1989a). However, these samples were barren of nannofossils. The stratigraphically highest sample known to contain nannofossils in CIROS-1 is from Lithological Unit 16, at 334.37 mbsf, with rare, poorly preserved specimens of *Coccolithus pelagicus* and *D. daviesii* (Monechi & Reale, 1997). Although *D. daviesii* is the most common component of Oligocene assemblages from CRP-2A, no definitive specimens of *C. pelagicus* have been identified during our preliminary examination. The sample at 334.37 mbsf, located near the base of the Upper Oligocene, is the only known nannofossil-bearing horizon in the Upper Oligocene at CIROS-1. At CRP-2A, there is more than 100 m of nannofossil-bearing strata in the Upper Oligocene *D. bisectus* Zone. This suggests, by correlation, that nannofossil-bearing strata should occur above Unit 16 in CIROS-1. Similarly, there was no systematic examination of the MSSTS-1 Upper Oligocene for calcareous nannofossils. As a result, it is difficult to judge whether or not the record of late Oligocene calcareous nannoplankton in CRP-2A is unique for the Ross Sea.

There was a significant addition to the calcareous nannofossil assemblage that occurred during the underlying episode of hemipelagic sedimentation. The thin siltstones interbedded with coarser lithotypes from 412.25 to 413.05 mbsf contain *Chiasmolithus altus*, in addition to *D. daviesii*, *D. hesslandii*, and *R. hampdenensis*. The last appearance datum (LAD) of *C. altus* has been well documented elsewhere in Chron C8n at 26.1 Ma (Berggren et al., 1995). The LAD of *C. altus* is used as the upper boundary of the *C. altus* Zone of late early to early late Oligocene age. This species appears to range down to a first appearance in the Lower Oligocene (Perch-Nielsen, 1985; de Kaenel & Villa, 1996), although Wei & Wise (1990) report this taxon significantly lower (upper to middle? Eocene) in the Weddell Sea. This species has been found in only two samples during our preliminary examination of CRP-2A, indicating that a significant part of the zone is missing. Diatom evidence (this volume) suggests that this interval is early Oligocene in age, suggesting that much of the upper part of the zone is missing in a major disconformity.

Samples in the interval from 426.49 to 456.32 mbsf are difficult to date biostratigraphically using calcareous nannofossils. All but three of the 13 samples examined from this interval are either barren or contain such very rare, poorly preserved nannofossils that biostratigraphical classification is impossible. Three samples having somewhat better assemblages still evidently lack any diagnostic species. This interval can be characterized only based on its stratigraphical relationship with the overlying (*C. altus*) and underlying (*R. oamaruensis*) zones, and, on

account of its position it is assigned tentatively to the combined *Dictyococcites daviesii/Blackites spinosus* Zone of early Oligocene age. The two zones have been combined because the biohorizon used to differentiate the two, the LAD of *Isthmolithus recurvus*, was not identified in our preliminary examination. This might suggest that the entire interval should be placed in the *D. daviesii* Zone. However, *I. recurvus* is rare in CRP-2A, having been identified from only one sample (459.52 mbsf) in the underlying zone.

The interval from 457.00 to 474.63 is well-characterized biostratigraphically by well-preserved assemblages containing *Reticulofenestra oamaruensis*. This high southern latitude species has a total range that defines the *R. oamaruensis* Zone of earliest Oligocene to latest Eocene age and is well-documented geochronologically. The FAD of *R. oamaruensis* appears to occur consistently in Chron C16 in the Southern Ocean (Wei & Wise, 1992), with its best placement within C16n.1n (Berggren et al., 1995), yielding an age of 35.4 Ma. The LAD of *R. oamaruensis* has been correlated to Chron 13r, although it may occur at the C13n/C13r boundary based on the record at ODP Site 699 (Wei, 1991; Berggren et al., 1995). Given this placement in C13n, it has been assigned an age of 33.7 Ma by Berggren et al. (1995), which is numerically the age of the Eocene/Oligocene boundary as used by them. However, if the record of ODP Site 699 is correct, the actual age of the LAD of *R. oamaruensis* should be slightly higher. Berggren et al. (1995) date the Chron C13n/C13r boundary at 33.545 Ma. This earliest Oligocene age assignment is appealing as it is more in keeping with the traditional assignment of the zone as straddling the Eocene/Oligocene boundary. Moreover, other palaeontological evidence from CRP-2A suggests that this interval is earliest Oligocene rather than latest Eocene in age. In fact, there is significant evidence from diatoms that suggests *R. oamaruensis* specimens in this interval may be reworked.

There is a thick interval of rock that is barren of calcareous nannofossils from 486.30 to 612.97 mbsf. Nevertheless, near the base of the hole, two samples yielded calcareous nannofossils. At 619.11 mbsf, a rare, poorly preserved assemblage contains only *Dictyococcites hesslandii*. A significantly better assemblage was recovered from the basal "fast track" sample at 623.60 mbsf that includes *Bicolumnus ovatus*, *Dictyococcites bisectus*, and *D. hesslandii*. *Bicolumnus ovatus* was first described from the Upper Eocene and Lower Oligocene of Maud Rise, Weddell Sea, but is also known to occur from the Upper Eocene and Lower Oligocene of the Falkland Plateau and Rio Grande Rise (Wei & Wise, 1990). More recently, it has been reported from as high as the Upper Oligocene (Zone NP 25) of the Iberian Abyssal Plain (de Kaenel & Villa, 1996). Thus, the species present in this assemblage cannot be used to assign an age for the base of CRP-2A.

## PALYNOLOGY

### INTRODUCTION

183 samples were collected for palynological analysis (Tab. 5.7), of which 122 "fast-track" and regular samples

were processed and studied at CSEC laboratory during the core characterization phase; finest grain size rocks were selected with a target sampling interval of 3 to 6 m. Palynological preparation followed the techniques used for CRP-1 and described by Cape Roberts Science Team (1998a) and Simes & Wrenn (1998), with only minor modification. Between 5 and 12 g of rock were processed for each sample. One tablet of *Lycopodium* spores (Lund University batch # 124961) was added to each sample before processing to enable later estimation of palynomorph concentration per weight of sediment. Microwave digestion in hydrochloric and hydrofluoric acid was followed by 7 minutes oxidation with concentrated nitric acid, decantation using a swirling method and sieving with 125 or 212 µm mesh to remove coarse mineral grains, and heavy liquid separation with sodium polytungstate. Finally, most organic residues were sieved to remove particles less than 6 µm diameter.

Very few modern contaminant pollen grains were seen during microscopic examination of the slides. Autofluorescence characteristics (using a Zeiss epi-illumination system III-RS with blue-violet excitation) were used as an aid to distinguish different pollen and spore components: modern pollen displayed a white autofluorescence, Cenozoic specimens yellow to orange colours, and Permian and lower Mesozoic pollen and spores dull red to no autofluorescence. The drilling mud used in CRP-2/2A was primarily the same synthetic polymer used in drilling of CRP-1, and had previously been found to contain negligible contamination. Guar gum, a mud additive of vegetable origin, also was used in CRP-2/2A. The residue retained by filtering a diluted suspension of the gum on a 6 µm sieve contained a minor amount of colourless fibres and other cellular material. This displayed white autofluorescence and could easily be distinguished from fossil material.

### PALYNOFACIES

A simple visual estimate of relative organic residue volume was made from the number and density of microscope slides produced (all recovered material was mounted), as time available did not permit more accurate estimation using *Lycopodium* spore counts. This value was divided by the weight of sample processed to obtain an approximate measure of the "palynological residue", or coarse organic matter content of the sediments (Fig. 5.6). Excluded from estimation were samples in which significant loss during processing was noted. The estimate may not reflect total sediment organic content, as organic residue particles less than 6 µm were removed by sieving. Amorphous organic matter in particular will have been removed by sieving and by nitric acid oxidation.

In general, total residue is not abundant above 306 mbsf, although there are peaks at about 230 and 260 mbsf. Below 306 mbsf residue is distinctly more abundant, with the exception of low values at 531.65 mbsf and 594.90-601.34 mbsf. The principal residue component consists of redeposited coal fragments. The dominance of these is partly controlled by hydrodynamic factors: the low values are probably due to current sorting in the sandstones at those levels.

Tab. 5.7 - Palynology sampling during core characterization.

Hole	Top	Base	Lab. #	Wt (g)	Lithology	Unit	Hole	Top	Base	Lab. #	Wt (g)	Lithology	Unit
2	13.31	13.32	62	7.50	sandy diamicton	2.1	2A	256.03	256.04	135	4.50	mudstone	9.4
2	15.74	15.75	60	8.00	muddy sand (diamicton)	2.1	2A	260.00	260.02	123	11.50	sandy mudstone	9.4
2	15.75	15.76	61	6.50	sandstone clast	2.1	2A	261.68	261.69			mudstone	9.4
2	21.02	21.03	63	6.50	sand (diamicton)	2.1	2A	266.03	266.04			v.f. sandstone	9.5
2	21.18	21.19	71	6.50	sand (diamicton)	2.1	2A	270.94	270.95	134	8.50	muddy f. sandstone	9.5
2	22.33	22.34	72	6.50	m. sand	2.2	2A	275.91	275.92			muddy f. sandstone	9.5
2	24.41	24.42	73	7.00	sandy diamicton	2.2	2A	285.57	285.58	137	10.50	clay bed in f. sand	9.5
2	25.44	25.45	74	6.50	sandy diamicton	2.2	2A	287.99	288.00			v.f. sand	9.5
2	25.86	25.87	75	9.00	sandy diamicton	2.2	2A	292.31	292.32	126	11.50	muddy f. sand	9.5
2	26.29	26.30	76	9.50	fine sand	2.2	2A	292.31	292.32	180*	10.00	muddy f. sand	9.5
2	26.36	26.37	77	11.00	fine sand	2.2	2A	296.32	296.33	138	10.50	sandy mudstone	10.1
2	26.79	26.80	78	10.50	muddy fine sand	3.1	2A	302.84	302.85			v.f. sandstone	11.1
2	26.89	26.90	80	11.00	muddy fine sand	3.1	2A	307.12	307.13	139	6.00	silty claystone	11.1
2	27.88	27.89	64	8.50	muddy v.f. sandstone	3.1	2A	309.98	309.99			v.f. sandstone	11.1
2	29.00	29.02	59	5.50	v.f. silty sand	3.1	2A	316.50	316.52	129	12.00	mudstone	11.2
2	32.75	32.76	79	9.50	muddy m. sandstone	3.1	2A	317.59	317.60	141	5.50	mudstone	11.2
2	34.38	34.39	65	6.00	muddy m. sandstone	3.1	2A	321.82	321.83			mudstone	11.2
2	36.24	36.28	56	5.50	m. sand	3.1	2A	325.66	325.67	142	8.00	siltstone	11.2
2	40.54	40.55	66	6.50	muddy fine sand	3.1	2A	330.86	330.87			mudstone	11.3
2	44.08	44.09	67	7.00	muddy fine sand	3.1	2A	335.29	335.30	143	9.00	mudstone	11.3
2	47.41	47.54	57	6.00	muddy fine sand	3.1	2A	339.80	339.82	128	9.50	mudstone	11.3
2	48.63	48.64	68	6.50	muddy sand (diamicton)	4.1	2A	339.80	339.82	181*	10.50	mudstone	11.3
2	51.96	51.97	69	9.00	v.f. sandy mudstone	4.1	2A	342.14	342.15			mudstone	11.3
2	54.17	54.18	70	6.00	muddy v.f. sandstone	5.1	2A	346.12	346.13	144	8.50	sandy mudstone	11.3
2A	52.96	52.97	84	11.00	muddy v.f. sandstone	5.1	2A	349.21	349.22			muddy f. sandstone (diamicctite)	12.1
2A	55.80	55.81	85	9.50	muddy v.f. sandstone	5.1	2A	353.61	353.62	145	9.00	sandy diamicctite	12.1
2	57.32	57.42	58	6.50	sandy mudstone	5.1	2A	358.20	358.22	133	8.50	mudstone	12.1
2A	59.97	59.98	86	11.50	mudstone	5.1	2A	360.00	360.01			siltstone	12.1
2A	63.28	63.29	87	7.50	mudstone	5.1	2A	361.33	361.34			sandy diamicctite	12.1
2A	67.63	67.64	89	9.00	mudstone	5.1	2A	363.00	363.01	147	8.00	mudstone	12.1
2A	70.79	70.80	90	7.00	mudstone	5.1	2A	369.85	369.86	148	10.50	muddy f. sandstone	12.1
2A	71.20	71.21	82	10.00	mudstone	5.1	2A	376.54	376.55			muddy f. sandstone	12.1
2A	75.59	75.60	81	7.00	muddy fine sandstone	6.1	2A	382.25	382.26	149	11.00	muddy v.f. sandstone	12.1
2A	76.12	76.13	91	8.50	v.f. sandy mudstone	6.1	2A	384.37	384.38			muddy f. sand	12.1
2A	79.44	79.45	93	6.50	v.f. sandy mudstone	6.1	2A	390.17	390.19	136	10.50	mudstone	12.1
2A	83.73	83.74	94	11.00	muddy f. sandstone (diamicctite)	6.2	2A	396.65	396.66			mudstone	12.1
2A	89.52	89.53	95	9.50	fine sandstone (diamicctite)	6.2	2A	401.05	401.06	152	10.00	muddy f. sandstone	12.2
2A	90.46	90.48	96	14.00	muddy v.f. sandstone	6.2	2A	405.57	405.58			sandy mudstone	12.2
2A	93.76	93.77	97	11.00	muddy v.f. sandstone	6.3	2A	412.25	412.27	140	11.50	muddy f. sandstone	12.2
2A	96.77	96.78	83	10.50	muddy v.f. sandstone	6.3	2A	416.95	416.96	153	12.00	muddy f. sandstone	12.2
2A	101.10	101.11	98	11.50	muddy v.f. sandstone (diamicctite)	7.1	2A	423.87	423.88			m. sandstone	12.2
2A	103.62	103.63	101	7.50	sandy diamicctite	7.1	2A	429.32	429.33	157	11.00	v.f. sandy mudstone	12.2
2A	106.00	106.01	103	8.00	sandy diamicctite	7.1	2A	437.69	437.70	158	12.50	mudstone	12.2
2A	109.13	109.14	102	9.00	f. sandstone	7.2	2A	443.17	443.18			mudstone	13.1
2A	111.06	111.07	104	11.00	f. sand	7.2	2A	444.76	444.78	146	10.50	mudstone	13.1
2A	113.50	113.51	105	8.50	mudstone	7.2	2A	449.22	449.23			mudstone	13.1
2A	114.23	114.24	106	12.50	v.f. sandstone	8.1	2A	453.26	453.27	159	11.50	sandy mudstone	13.1
2A	114.71	114.72	107	12.00	v.f. sandstone	8.1	2A	458.52	458.53			sandy mudstone	13.1
2A	118.88	118.89	108	11.00	muddy v.f. sandstone	8.1	2A	463.54	463.55			sandy mudstone	13.1
2A	122.55	122.56	109	10.00	muddy v.f. sandstone	8.1	2A	464.98	465.18	151	11.50	sandy mudstone	13.1
2A	123.50	123.51	110	11.00	muddy v.f. sandstone	8.1	2A	467.90	467.91			sandy mudstone	13.1
2A	128.09	128.10	111	10.50	muddy v.f. sandstone	8.1	2A	471.07	471.08			sandy mudstone	13.1
2A	130.90	130.92	88	11.50	muddy f. sandstone	8.2	2A	473.97	473.98			muddy f. sandstone	13.1
2A	132.14	132.15	112	11.50	f. sandstone	8.2	2A	474.97	474.98	165	10.50	muddy f. sandstone	13.1
2A	135.08	135.09			v.f. sand	8.2	2A	480.81	480.82	160	11.00	sandy mudstone	13.1
2A	139.91	139.92	115	10.50	v.f. sandy mudstone	8.3	2A	484.54	484.55			v.f. sandy mudstone	13.1
2A	141.27	141.28			v.f. sandy mudstone	8.3	2A	486.32	486.34	150	8.50	v.f. sandy mudstone	13.1
2A	145.59	145.60			v.f. sandy mudstone	8.3	2A	494.10	494.11	166	9.50	laminated v.f. sandstone	13.1
2A	147.53	147.54	116	6.00	v.f. sandy mudstone	8.3	2A	499.02	499.03			f. sandstone	13.1
2A	149.55	149.57			v.f. sandy mudstone	8.3	2A	502.55	502.56	167	11.00	mudstone	13.1
2A	150.77	150.78			v.f. sandy mudstone	8.3	2A	502.56	502.57			lam. siltstone/v.f. sandstone	13.1
2A	154.47	154.48	117	11.50	v.f. sandy mudstone	8.4	2A	507.77	507.79	156	11.00	siltstone	13.1
2A	157.09	157.10			mudstone	8.4	2A	509.80	509.81			lam. mudstone/v.f. sandstone	13.1
2A	158.51	158.53	92	10.50	v.f. sandy mudstone	8.4	2A	515.82	515.83	168	12.00	muddy v.f. sandstone (intraclast)	13.1
2A	161.74	161.75			v.f. sandy mudstone	8.4	2A	523.36	523.37			muddy v.f. sandstone	13.1
2A	165.89	165.90	118	7.00	v.f. sandy mudstone	8.4	2A	524.46	524.48	155	11.00	v.f. sandstone	13.1
2A	168.94	168.95			v.f. sandy mudstone	8.4	2A	531.65	531.66	169	12.50	green m. sandstone	14.1
2A	171.74	171.75			v.f. sandy mudstone	8.4	2A	536.50	536.51	171	12.50	mudstone	15.1
2A	173.44	173.46	119	11.00	v.f. sandy mudstone	8.4	2A	540.90	540.91			muddy v.f. sandstone	15.1
2A	176.18	176.19			v.f. sandy mudstone	8.4	2A	543.81	543.83	154	10.50	siltstone	15.1
2A	177.75	177.76	120	7.50	v.f. sandy mudstone	8.4	2A	548.46	548.47	172	12.00	siltstone	15.2
2A	177.90	177.92	100	11.50	v.f. sandy mudstone	8.4	2A	556.06	556.07	173	13.00	muddy v.f. sandstone	15.2
2A	178.85	178.86			v.f. sandy mudstone	8.4	2A	561.31	561.32			muddy v.f. sandstone	15.2
2A	181.73	181.74	121	8.00	v.f. sandy mudstone	8.4	2A	563.97	563.98			muddy f. sandstone	15.2
2A	185.24	185.25			muddy v.f. sand	9.1	2A	564.68	564.70	162	9.50	v.f. sandy mudstone	15.2
2A	187.45	187.46	122	8.00	f. sandstone	9.2	2A	569.77	569.78			sandy diamicctite	15.2
2A	193.96	193.97			muddy f. sandstone (diamicctite)	9.3	2A	575.36	575.37	174	11.00	mudstone	15.3
2A	195.70	195.72	99	12.50	v.f. sandstone (diamicctite)	9.3	2A	579.04	579.05			siltstone	15.3
2A	199.09	199.10	125	10.00	muddy f. sandstone (diamicctite)	9.3	2A	583.41	583.42			muddy v.f. sandstone	15.3
2A	202.34	202.35			muddy f. sandstone	9.3	2A	584.59	584.61	161	9.50	v.f. sandy mudstone	15.3
2A	207.21	207.22	127	5.00	muddy f. sandstone	9.3	2A	588.13	588.14			f. sandstone	15.4
2A	211.25	211.26			muddy v.f. sandstone	9.3	2A	594.90	594.91	175	8.50	muddy f. sandstone	15.4
2A	215.24	215.25	130	7.00	muddy f. sandstone	9.3	2A	601.34	601.35	176	11.00	muddy f. sandstone	15.4
2A	215.49	215.52	113	10.00	muddy f. sandstone	9.3	2A	603.06	603.07			lam. v.f. sandstone/siltstone	15.5
2A	218.17	218.18			muddy v.f. sandstone	9.3	2A	604.44	604.46	164	12.50	sandy mudstone	15.5
2A	220.52	220.53			muddy f. sandstone	9.3	2A	608.25	608.27	170	-	coal pebble	15.5
2A	227.01	227.02	131	6.00	muddy f. sandstone	9.3	2A	608.33	608.34			lam. v.f. sandstone/siltstone	15.5
2A	232.90	232.91			muddy f. sandstone	9.3	2A	612.60	612.61	177	11.00	muddy f. sandstone	15.5
2A	236.34	236.35	114	11.50	muddy v.f. sandstone	9.3	2A	620.21	620.22	179	12.00	v.f. sandy mudstone	15.6
2A	242.82	242.83			muddy v.f. sandstone	9.3	2A	623.77	623.79	163	10.50	sandy mudstone	15.6
2A	245.49	245.50	132	5.50	mudstone	9.3	2A	624.14	624.15	178	12.00	v.f. sandy mudstone	15.6
2A	251.20	251.21			mudstone	9.4							

Note: blank laboratory numbers = reserved samples; \* = reprocessed sample.

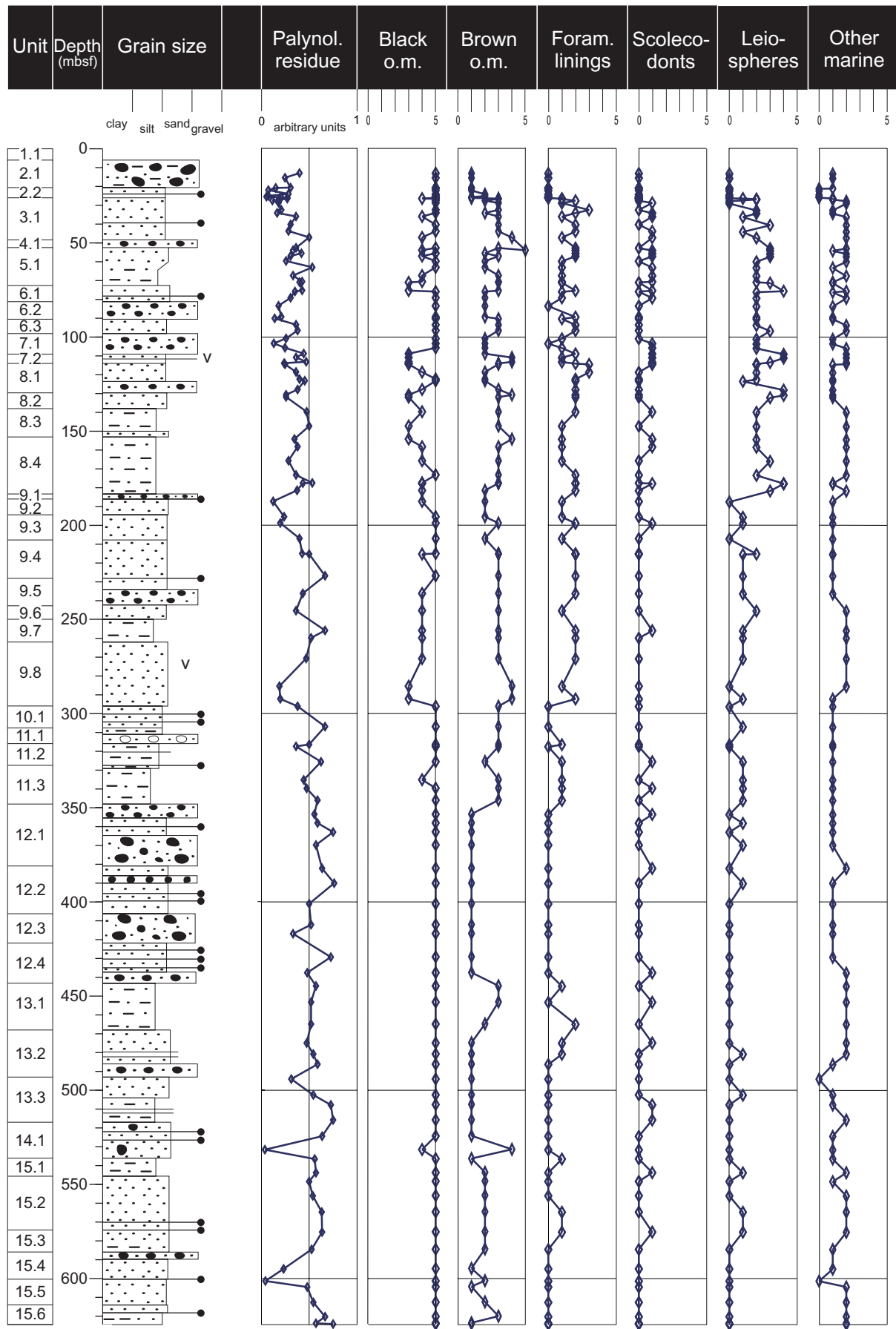
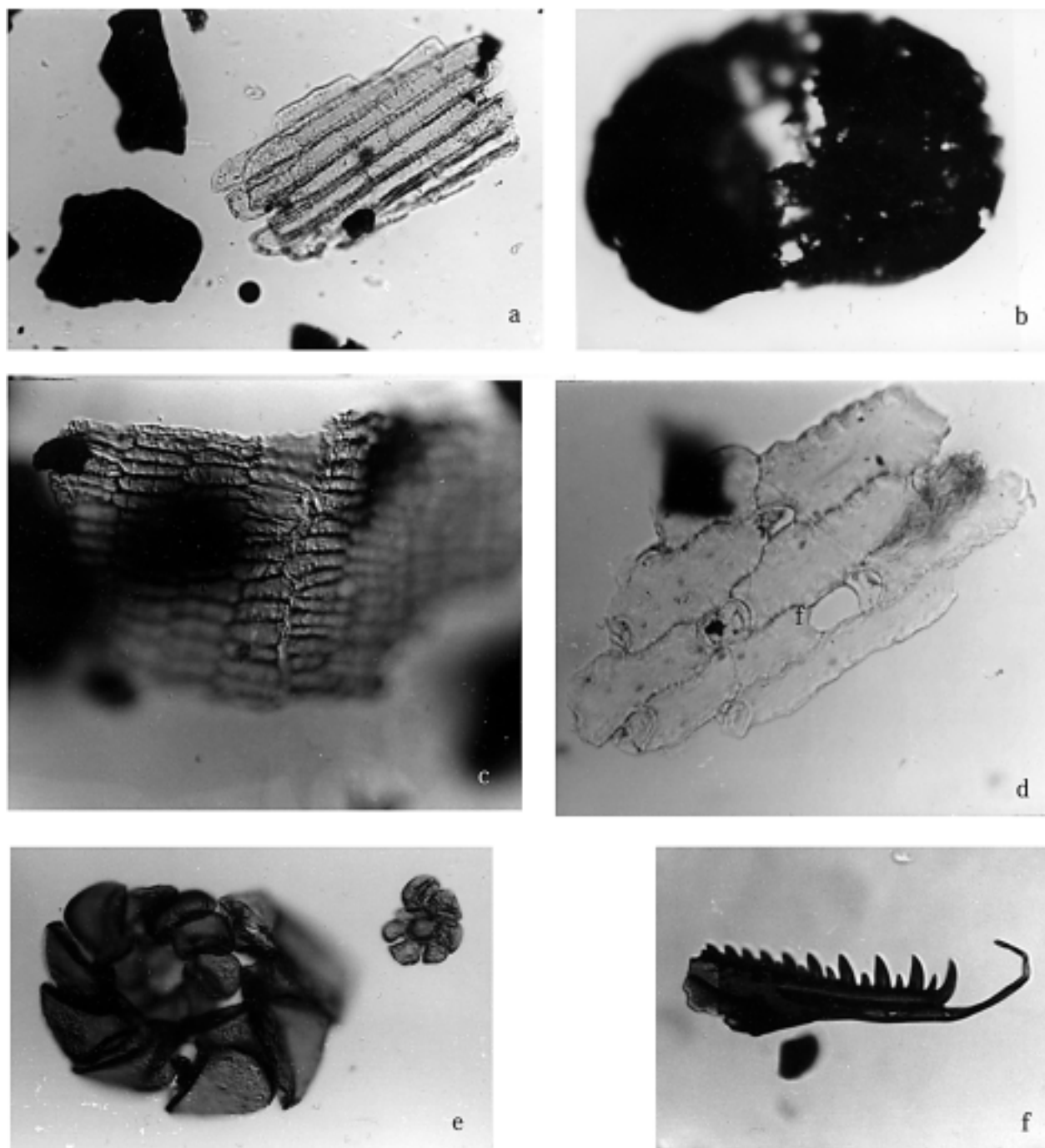


Fig. 5.6 - Palynofacies: relative abundance of organic particulate material (palynological residue) per unit weight of sediment; and relative abundance of major components of the organic matter classed according to a semi-quantitative scale by visual estimation: 0 - absent; 1 - rare, one to a few specimens per sample; 2 - sparse, moderate numbers of specimens per sample; 3 - common, very many specimens per sample; 4 - abundant, major component of organic residue; 5 - prolific, dominant component of residue.



*Fig. 5.7* - Palynofacies: photomicrographs of selected organic material and palynomorphs found in CRP-2/2A samples. *a*) light-coloured woody phytoclast and black recycled coaly fragments: depth 620.21-620.22 mbsf, slide number P179/2, England Finder coordinates O40/0, magnification x200; *b*) black thermally metamorphosed recycled taeniate bisaccate pollen: 531.65-531.66 mbsf, P169/1, V41/0, x1000; *c*) plant tissue of undetermined affinity: 524.46-524.48 mbsf, P155/3, V39/4, x250; *d*) plant cuticle with stomata, of undetermined affinity: 335.29-335.30 mbsf, P143/2, E47/4, x1000; *e*) microforaminiferal linings: 44.08-44.09 mbsf, P67/1, H50/1, x250; *f*) jaw apparatus of polychaete annelid (scolecodont): 474.97-474.98 mbsf, P165/2, F36/3, x250.

Relative proportions of components of the palynological material (Batten, 1996), excluding amorphous organic matter, were classed by visual inspection of the microscope slides using a 5-part scale (Fig. 5.6). The major components include:

- black organic matter: opaque angular, more or less equidimensional particles of *c.* 10-120  $\mu\text{m}$  diameter, a range determined by the mesh of sieves used in

preparation (Fig. 5.7a); these are regarded as detrital coal which, from the identified provenance of macroscopic sediment clasts (see Sedimentology chapter) and the occurrence of recycled Permian and Triassic pollen and spores (*e.g.* Figs. 5.7b & 5.11j, l & m), is certainly derived from the Beacon Supergroup; the component dominates the palynological material in almost all samples, except a few in the upper part of

the section in which the total amount of residue is small and in which brown organic matter and foraminiferal linings assume a greater relative proportion;

- brown organic matter: translucent brown, structured organic matter; probably mostly phytoclasts, *i.e.* derived from plants, and including mainly wood but also some cuticle and other resistant tissue (Fig. 5.7a, c & d); moderate values prevail in the section above 350 mbsf, except for low values in Plio-Pleistocene LSU 2.1 and 2.2, but below 350 mbsf there are relatively low values except for peaks around 450 mbsf in LSU 13.1, at 531.65 mbsf in the well-sorted sandstone of LSU 14.1, and near the base of the section in LSU 15.6;
- foraminiferal linings: the “chitinous” test linings of mainly benthic foraminifera (Fig. 5.7e); these are relatively abundant in the section above 306 mbsf, except for the Plio-Pleistocene interval, but attain similar values in only a few parts of the section below 306 mbsf - peaks in relative abundance in the lower section reflect relatively finer-grained intervals in LSU 13.1, 13.2, and 15.1-15.3, in which conditions were apparently more favourable for foraminifera, and possibly intervals where sediment accumulation rates were lower with less of a dilution effect;
- leiospheres: smooth-walled cysts or cell walls of marine algae (species of *Leiosphaeridia*, Fig. 5.9i, and *Sigmopollis*) of uncertain affinity, classed as Acritarcha (see succeeding section); these are clearly most abundant between the top of the Miocene section at about 27 mbsf and the base of LSU 8.4 at about 180 mbsf, a distribution consistent with their high abundance in the lower part of the CRP-1 Miocene section.

Minor but either conspicuous or palynologically significant components also recorded include:

- other marine microplankton, including spinose and other Acritarcha (Fig. 5.9c-e & h), Prasinophyceae (*e.g.* *Tasmanites*, Fig. 5.9g; *Cymatiosphaera*, Fig. 5.9h), and Dinophyceae (*e.g.* Fig. 5.8a-i); rare to sparse throughout the section; their detailed distribution and significance is discussed in the following section;
- scolecodonts: these are dispersed parts of the mandibles and maxillary apparatus (feeding organs) of polychaete annelid worms (Szaniawski, 1996), but the component may also include superficially similar arthropod and mollusc parts (Fig. 5.7j); rare throughout the sequence but more consistently present in the section above about 200 mbsf; commonly associated with intervals rich in foraminiferal test linings;
- pellets: approximately ellipsoidal aggregates of amorphous and fine particulate organic matter were recorded only in LSU 7.2 and 8.1 in the interval 111.06-118.88 mbsf, where they are rare to sparse; they are probably fecal pellets of marine invertebrates such as copepods, crustaceans, or polychaetes;
- pollen and spores (*e.g.* Fig. 5.10a-m): these are rare almost throughout the section, attaining moderate numbers between 40.54 and 47.41 mbsf in the lower part of LSU 3.1 and in a number of samples below 306 mbsf, in LSU 11.3, 13.1, 14.1, 15.1, 15.2, and 15.3

(there may be an association of these higher values with relatively abundant brown organic matter, reflecting a similar terrestrial vegetation source for this material; detailed distribution of various taxa and groups is discussed in a following section).

## MARINE PALYNOMORPHS

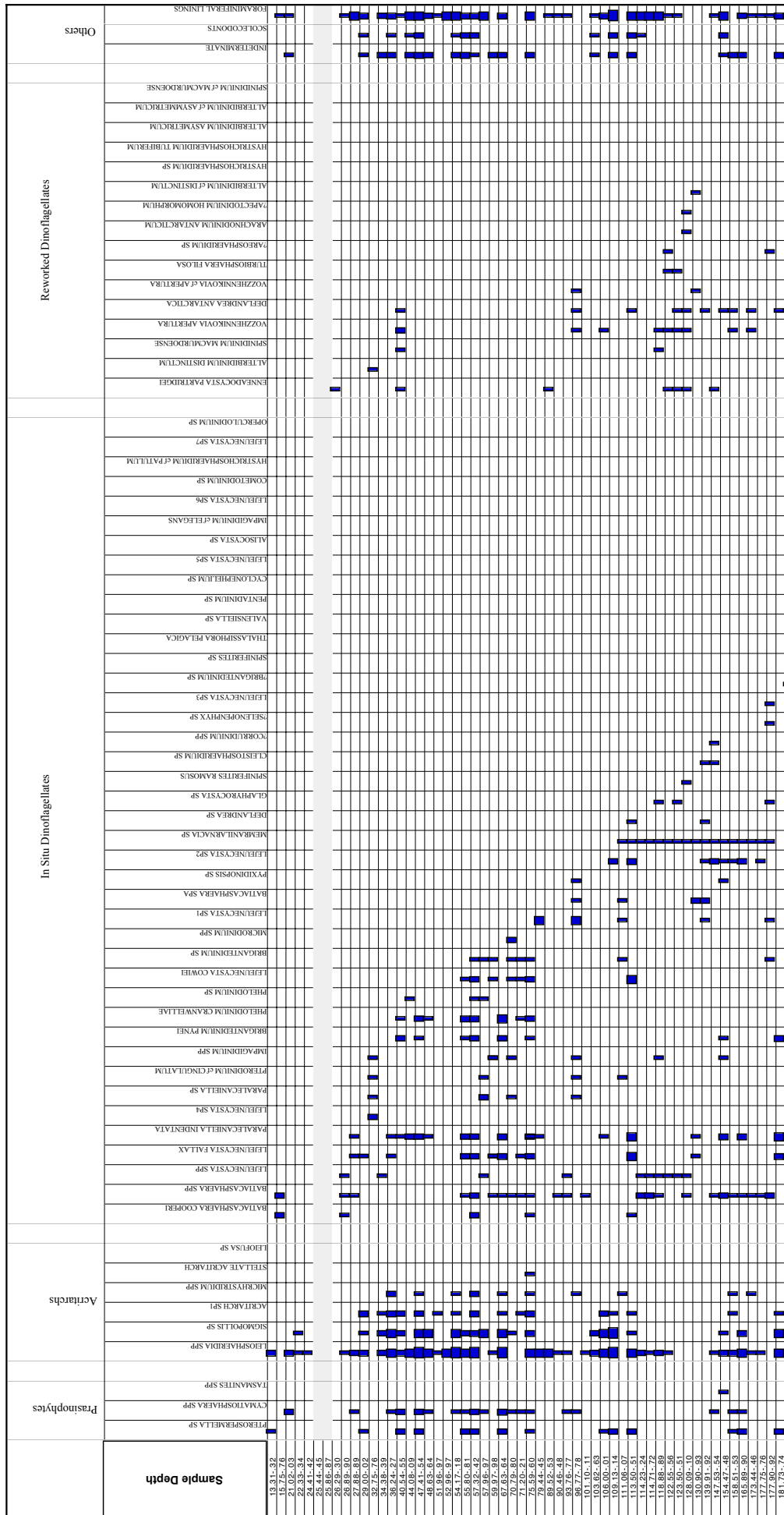
### Assemblage Details

The marine palynomorph contents of 116 samples were examined. Well-preserved marine palynomorphs were recovered, often in high numbers, from most samples examined (Tab. 5.8). Many marine palynomorphs mentioned in this report are illustrated in figures 5.8 and 5.9. Most species not figured here are illustrated in Hannah et al. (1998). The marine palynomorphs from CRP-1 (Hannah et al., 1998; Wrenn et al., 1998) represent a new early Miocene assemblage that had not previously been recorded. Core from CRP-2/2A extends this new *in situ* assemblage down into the Oligocene and then adds additional new *in situ* early Oligocene material at its base. Together, the two wells bridge a significant gap in the Antarctic marine palynomorph record between the older group of largely Palaeogene species referred to as the Transantarctic flora (Wrenn & Hart, 1988) first described by Wilson (1967), and recent material (see McMinn, 1995, for a discussion of this supposed gap). Many of the taxa recorded here are new and are referred to in open nomenclature. A more comprehensive study of the flora is planned for the Science Results Volume on CRP-2/2A, which should lead to the establishment of a potentially useful series of biostratigraphic datums for the Ross Sea region.

*In situ* dinoflagellate cysts (dinocysts) are common and are dominated by protoperidinioid taxa including *Phelodinium* and *Batiacasphaera*. Of particular note is the genus *Lejeunecysta* which is represented by up to six new species in addition to *Lejeunecysta cowiei* and the common *Lejeunecysta fallax*. Acritarchs, mainly *Sigmopollis* and several species of *Leiosphaeridia* are common throughout the drill hole but dominate the assemblage in the upper 160 m of the Oligo-Miocene section. The phycoma of prasinophyte green algae are present throughout the drill hole (*Pterospermella* and several species of *Cymatiosphaera*).

Several species of the Palaeogene Transantarctic flora were recovered. *Vozzhennikovia apertura* is the most common form, but *Enneadocysta partridgei* (Fig. 5.8f), *Deflandrea antarctica*, *Spinidinium macmurdoense* (Fig. 5.8h), *Turbiosphaera filosa* (Fig. 5.7h) and *Arachnodinium antarcticum* (Fig. 5.8d) were also recorded. With the possible exception of specimens from the bottom of the core, all are considered reworked. The presence of *Enneadocysta partridgei* within the Plio-Pleistocene section (26.29-26.30 mbsf) is the highest recorded appearance of this flora in the drill hole. Four species were recorded in a single sample at 40.54-40.55 mbsf. This sudden burst of reworking is probably due to the processing of a clast of Eocene material. Below about 122 mbsf,

Tab. 5.8 - Marine palynomorphs from the entire CRP-2/2A core. Note: shading = barren sample.





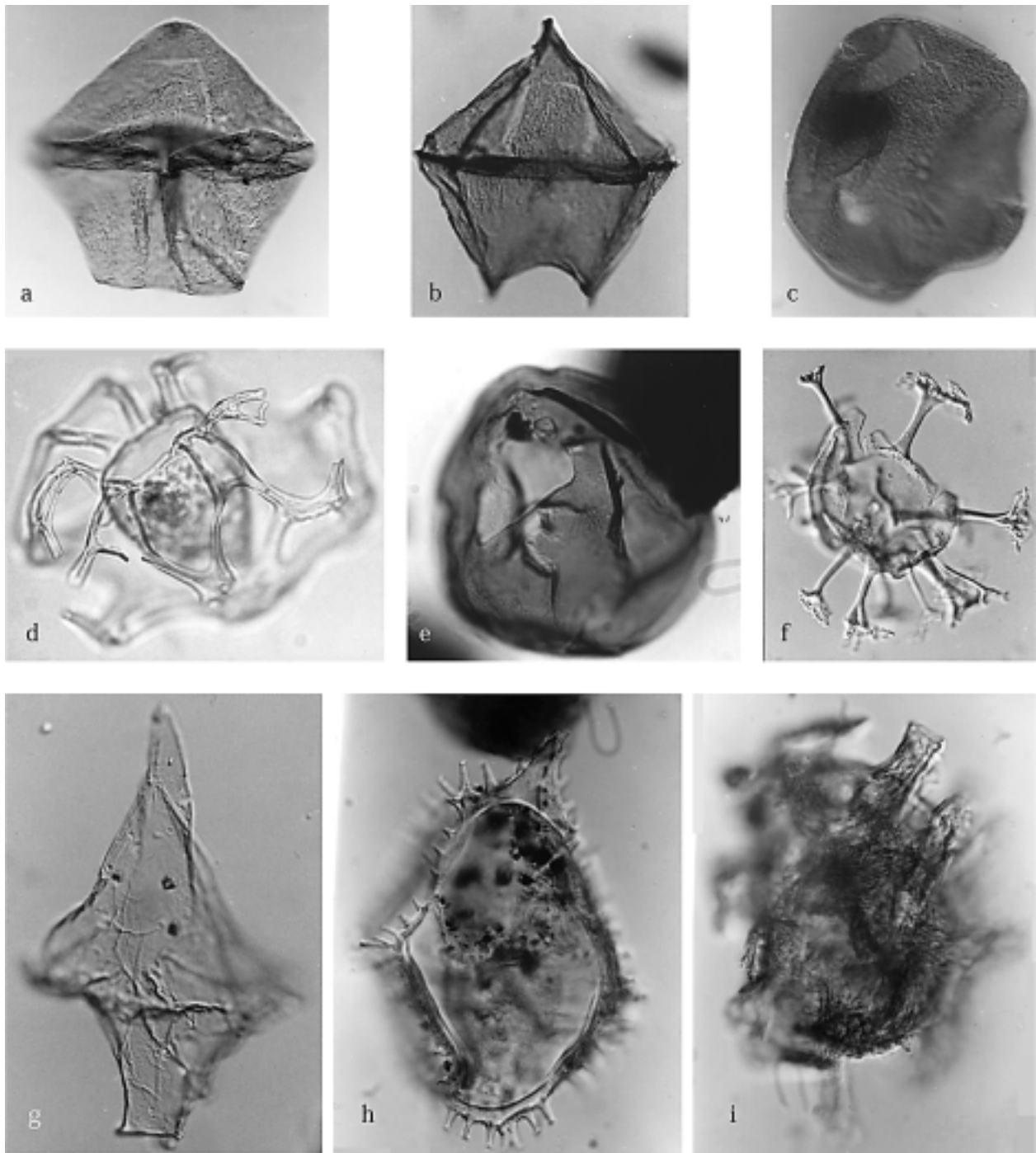


Fig. 5.8 - Selected marine palynomorphs from CRP-2/2A. a) *Lejeunecysta* sp.1: depth = 256.03-256.04 mbsf, slide number = P135/2, England finder coordinates = N38/4, length = 80  $\mu\text{m}$ ; b) *Lejeunecysta* sp. 6: 486.32-486.34 mbsf, P150/3, length = 110  $\mu\text{m}$ ; c) *Lejeunecysta* sp.5: 215.49-215.52 mbsf, P113/1, Q42/1, length = 99  $\mu\text{m}$ ; d) *Arachnodinium antarcticum*: 125.09-125.10 mbsf, single grain mount 001, width of central body = 39  $\mu\text{m}$ ; e) ?*Brigantedinium* sp.: 515.82-515.83 mbsf, P168/3, D55, width of central body = 47  $\mu\text{m}$ ; f) *Enneadocysta partridgei*: 346.12-346.13 mbsf, P144/1, V41, length=55  $\mu\text{m}$ ; g) *Lejeunecysta* sp.7: 495.02-495.04 mbsf, P151/2, M38, length = 70  $\mu\text{m}$ ; h) *Spinidinium macmurdoense* : 316.50-316.52 mbsf, P129/3, P45/4, length = 70  $\mu\text{m}$ ; i) *Turbiosphaera filosa*: 346.12-346.13 mbsf, P144/1, W39/4, width of central body = 61  $\mu\text{m}$ .

reworking becomes more persistent. It is particularly intense between samples at 464.98-454.18 and 444.76-444.78 mbsf.

The Oligo-Miocene *in situ* marine palynomorph assemblage can be subdivided into three informal units:

- *Marine Palynomorph Unit I*: 26.89-26.90 to 181.73-181.74 mbsf. Samples from Unit I yielded some of the richest marine palynomorph floras in the drill hole. Assemblages are commonly dominated by high

numbers of the acritarchs *Leiosphaeridia* and *Sigmopollis*. The base of this interval is marked by the last down-hole occurrence of *Sigmopollis* and the dinocysts *Paralecaniella indentata* and *Lejeunecysta fallax*, which are restricted to this interval. At approximately the same level there is a gradual change down-hole to significantly lower numbers of *Leiosphaeridia*. The three species of *Leiosphaeridia* previously recognised in CRP- 1 (Hannah et al., 1998)

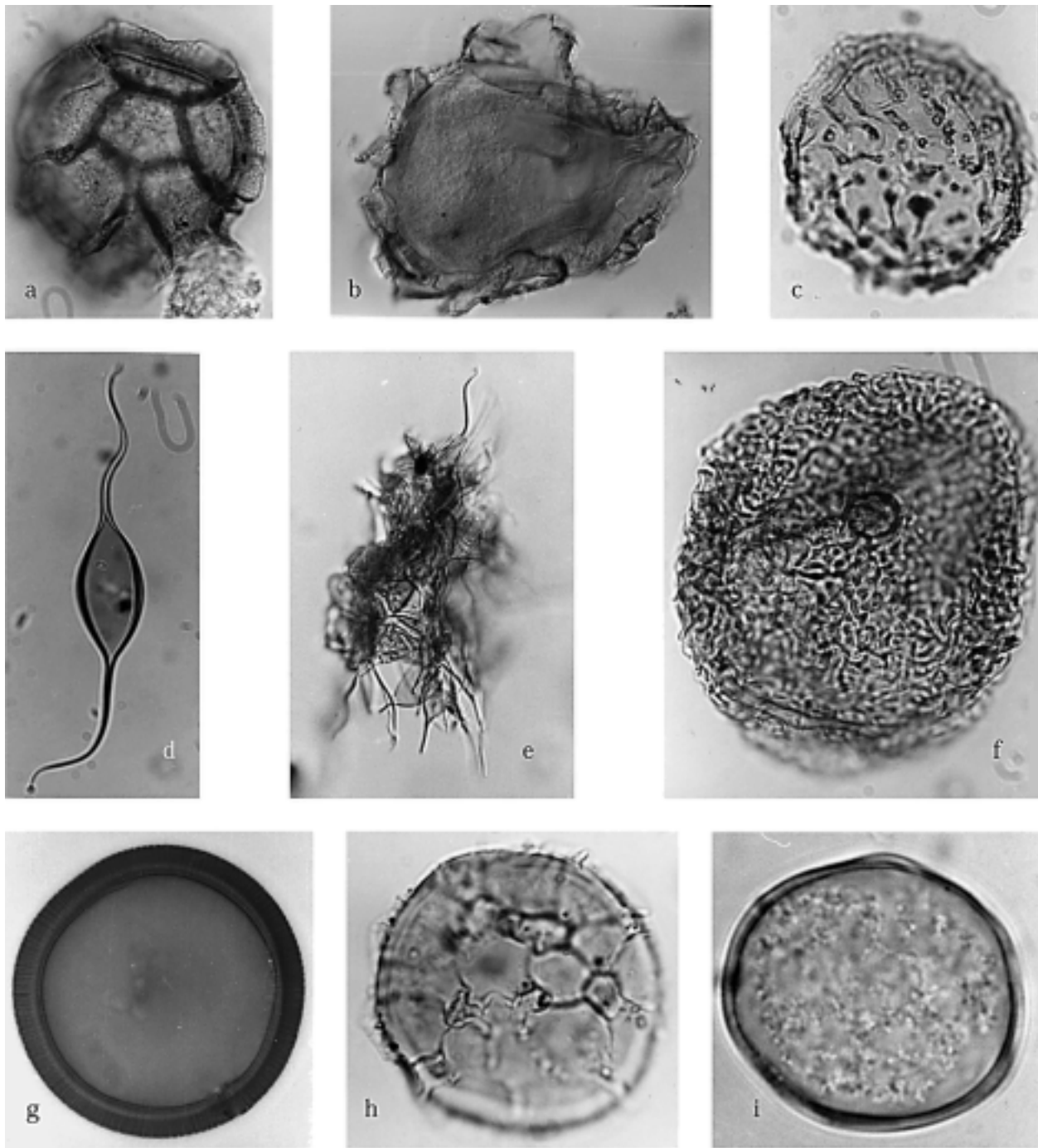


Fig. 5.9 - Selected marine palynomorphs from CRP-2/2A. a) *Impagidinium cf elegans*: depth = 536.50-536.51 mbsf, slide number = 171/4 England finder co ordinates = C46/2, length = 94  $\mu$ m; b) *Glaphrocysta* sp.: 256.03-256.04 mbsf, P135/1, P40/1, width = 77  $\mu$ m; c) *Micrhystridium* sp.: 464.98-465.18 mbsf, P155/1, P40/1, width = 29  $\mu$ m; d) *Leiofusa* sp.: 316.50-316.52 mbsf, P129/2, S38, length = 72  $\mu$ m; e) *Leiofusa* ?colony: 307.12-307.13 mbsf, P139/1, S38, length = 115  $\mu$ m; f) ?*Pyxidinospis* sp.: 453.26-453.27 mbsf, P159/1, O54/3, width = 50  $\mu$ m; g) *Tasmanites* sp.: 260.00-260.02 mbsf, P123/1, N37/2, width = 100  $\mu$ m; h) *Cymatiosphaera* sp.: 453.26-453.27 mbsf, P159/1, E46/4, width = 29  $\mu$ m; i) *Leiosphaeridia* sp.: 75.59-75.60 mbsf, P81/1, U38/4, width = 27  $\mu$ m.

are all present in this unit and additional forms have been recognized, particularly in the two lower units. Several species of *Cymatiosphaera* and *Pterospermella* make up a small proportion of assemblages.

In Unit I both the number and diversity of spinose acritarchs is very low and the assemblage very similar to that recorded from between 99.01 mbsf and the bottom of the hole in CRP-1. The similarity between the assemblages documented in Unit I of CRP-2/2A

and the basal part of CRP-1 is underscored by the presence of the dinocyst *Phelodinium cranwelliae* in the upper part of Unit I. This species occurs persistently below 112.44 mbsf in CRP-1, although it does have a patchy distribution up to 82.18 mbsf. Other distinctive proteroperidinioid dinocysts described from CRP-1 (*Batiacasphaera cooperi*, *Brigantedinium pynei*, and *Lejeunecysta cowiei*) are also found in the upper part of Unit I.

- *Marine Palynomorph Unit II: 187.45-187.46 to 296.32-296.33 mbsf.* This interval is bounded above by the first appearance datum (FAD) of *Sigmopolis*, *Paralecaniella indentata* and *Lejeunecysta fallax*, coupled with a decrease in number and diversity in leiospheres. Its base is placed at the FAD of the dinocyst *Lejeunecysta* sp.1 (a distinctive compact form, Fig. 5.7a), and the first appearance datum (FAD) of *?Pyxidinospis* (Fig. 5.9f) together with the incoming of the fusiform acritarch *Leiofusa* (Fig. 5.9d). Assemblages from this interval are generally sparse with low acritarch and prasinophyte numbers. *Lejeunecysta* sp.1 is present in all but one sample from Unit II.
- *Marine Palynomorph Unit III: 307.12-307.13 to bottom of hole.* The top of this interval is placed at the FAD of *Lejeunecysta* sp.1, and the LADs of *?Pyxidinospis* sp. and the fusiform acritarch *Leiofusa*. The interval continues to the bottom of the hole. A sharp increase in coaly fragments accompanies the dinocyst and acritarch changes. In some samples, *Leiofusa* is abundant. Although usually occurring as single grains in two samples (at 307.12-307.13 and 480.81-480.82 mbsf, Fig. 5.9d), clumps consisting of numerous individuals were located which are interpreted as colonies (Fig. 5.9e). The significance of these forms in large numbers at the base of the hole is unclear. *Lejeunecysta* sp.6 (Fig. 5.8c) is another distinctive protoperidinioid dinocyst with two prominent antapical horns and an elongate apical horn. It is one of several new species of *Lejeunecysta* which dominate the dinocyst assemblages in this interval. *?Pyxidinospis* sp. (Fig. 5.8f) is a moderate to large dinocyst with a variably rugulose wall texture. Some specimens clearly show a precingular archaeopyle and can be confidently assigned to this genus. However, on some individuals an apical archaeopyle may be present. In addition, the variation in the wall texture suggests that further work may subdivide this into several species. The appearance of distinctive species of *Lejeunecysta* and *Impagidinium* cf. *elegans* (Fig. 5.9a) at 453.26-453.27 mbsf offers the possibility that Unit III may be subdivided further.

### Age and Environmental Significance

Since most of the *in situ* marine palynomorph assemblage is either undescribed or reworked, little can be added to the age determination of CRP-2/2A provided by other microfossil groups. Because the elements of the Transantarctic flora present in Unit III are still most likely reworked, it appears that the drill hole did not reach the earliest Oligocene/Eocene dinoflagellate assemblage recorded in CIROS-1 (Hannah, 1997; Wilson, 1967). The presence of *Lejeunecysta fallax* suggests an age of no younger than middle Miocene for the section below 29.00-29.02 mbsf

Wrenn et al. (1998) recognized two distinct sections in the Miocene part of CRP-1, reflecting differing environmental conditions at the time of deposition. The

section above 99.01 mbsf in CRP-1 is characterized by abundant acanthomorph acritarchs. It was suggested that high acanthomorph numbers were linked to the presence of seasonal sea-ice during deposition. The section below 99.01 mbsf is dominated by leiospheres and *Sigmopolis*, and a lack of acanthomorphs indicating perhaps a lack of seasonal sea-ice.

Acanthomorph acritarchs are relatively uncommon in CRP-2/2A, and they never reach the frequency and abundance recorded in CRP-1, with the possible exception of the sample at 36.24-36.27 mbsf which does contain a modest number. If the tentative linkage made by Wrenn et al. (1998) were to be substantiated, this would suggest that seasonal sea-ice was not common or did not exist during the deposition of most of the Oligo-Miocene interval of CRP-2/2A. Alternately, the absence of acanthomorphs may be a result of other, perhaps evolutionary reasons.

There is no analogous section in CRP-1 to Unit III. This interval is characterized by protoperidinioid cysts, persistent occurrence of *Cymatiosphaera* (but not the other common prasinophyte algae *Pterospermella*, which is largely restricted to Units I & II), and the presence of the fusiform acritarch *Leiofusa*. The palaeoenvironmental significance of this interval is unclear.

### TERRESTRIAL PALYNOMORPHS

#### Distribution

A total of 123 samples was examined. A great scarcity of terrestrial palynomorphs (spores and pollen) and a lack of any major change down-hole characterizes CRP-2/2A (Tab. 5.9). Both presumed contemporaneous and recycled components can be recognized, the latter including Cenozoic forms (most likely Eocene) and Permian to Mesozoic components.

The terrestrial succession is subdivided into two broad units. Although total numbers of recovered taxa and specimens remain very low, there is a significant increase in species diversity and spore and pollen abundance below approximately 300 mbsf. Recycled assemblages occur in intervals or individual samples and include what are interpreted as recycled Eocene, Jurassic-Cretaceous, and Permian-Triassic specimens. A significant increase in Permian-Triassic palynomorphs is also noted below 300 mbsf.

Preservation of the Cenozoic palynomorphs, including presumed contemporaneous and recycled specimens, is generally good to very good. There are some poor specimens, however, that are broken and torn, or have mineral scarring from pyritization, particularly in the lower part of the hole. The Cenozoic specimens are mostly light yellow to yellow in colour, although some have a darker (orange) tinge and most of these are presumed to be recycled from older Cenozoic rocks (see below). The recycled Jurassic-Cretaceous and Permian-Triassic palynomorphs are generally less well-preserved, although a few very good specimens were encountered. Exinal colors are darker, ranging from orange and brown to black, with a few yellow-orange specimens obviously much less affected by thermal metamorphism.





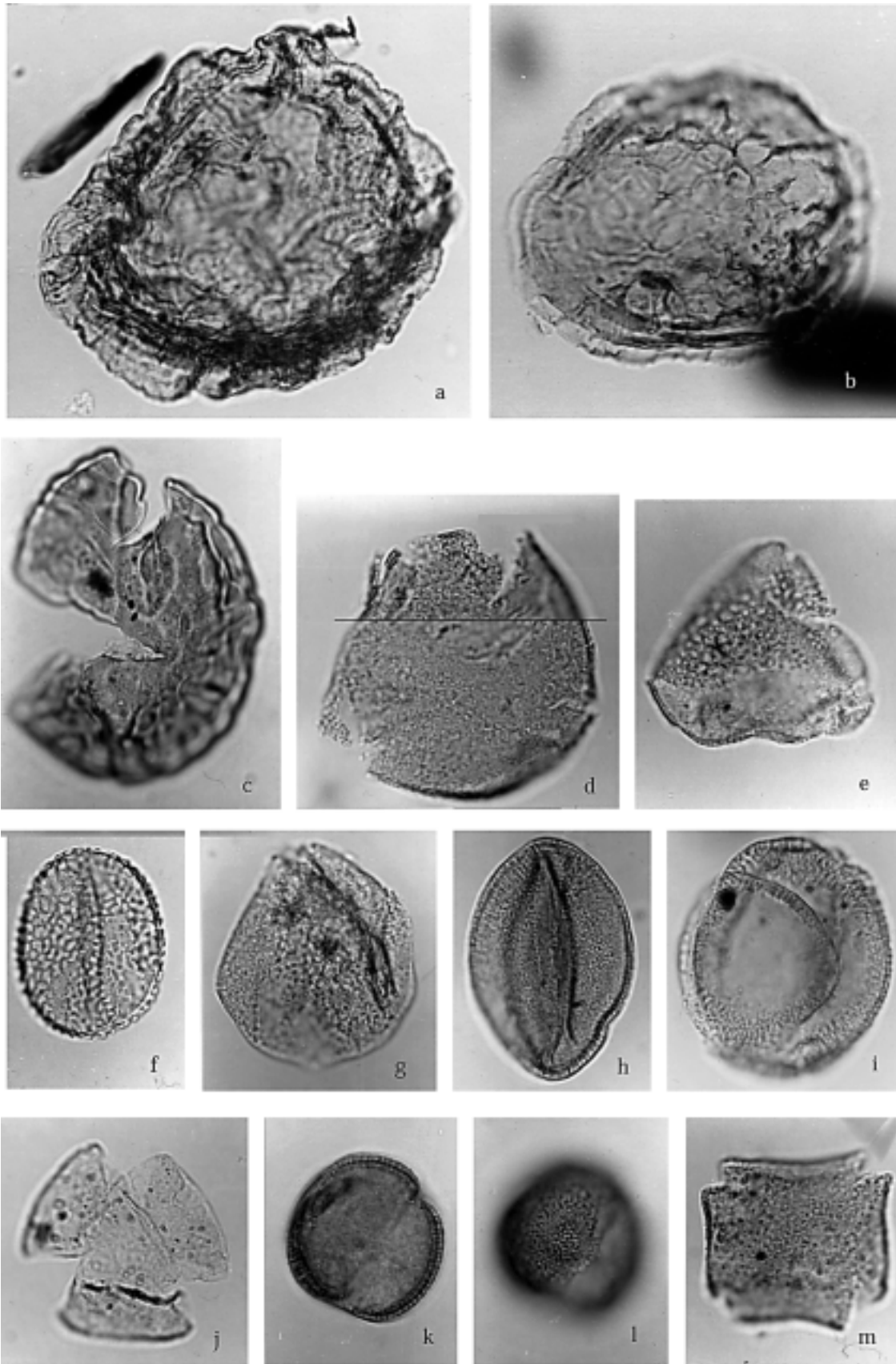


Fig. 5.10 - Photomicrographs of selected spores and pollen from CRP-2/2A, all at magnification approximately x1000. All are Cenozoic taxa. a) Marchantiaceae, depth 123.50-123.51 mbsf, P110/2, England Finder coordinates C45/0, maximum dimension 78  $\mu\text{m}$ ; b) *Ricciaesporites* sp., 575.36-575.37 mbsf, P174/2, M42/0, 67  $\mu\text{m}$ ; c) *Coptospora* sp., 260.00-260.02 mbsf, P123/1, X36/4, 78  $\mu\text{m}$ ; d) *Assamiapollenites incognitus* Pocknall & Mildenhall, 215.49-215.52 mbsf, P113/2, K43/2, 44  $\mu\text{m}$ ; e) *Phormium* sp., 346.12-346.13 mbsf, P144/1, P43/3, 34  $\mu\text{m}$ ; f) *Liliacidites variegatus* Couper, 536.50-536.51 mbsf, P171/1, E38/0, 36  $\mu\text{m}$ ; g) *Cyperaceapollis* sp., 444.76-444.78 mbsf, P146/2, O35/1, 39  $\mu\text{m}$ ; h) *Tricolpites* sp.a, 21.02-21.03 mbsf, P63/1, N52/3, 45  $\mu\text{m}$ ; i) *Tricolpites* sp.a, irregularly syncolpate specimen, 113.50-113.51 mbsf, P105/2, N43/2, 44  $\mu\text{m}$ ; j) *Tricolpites* sp.b, 453.26-453.27 mbsf, P159/3, G36/0, 32  $\mu\text{m}$ ; k, l) *Tricolpites* sp.c, different focus levels, 27.88-7.89 mbsf, P64/1, E51/2, 29  $\mu\text{m}$ ; m) *Stylidiaceae*, 47.41-47.54 mbsf, P57/1, W50/0, 31  $\mu\text{m}$ .

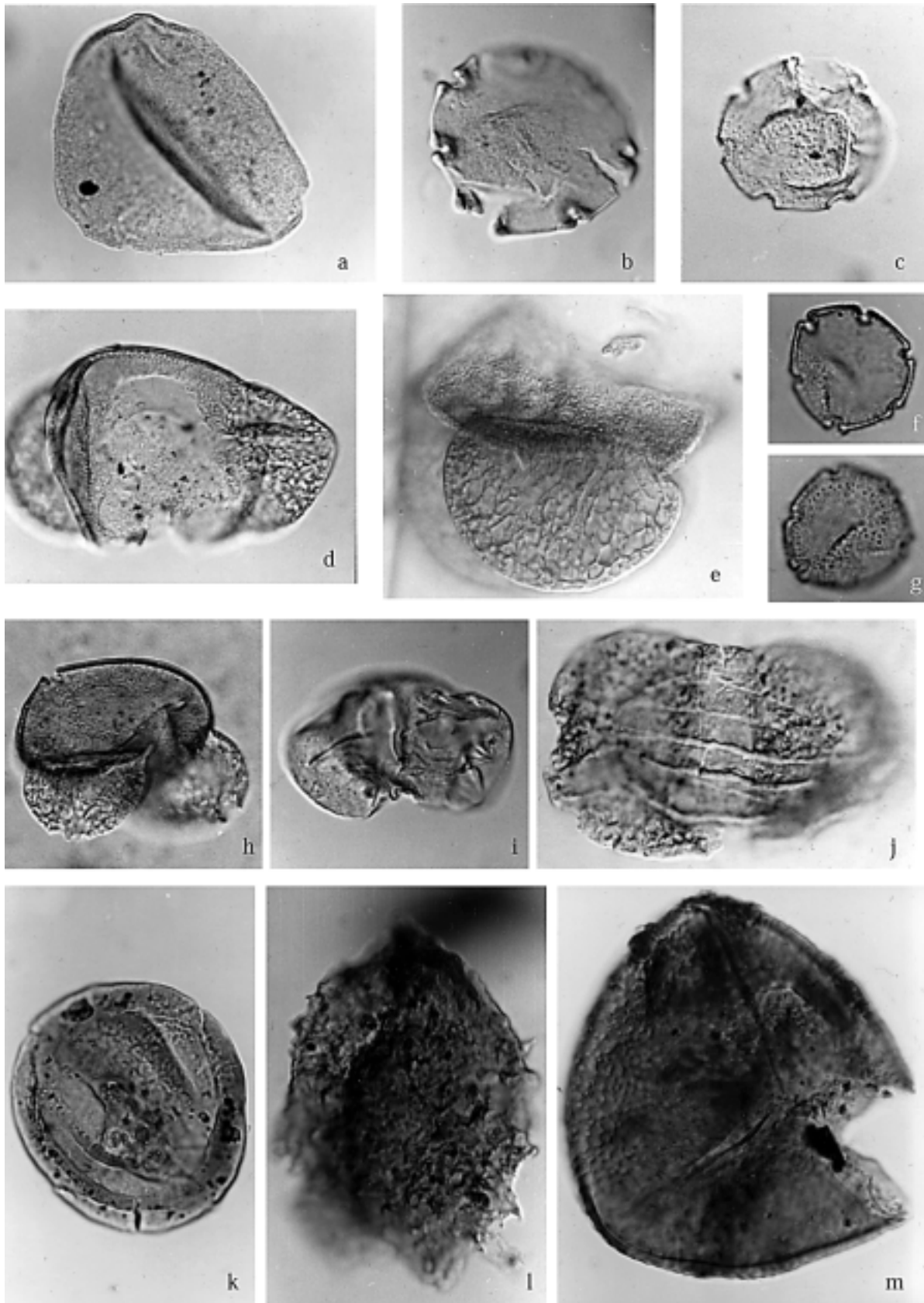


Fig. 5.11 - Photomicrographs of selected spores and pollen from CRP-2/2A, all at magnification approximately x1000. Figures a) to g) are Cenozoic taxa, figures j, l, m are recycled Permian-Triassic taxa, figure k) is a recycled Jurassic-Cretaceous taxon. a) *Triporopollenites* sp., 256.03-256.04 mbsf, P135/1, O35/0, 42  $\mu\text{m}$ ; b) *Nothofagidites flemingii* (Couper) Potonić, 40.54-40.55 mbsf, P66/1, Q36/4, 37  $\mu\text{m}$ ; c) *Nothofagidites lachlaniae* (Couper) Pocknall & Mildenhall, 584.59-584.61 mbsf, P161/2, H42/4, 30  $\mu\text{m}$ ; d) *Podocarpidites* sp.a, 548.46-548.47 mbsf, P172/2, P43/4, 59  $\mu\text{m}$ ; e) *Podocarpidites* sp.b, 22.33-22.34 mbsf, P72/1, F56/2; f, g) *Nothofagidites* sp. (*fusca* group), different focus levels, 594.90-594.91 mbsf, P175/1, T55/0, 23  $\mu\text{m}$ ; h) *Podocarpidites* sp.a, 390.17-390.19, P136/1, M51/2; i) *Podocarpidites* cf. *exiguus* Harris, 353.61-353.62 mbsf, P145/1, Y58/1, 41  $\mu\text{m}$ ; j) *Protahaploxypinus* sp., 44.08-44.09 mbsf, P67/1, E40/2, 63  $\mu\text{m}$ ; k) *Corollina* sp., 480.81-480.82 mbsf, P160/single mount, 45  $\mu\text{m}$ ; l) *Aratrisporites parvispinosus* Leschik em. Playford, 474.97-474.98 mbsf, P165/1, U40/0, 66  $\mu\text{m}$ ; m) *Pseudoreticulatispora pseudoreticulata* (Balme & Hennelly) Bharadwaj & Srivastava, 57.32-57.42, P58/1, E48/2, 69  $\mu\text{m}$ .

Cape Roberts Science Team, 1998c, p. 106, and Raine, 1998, for comments on this species).

*Terrestrial palynomorph Unit II, ~306 to 624.15 mbsf.* This interval includes an increased diversity and abundance of palynomorphs, particularly *Nothofagidites* spp. (including *N. flemingii*, *N. cf. flemingii* - a smaller form, *N. lachlania* [Fig. 5.11c], *N. spp.* [undifferentiated *fusca* group, e.g. Fig. 5.11f-g]), and various species of *Podocarpidites* spp. Numbers increase again at about 437 mbsf and below.

Notable occurrences and possibly significant datums in this interval include the LAD of *Podocarpidites* sp.a at 316.50-316.52 mbsf; the First Appearance Datum (FAD) of Marchantiaceae at 339.80-339.82 mbsf; and occurrence of *Phormium* sp. at 346.12-346.13, *Cyperaceae pollis* sp. at 444.76-444.78, and *Ranunculaceae* at 488.32-488.34 mbsf.

The conifer pollen species *Podocarpidites* sp.a (Fig. 5.11d,h) occurs throughout most of the lower interval, together with other species of *Podocarpidites*. These, along with taxa such as *Phormium* sp. (Fig. 5.10e), *Cyperaceae pollis* sp. (Fig. 5.10g) and *Ranunculaceae*, may prove useful age indicators in the future, although the single occurrences of the latter three in no way can reflect their total ranges. In New Zealand, examples of *Phormium* sp. with a morphology similar to that of the modern species of the genus have an FAD in the Late Eocene or Oligocene (Raine, unpublished data).

### Palaeoenvironmental Significance

The rare and extremely low number of species of terrestrial palynomorphs preserved in the CRP-2/2A drill hole provides a picture of a very sparse vegetation which survived essentially unchanged for much of the Oligocene and Miocene. Both sparseness of vegetation and dilution by rapid sediment accumulation rate contributed to the rarity of spores and pollen in the core. The total numbers of presumed contemporaneous terrestrial palynomorphs are so low that they probably do not adequately reflect the local (or regional) vegetation. Even so, it is possible to reconstruct at least part of the vegetation in the sampled Oligocene to Miocene section.

Prior to deposition of the basal sediments of CRP-2/2A, the relatively rich Antarctic Eocene vegetation had disappeared, presumably in response to major cooling and glaciation of the landscape near the end of the Eocene. In New Zealand a major vegetational change, also in response to cooling, occurred near the top of the Upper Eocene Kaiatan Stage (~36-35 Ma) (Pocknall, 1989; Hollis et al., 1997).

Assemblages in the lowermost part of CRP-2/2A never reach the richness in species diversity and abundance seen in the Eocene McMurdo Sound erratics (Wilson, 1967; Askin, unpubl. data) or in the Eocene lower part of CIROS-1 where a great variety of angiosperm taxa, including Proteaceae and representatives of other families not encountered here, were recorded (Mildenhall, 1989). Instead, the Lower Oligocene assemblages found in the lower part of the core suggest a low diversity woody

vegetation which included several species of *Nothofagus* and podocarpaceous conifers, several other angiosperm families, and few cryptogams except for bryophytes (mosses and liverworts). Many of the important components of the prior Eocene flora are missing, for example several species of Proteaceae, various other angiosperms, gymnosperms and cryptogams.

Further deterioration of conditions in this part of Antarctica resulted in additional loss of various components from the land flora. Unglaciated parts of the Late Oligocene to Miocene landscape supported a much reduced flora, probably a low-growing sparse tundra vegetation, as discussed by Raine (1998) for the CRP-1 core. The vegetation included at least one (though possibly more) species of *Nothofagus*, at least one species of podocarpaceous conifer, and a few other angiosperms and cryptogams including mosses. Physiognomically similar vegetation occurs today in the northern Arctic region. Elements of the Antarctic Neogene flora survive in the modern Subantarctic and southern alpine floras.

### Possible Recycled Cenozoic Palynomorphs

It is likely that some or many of the Cenozoic spores and pollen are recycled from older Cenozoic rocks. Particularly obvious is the interval with three samples (40.54-40.55, 44.08-44.09, 47.41-47.54 mbsf) in the Lower Miocene (Tab. 5.9). These samples contain significantly increased numbers of palynomorphs, mainly *Nothofagidites* spp. Some of these specimens have a slightly darker exinal colour, suggestive of a greater burial history, but many are indistinguishable from presumed in-place specimens. Most of these species (which have ranges throughout much of the Cenozoic of New Zealand) were also observed in the Quaternary and Miocene parts of CRP-1 (Cape Roberts Science Team, 1998b, 1998c; Raine, 1998) and in the Eocene McMurdo Sound erratics (Askin, unpubl. data). The 40 to 48 mbsf interval is also characterized by abundant recycled Eocene dinoflagellate cysts, lending credence to the notion that these spore and pollen specimens are recycled from Eocene sediments.

### Recycled Jurassic-Cretaceous Palynomorphs

Sporadic single occurrences of spore and pollen taxa typical of Jurassic-Lower Cretaceous strata (such as *Corollina* spp., Fig. 5.11k; *Callialasporites segmentatus*) were noted in the drill hole, the highest occurrence being at 93.76-93.77 mbsf. None of the taxa recorded has a restricted range. A possible source of this material is sedimentary strata of the Jurassic Ferrar Group. Palyniferous Jurassic sedimentary rocks have been reported (Tasch & Lammons, 1977) from Carapace Nunatak, upstream of and slightly to the north of Mackay Glacier.

### Recycled Permian-Triassic Palynomorphs

Well-preserved yellow-orange specimens to barely recognizable black corroded remnants of Permian-Triassic spores and pollen occur sporadically throughout most of

the drill hole (*e.g.* Figs. 5.7b & 5.11j, l, m). There is a significant increase in the frequency of these occurrences below ~306 mbsf. As identified in table 5.9, some of these taxa have restricted Permian or Triassic ranges in the Transantarctic Mountains and elsewhere. The provenance of these specimens is the Permian-Triassic Victoria Group of the Beacon Supergroup. Much of the organic material recovered in the palynology samples comprises black coaly fragments interpreted as derived from the Beacon Supergroup (see section on Palynofacies above). Judging from the greater abundance of Beacon palynomorphs below ~306 mbsf, erosion and redeposition of Beacon Supergroup strata were greater during that part of the Oligocene represented by this lower section of the drill hole. At some levels above this, occurrences may represent short intervals of down-cutting into Beacon strata. These are sometimes recognizable immediately above erosion surfaces (such as in 26.29-26.30 and 26.36-26.37 mbsf). Other occurrences may simply result from incorporation of a Beacon microclast into the sediment. The sample at 130.90-130.93 mbsf contains several specimens of varying ages (Permian and Triassic) and varying states of preservation and thermal alteration (from orange specimens to black skeletal remnants), suggestive of erosion from different parts of the Beacon Supergroup and from different areas. At 531.65-531.66 mbsf, an unconsolidated green sand with coaly granules yielded an assemblage composed entirely of black corroded specimens (*eg.* Fig. 5.7b). Most of these are recognizable as bisaccate and taeniate bisaccate pollen and are probably of Permian age, suggestive of erosion of the Permian Weller Coal Measures. This is also the likely source of the high rank coal pebble at 608.25-608.27 mbsf, from which no palynomorphs could be extracted.

## MACROPALAEONTOLOGY

### INTRODUCTION

Macrofossils visible in the half of the core available for sampling (and locally in the archive half) were all recorded (Fig. 5.12, Tab. 5.10). Potential macrofossil-bearing core intervals were, in some cases, specifically searched for less obvious body fossils and moulds through the inspection of fractured surfaces. A few macrofossils were also identified within micropalaeontological (foraminifera) residues. Macrofossils are locally abundant throughout the CRP-2/2A core in both lithified and semi-lithified sediment, and within concretions, although not in all lithostratigraphical units.

Preservation is highly variable. Pristine shells are relatively common in fine-grained sediments, especially in association with mudstone lithologies in LSU 8.4, 9.3 and 9.4. In most cases, however, diagenetic processes have affected the calcareous skeletal parts resulting in a variety of preservation of macrofossils, ranging from slightly chalky to complete dissolution of the shell. Aragonitic fossils (*e.g.* corals and gastropods) are seldom preserved and never in good condition; corals typically display a sugar-like texture, whereas gastropods are

normally completely leached and preserved as moulds; in some rare cases, shells show advanced stages of decalcification and deposition of secondary cements. Concretion development is also common at specific levels of the core CRP-2/2A core, resulting in semi-indurated sediment up to fossiliferous "limestones" (LSU 9.4, 9.7 and 15.1, Fig. 5.13). Pyritization is rare and in most cases not advanced; *e.g.* pyritized infillings of serpulid tubes (178.89 mbsf) and bivalves (182.17 mbsf).

Thus far, 324 macrofossil-bearing horizons have been identified in the CRP-2/2a core. In consideration of the preliminary character of the present report, most taxonomic nomenclature is left open and suitable for revision. The preliminary list of macrofossils is reported in appendix 1.

### TAXONOMIC REMARKS

Various groups of marine macroinvertebrates are represented in the CRP-2/2A core. These are: Mollusca, Annelida, Cnidaria, Echinodermata, Bryozoa and Porifera, while the possible occurrence of Brachiopoda (161.52 mbsf) awaits confirmation. Vertebrates are represented by the rare occurrence of fish scales (166.64 mbsf) and teeth.

Relatively few fossils are sufficiently well-preserved to be discussed in detail regarding their taxonomic position and only some general and very preliminary comments are provided here.

### Mollusca

Mollusca are by far the dominant taxonomic group in the macrofossil assemblages documented in the CRP-2/2A core. This phylum includes representatives of Bivalvia (with a minimum of seven species recognized so far, but possibly in excess of ten), Gastropoda (four-five species at least) and Scaphopoda (one species, uncertain).

*Class Bivalvia.* Fragmented or whole bivalves are widespread throughout the core, with the exception of LSU 4.1, 10.1, 11.1, 11.2, 13.3, 14.1, 15.3, 15.5, and 15.6, which appear barren of macrofossils; they are also the most common of the macrofossils.

- 1- Large protobranchs have been positively recognized in LSU 9.7. Material ranges from fresh to highly decalcified. Unfortunately, no complete fresh shells are available for inspection. Preliminary determination is based on the very few specimens showing some diagnostic features. A very decalcified and incomplete specimen (210.10 mbsf; Fig. 5.14a) shows evidence of a taxodont hinge; the best preserved specimen is a left valve from 260.83 mbsf whose shell is reminiscent of *Yoldia* (Fig. 5.14b).
- 2 - Pectinids (scallops) are rare and mostly occur as incomplete and/or abraded fragments in LSU 2.1 to 6.3, and 8.4. The best specimen is an incomplete shell (broken during drilling and lacking most of the diagnostic shell parts) tentatively assigned to *Adamussium*.
- 3 - Mytilids (mussels) dominate the macrofossil assemblages in LSU 12.4, 13.1, 13.2 and 15.4

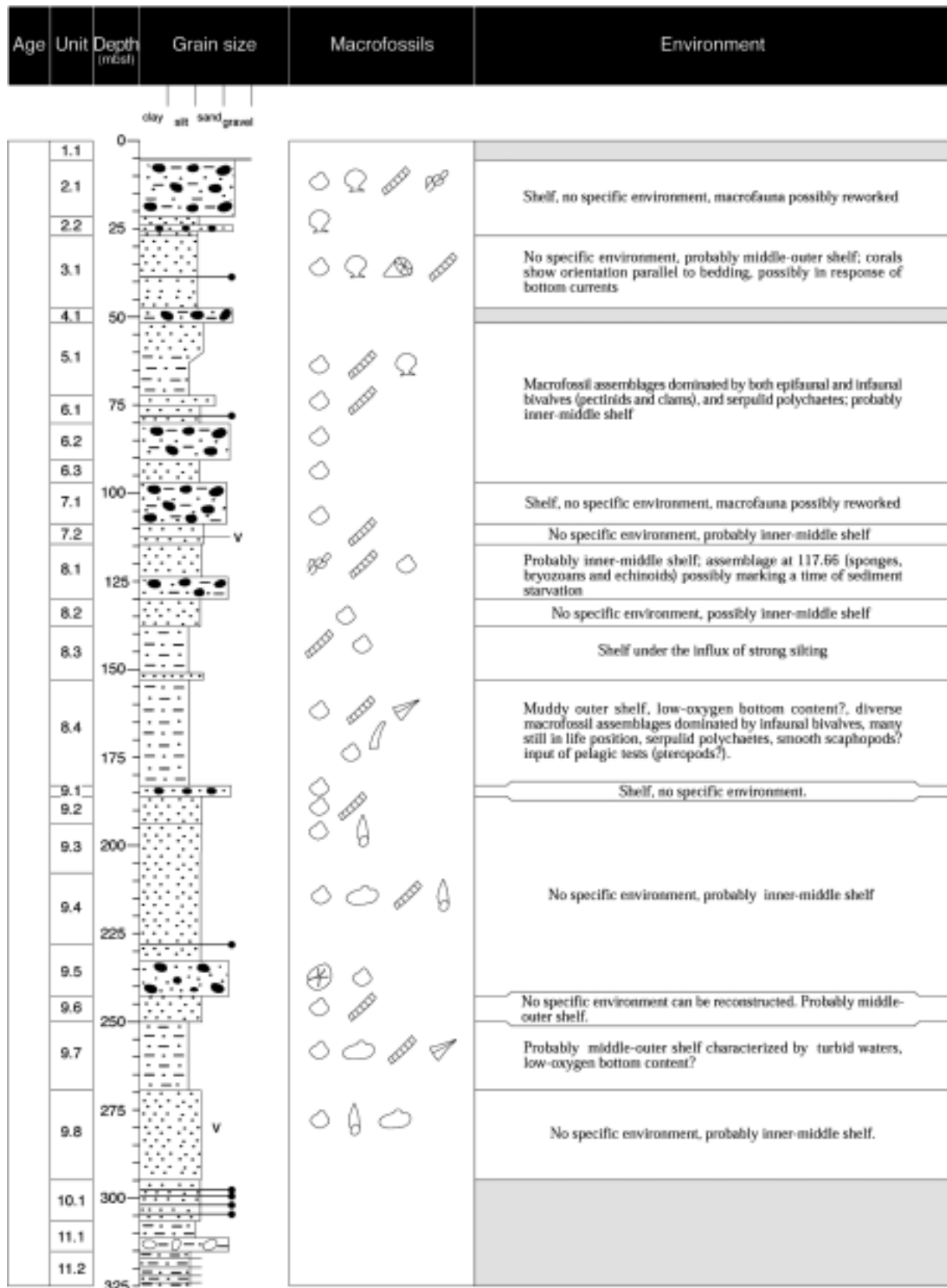


Fig. 5.12 - Lithostratigraphical summary of CRP-2/2A drill hole showing position and composition of the major macrofossil assemblages and their palaeoenvironmental significance.

(Fig. 5.14c). Mytilids apparently belong to a single species of a modioloid mussel (probably *Modiolus*). Most specimens appear to be still articulated and some are in life position. *Modiolus* is known from Early Tertiary deposits on Seymour Island, Antarctic

Pensinsula (Stilwell & Zinsmeister, 1992) but it is unknown from younger beds in Antarctica.

4 - Veneracean? clams occur in LSU 8.4 and 9.3. The only relatively well-preserved specimen shows concentric grooves on the external surface.

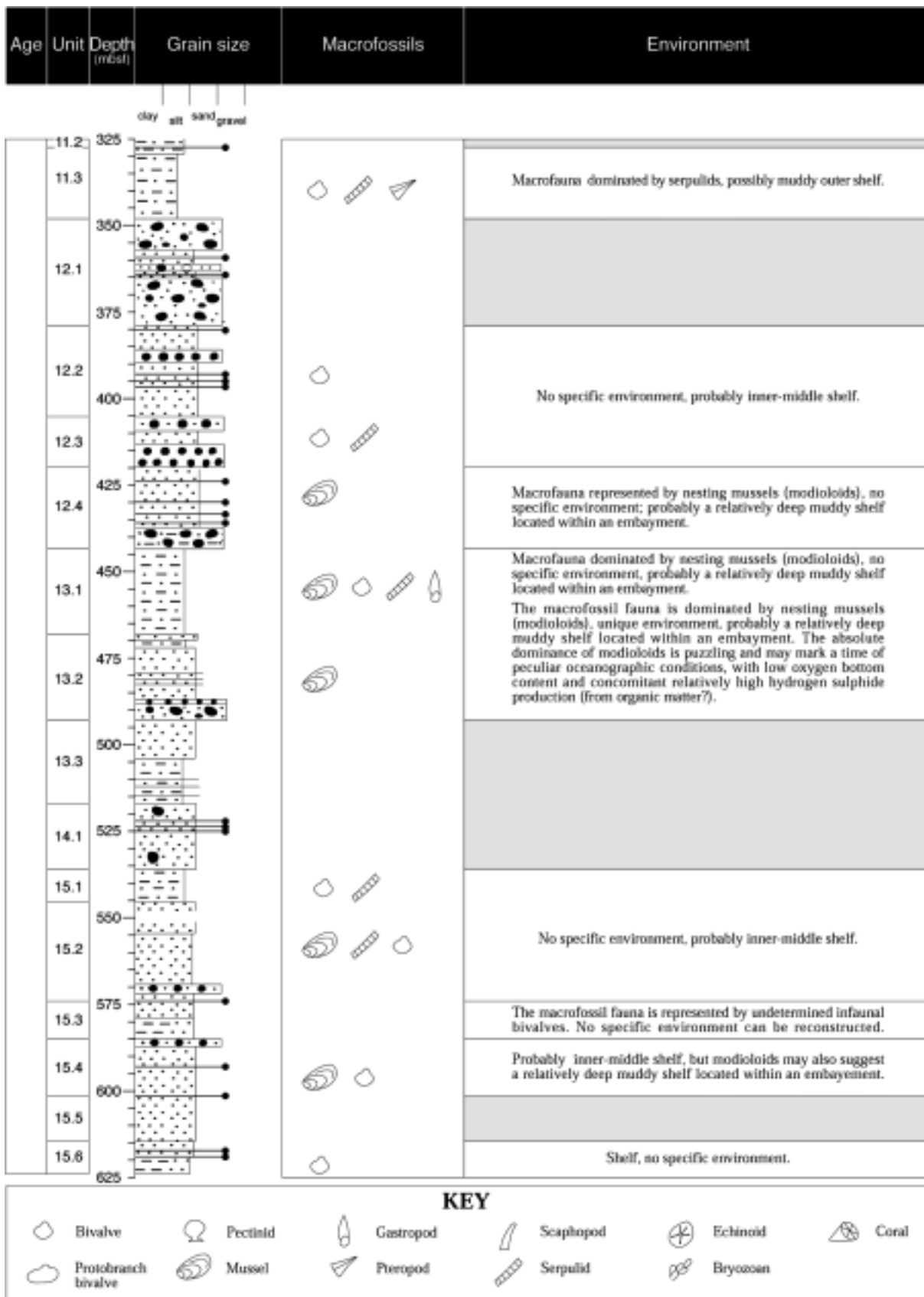


Fig. 5.12 - Continued.

5 - A square-shaped, shell shows some resemblance to species belonging to the nesting bivalve genus *Hiatella* (Fig. 5.14d) the advanced decalcification of the shell prevents any further taxonomic speculation at present.

*Class Gastropoda.* Gastropods are rare and are represented by a few decalcified specimens and moulds. Remarkable is the discovery of possible holoplanktic mollusca (thecosomatous pteropods). A few broken shells from LSU 8.4 (still retaining some original shell material),

Table 5.10 - Inventory of CRP-2/2A macrofossils.

<b>LSU 2.1</b>	96.71-96.76 mbsf: pectinid and other bivalve fragments
6.95-7.02 mbsf: unidentified macrofossil fragment	96.79-96.84 mbsf: unidentified macrofossil fragment
9.13-9.14 mbsf: unidentified macrofossil	
10.12-10.13 mbsf: unidentified mollusc fragment	<b>LSU 7.1</b>
10.14-10.15 mbsf: unidentified bivalve fragment	100.59-100.60 mbsf: unidentified small bivalve (decalcified)
10.28-10.29 mbsf: unidentified bivalve fragment	100.60 mbsf: unidentified small bivalve
10.46-10.47 mbsf: unidentified bivalve fragment	<b>LSU 7.2</b>
15.15-15.16 mbsf: unidentified bivalve (pectinid?) fragment	114.00-114.01 mbsf: serpulid polychaete tubes
15.76-15.86 mbsf: unidentified bivalve fragment	
16.30-16.38 mbsf: bryozoan and bivalve fragment, echinoid spines	<b>LSU 8.1</b>
19.84-19.90 mbsf: serpulid polychaete tube fragment, echinoid spines	116.00-116.01 mbsf: serpulid polychaete tubes
<b>LSU 2.2</b>	117.32-117.34 mbsf: unidentified small bivalve (decalcified)
20.50-20.51 mbsf: unidentified bivalve fragment	117.66-117.72 mbsf: bryozoans (aligned), sponge-spicule mats?, echinoid theca? (fragments)
22.05-22.06 mbsf: bivalve (pectinid?) fragment	117.75-117.76 mbsf: unidentified bivalve (decalcified), serpulid polychaete tubes?
22.12-22.13 mbsf: pectinid ("Chlamys"?) fragment	118.20-118.21 mbsf: serpulid polychaete tube (decalcified)
23.90-23.19 mbsf: bivalve (pectinid?) fragment	119.30-119.31 mbsf: unidentified bivalve ( <i>Hiatella?</i> ) (decalcified)
24.49-24.51 mbsf: bivalve (pectinid?) fragment	119.64-119.66 mbsf: unidentified thin shelled bivalve
<b>LSU 3.1</b>	119.77-119.80 mbsf: unidentified thin shelled bivalve
33.38-33.39 mbsf: bivalve fragment	121.43-121.45 mbsf: unidentified bivalve (decalcified)
33.74-33.75 mbsf: bivalve fragment	121.54-121.56 mbsf: unidentified small bivalve (decalcified)
34.62-34.63 mbsf: unidentified macrofossil fragment	126.55-126.56 mbsf: bivalve fragments (pectinid), polychaete serpulid tube
34.77-34.78 mbsf: unidentified macrofossil fragment	
35.94-35.96 mbsf: bivalve fragment	<b>LSU 8.2</b>
36.01-36.05 mbsf: solitary coral? fragment (sugar-like texture)	133.72-133.74 mbsf: unidentified bivalve
36.21-36.22 mbsf: pectinid and solitary coral? fragment (sugar-like texture)	135.48-135.51 mbsf: unidentified macrofossil
36.24-36.27 mbsf: solitary coral?	137.74-137.75 mbsf: concretion with unidentified thin shelled bivalves
36.29-36.30 mbsf: bivalve (pectinid) fragment	
36.50-36.51 mbsf: solitary coral? (sugar-like texture)	<b>LSU 8.3</b>
37.17-37.18 mbsf: serpulid polychaete tube	138.39-138.41 mbsf: unidentified thin shelled ?bivalve
39.91-39.92 mbsf: unidentified macrofossil (bivalve?, coral?) fragment	138.43-138.45 mbsf: serpulid polychaete tubes
40.12-40.13 mbsf: unidentified bivalve fragment (very small)	141.74-141.78 mbsf: bunch of serpulid polychaete tubes (recrystallized)
<b>LSU 5.1</b>	<b>LSU 8.4</b>
54.11-54.14 mbsf: undet thin shelled bivalve (pectinid)	158.38-158.48 mbsf: serpulid polychaete tube (only mold)
54.23-54.26 mbsf: undet thin shelled bivalve (pectinid?)	161.52-161.54 mbsf: unidentified ribbed clam or brachiopod
54.28-54.26 mbsf: pectinid ("Adamussium"?) fragment	162.98-163.06 mbsf: serpulid polychaete tube fragment
54.32-54.33 mbsf: undet thin shelled bivalve	163.41-163.42 mbsf: serpulid polychaete tube, scaphopod?
54.61-54.64 mbsf: concretion with undet thin-shelled bivalve	163.56-163.58 mbsf: serpulid polychaete tube or scaphopod?
54.83-54.84 mbsf: undet bivalve, serpulid polychaete tube? fragment	163.87-163.88 mbsf: articulated bivalve (decalcified)
54.94-54.98 mbsf: undet thin shelled bivalve (pectinid?)	165.41-165.42 mbsf: unidentified scaphopod?
55.79-55.80 mbsf: undet bivalve fragment	165.48-165.50 mbsf: articulated bivalve (veneracean?)
55.87-55.88 mbsf: unidentified macrofossil (serpulid?bivalve?) concreted	165.79-165.80 mbsf: articulated bivalve (veneracean?)
56.00-56.01 mbsf: undet bivalve ( <i>Hiatella</i> ?) fragment	166.64-166.65 mbsf: unidentified macrofossils, fish scale
56.03-56.04 mbsf: serpulid polychaete tube	168.17-168.20 mbsf: unidentified large bivalve
56.19-56.20 mbsf: serpulid polychaete tube?	167.83-167.84 mbsf: unidentified tubular macrofossil
56.48-56.51 mbsf: serpulid polychaete tubes?	168.17-168.20 mbsf: relatively large, thin shelled bivalve
57.32-57.42 mbsf: serpulid polychaete tube	169.38-169.40 mbsf: fresh unidentified macrofossil (broken during preparation) most probably an articulated small bivalve
63.69-63.71 mbsf: serpulid polychaete tube (fragment)	170.92-170.94 mbsf: concretion with thecosomatous pteropod?
71.42-71.47 mbsf: well preserved (but broken by drilling) pectinid ("Adamussium"?)	176.30-176.33 mbsf: large thin shelled bivalve (pectinid?) almost encased in semi-endurated mudstone
<b>LSU 6.1</b>	176.74-176.75 mbsf: scaphopod (fresh, but incomplete shell) or perhaps a thecosomatous pteropod
75.60-75.67 mbsf: serpulid polychaete tube	178.11-178.13 mbsf: unidentified thin shelled bivalve
80.10-80.13 mbsf: concretion with unidentified bivalves	178.89-178.91 mbsf: serpulid polychaete tubes (pyritized)
80.55-80.58 mbsf: serpulid polychaete tube	179.25-179.27 mbsf: unidentified thin shelled macrofossil.
80.65-80.68 mbsf: serpulid polychaete tubes (well preserved); bivalves ( <i>Hiatella</i> ?; articulated but decalcified)	180.08-180.10 mbsf: thecosomatous pteropod? (fresh)
<b>LSU 6.2</b>	180.17-180.22 mbsf: unidentified articulated bivalve (veneracean?), pectinid ( <i>Adamussium</i> ?)
86.42-86.43 mbsf: unidentified macrofossil	182.17-182.22 mbsf: unidentified articulated bivalve (pyritized), serpulid polychaete tube
90.49-90.51 mbsf: bivalve (? pectinid) fragment	
91.36-91.38 mbsf: bivalve (?pectinid) fragment	<b>LSU 9.1</b>
<b>LSU 6.3</b>	184.14-184.16 mbsf: unidentified thin shelled bivalve
91.46-91.47 mbsf: unidentified bivalve fragment	184.29-184.31 mbsf: unidentified thin bivalve fragment
91.56-91.57 mbsf: unidentified bivalve (decalcified)	184.96-184.98 mbsf: unidentified thin bivalve fragment
91.88-91.89 mbsf: small unidentified macrofossil fragment	
93.16-93.17 mbsf: unidentified bivalve (decalcified)	<b>LSU 9.2</b>
95.30-95.42 mbsf: concretion with unidentified thin shelled bivalves	191.18-191.19 mbsf: unidentified large and articulated thin shelled bivalve
95.51 mbsf: mbsf: unidentified thin shelled bivalve	191.24-191.25 mbsf: unidentified macrofossil

Table 5.10 - Continued.

192.41-192.42 mbsf: unidentified large thin shelled bivalve	226.85-226.89 mbsf: relat. large unidentified turritiform, high-spire gastropod (recrystallized)
192.65-192.66 mbsf: unidentified small macrofossil fragment	227.27-227.33 mbsf: unidentified bivalve ( <i>Yoldia?</i> )
193.40-193.42 mbsf: unidentified thin shelled bivalve	
193.43-193.44 mbsf: unidentified thin shelled bivalve	
193.48-193.49 mbsf: unidentified macrofossil fragment	
<b>LSU 9.3</b>	<b>LSU 9.5</b>
193.73-193.75 mbsf: unidentified tiny bivalve fragments	227.39-227.42 mbsf: unidentified ribbed bivalve, juvenile unidentified articulated bivalve
193.81-193.83 mbsf: unidentified relatively large thin shelled bivalve	228.94-228.96 mbsf: unidentified thin costate articulated bivalve
194.87-194.91 mbsf: unidentified small articulated bivalves, serpulid polychaete tube	230.22-230.25 mbsf: echinoid
195.29-195.32 mbsf: unidentified thin shelled bivalve	231.16-231.19 mbsf: unidentified thin shelled bivalve fragment
195.36-195.37 mbsf: unidentified thin shelled, articulated and costate bivalve	232.47-232.49 mbsf: unidentified thin costate bivalve fragment
195.44-195.48 mbsf: unidentified articulated bivalve (veneracean?, decalcified)	232.98-233.00 mbsf: unidentified thin shelled articulated bivalve
195.51-195.52 mbsf: unidentified tiny bivalve fragments	233.43-233.47 mbsf: unidentified bivalve? fragment
195.75-195.78 mbsf: unidentified thin shelled bivalve	234.99-235.03 mbsf: unidentified articulated bivalve
196.21-196.23 mbsf: unidentified relatively large thin shelled bivalve	236.54-236.55 mbsf: unidentified bivalve fragment
196.63-196.66 mbsf: unidentified thin shelled bivalve	236.61-236.64 mbsf: unidentified macrofossil (echinoid?)
197.02-198.03 mbsf: unidentified thin shelled bivalve (decalcified)	238.60-238.62 mbsf: unidentified bivalve fragment
197.00-198.04 mbsf: unidentified thin shelled bivalve	240.13-240.14 mbsf: unidentified bivalve fragment
197.14-198.15 mbsf: unidentified bivalve fragments	
197.24-197.25 mbsf: unidentified thin shelled bivalve	<b>LSU 9.6</b>
197.55-197.57 mbsf: unidentified macrofossil fragment	244.80-244.83 mbsf: unidentified bivalve fragment
197.67-197.72 mbsf: unidentified tiny bivalve fragment	246.97-247.00 mbsf: unidentified articulated bivalve (protobranch?)
197.96-197.98 mbsf: unidentified thin shelled bivalve	247.09-247.12 mbsf: unidentified thin shelled bivalve
198.02-198.04 mbsf: unidentified articulated bivalve (decalcified)	247.67-247.71 mbsf: serpulid polychaete attached on unidentified bivalve shell fragment
198.04-198.05 mbsf: unidentified thin shelled bivalve	249.65-249.69 mbsf: concretion with numerous unidentified bivalves, many still articulated (coquina)
198.07-198.08 mbsf: unidentified thin shelled bivalve	
198.08-198.12 mbsf: unidentified thin shelled bivalve	<b>LSU 9.7</b>
198.52-198.53 mbsf: unidentified bivalve	250.96-250.97 mbsf: unidentified macrofossil
198.73-198.74 mbsf: unidentified thin shelled bivalve	251.32-251.36 mbsf: unidentified bivalve fragment
198.93-198.94 mbsf: unidentified macrofossil.	254.99-255.03 mbsf: unidentified bivalve ( <i>Yoldia?</i> )
199.56-199.59 mbsf: low-spined, globose gastropod, turritiform high-spined gastropod, ribbed articulated bivalve	255.27-255.30 mbsf: thecosomatous pteropod?
199.72-199.75 mbsf: unidentified bivalve (decalcified)	256.04-256.05 mbsf: serpulid polychaete tube
199.82-199.85 mbsf: unidentified bivalve (decalcified)	256.40-256.43 mbsf: unidentified articulated bivalve (protobranch?)
199.91-199.93 mbsf: unidentified macrofossil (decalcified)	256.58-256.59 mbsf: unidentified thin shelled bivalves
200.97-200.99 mbsf: unidentified articulated bivalve	257.60-257.63 mbsf: unidentified articulated bivalve
205.39-205.42 mbsf: unidentified bivalve (decalcified)	258.65-258.68 mbsf: unidentified articulated bivalve
	259.16-259.20 mbsf: many serpulid polychaete tubes
	259.21-259.25 mbsf: serpulid polychaete tubes
	259.49-259.61 mbsf: unidentified bivalve ( <i>Yoldia?</i> )
	260.83-260.87 mbsf: unidentified bivalve ( <i>Yoldia?</i> )
	262.02-262.12 mbsf: unidentified articulated ribbed bivalve (or brachiopod?)
<b>LSU 9.4</b>	262.21-262.24 mbsf: unidentified articulated bivalve ( <i>Yoldia?</i> )
208.58-208.60 mbsf: unidentified bivalve	262.67-262.69 mbsf: unidentified articulated bivalve
209.19-209.22 mbsf: unidentified bivalves (decalcified)	
209.33-209.35 mbsf: protobranch? bivalve	<b>LSU 9.8</b>
209.45-209.49 mbsf: unidentified articulated bivalve (decalcified)	263.16-263.20 mbsf: unidentified bivalve ( <i>Yoldia?</i> ), serpulid polychaete tube
210.10-210.14 mbsf: large protobranch bivalve	263.98-264.01 mbsf: unidentified bivalve? fragment
210.20-210.27 mbsf: unidentified bivalve fragment	285.15-285.93 mbsf: turritiform, high-spined gastropod
210.24-210.30 mbsf: concretion with globose low-spined and turritiform, high-spined gastropods (two species), serpulid polychaete tubes, articulated costate bivalve (mostly decalcified)	285.65-285.68 mbsf: unidentified articulated bivalve
214.07-214.10 mbsf: unidentified macrofossil	291.95-292.03 mbsf: unidentified articulated bivalve
215.24-215.26 mbsf: unidentified thin shelled bivalve	294.07-294.13 mbsf: unidentified large bivalve (mould)
214.34-214.36 mbsf: unidentified bivalve (decalcified)	
215.60-215.68 mbsf: unidentified bivalve	<b>LSU 11.3</b>
216.35-216.38 mbsf: serpulid polychaete tube? unidentified bivalve fragment	328.73-328.76 mbsf: serpulid polychaete tube
216.93-216.96 mbsf: unidentified thin shelled bivalve	338.75-338.79 mbsf: serpulid polychaete tube
217.75-217.78 mbsf: unidentified thin shelled bivalve	341.79-341.87 mbsf: many serpulid polychaete tubes
218.09-218.12 mbsf: unidentified thin shelled bivalve	342.07-342.15 mbsf: many serpulid polychaete tubes, most parallel to bedding
219.18-219.21 mbsf: unidentified thin shelled bivalve	342.26-342.30 mbsf: unidentified tubular macrofossil
219.53-219.56 mbsf: unidentified thin shelled bivalve	344.35-344.38 mbsf: thecosomatous pteropod, unidentified bivalve?
220.45-220.47 mbsf: unidentified thin shelled bivalve	
220.97-220.99 mbsf: unidentified thin shelled bivalve	<b>LSU 12.2</b>
222.35-222.38 mbsf: unidentified bivalve fragments	403.30-403.32 mbsf: unidentified macrofossil fragments
223.13-223.15 mbsf: unidentified thin shelled bivalves	403.36-403.38 mbsf: unidentified bivalve fragments
224.03-224.06 mbsf: unidentified macrofossil fragment	403.40-403.41 mbsf: unidentified macrofossil fragments
224.17-224.20 mbsf: unidentified articulated bivalve (protobranch?)	403.54-403.55 mbsf: unidentified macrofossil fragments
224.30-224.32 mbsf: unidentified thin shelled bivalve fragment	404.85-404.86 mbsf: unidentified macrofossil fragments
224.41-224.47 mbsf: unidentified articulated bivalve	
224.54-224.57 mbsf: unidentified bivalve ( <i>Yoldia?</i> )	<b>LSU 12.3</b>
224.84-224.88 mbsf: unidentified articulated bivalve	406.08-406.09 mbsf: unidentified bivalve fragments
225.58-225.61 mbsf: unidentified bivalve	411.32-411.36 mbsf: unidentified bivalve fragments
225.96-226.00 mbsf: unidentified bivalve fragment	413.19-413.22 mbsf: serpulid polychaete tube

Table 5.10 - Continued.

<b>LSU 12.4</b>	469.87-469.93 mbsf: articulated modioloid bivalves
441.59-441.62 mbsf: articulated bivalve (modioloid?)	482.91-482.93 mbsf: modioloid bivalve
	483.15-483.18 mbsf: modioloid? bivalve
<b>LSU 13.1</b>	<b>LSU 15.1</b>
443.10-443.12 mbsf: unidentified thin shelled bivalve	539.37-539.38 mbsf: unidentified macrofossil fragment
443.50-443.56 mbsf: articulated modioloid bivalves	540.00-540.01 mbsf: unidentified macrofossil fragment
443.91-443.93 mbsf: unidentified articulated bivalve	540.53-540.54 mbsf: unidentified macrofossil fragment
444.09-444.12 mbsf: unidentified gastropod	540.58-540.60 mbsf: unidentified macrofossil fragments
444.31-444.33 mbsf: serpulid polychaete tube	540.61-540.62 mbsf: serpulid polychaete tube?
444.62-444.64 mbsf: articulated modioloid bivalve	541.35-541.36 mbsf: unidentified bivalve fragment
444.72-444.76 mbsf: unidentified marine plant?	544.23-544.24 mbsf: unidentified macrofossil fragment
445.05-445.07 mbsf: unidentified articulated bivalve	544.72-544.73 mbsf: unidentified macrofossil fragment
445.11-445.15 mbsf: articulated juvenile modioloid bivalves	544.80-544.82 mbsf: unidentified bivalve fragment
446.33-446.38 mbsf: unidentified articulated bivalve	
446.65-446.67 mbsf: articulated modioloid bivalve	<b>LSU 15.2</b>
446.59-446.63 mbsf: unidentified bivalve	556.03-556.04 mbsf: unidentified articulated bivalve?
447.24-447.26 mbsf: serpulid polychaete tube	558.74-558.75 mbsf: serpulid polychaete tube?
447.43-447.48 mbsf: articulated modioloid bivalves	559.04-559.07 mbsf: serpulid polychaete tube
447.69-447.81 mbsf: articulated modioloid bivalve	559.71-559.72 mbsf: serpulid polychaete tube?
448.02-448.04 mbsf: modioloid bivalve	560.43-560.44 mbsf: unidentified macrofossil fragment
448.17-448.19 mbsf: serpulid polychaete tube	560.67-560.68 mbsf: undetermined macrofossil fragment
448.58-448.61 mbsf: depressed-spined gastropod	560.95-560.96 mbsf: undetermined macrofossil fragment
449.31-449.35 mbsf: articulated modioloid bivalve	560.98-560.99 mbsf: unidentified bivalve fragment
449.64-449.69 mbsf: articulated modioloid bivalves	561.08-561.09 mbsf: unidentified macrofossil fragment
450.68-450.73 mbsf: articulated modioloid bivalves	561.54-561.55 mbsf: unidentified macrofossil fragment
452.55-452.57 mbsf: unidentified articulated bivalve (decalcified)	563.61-563.62 mbsf: serpulid polychaete tube?
454.45-454.49 mbsf: turritiform, high-spined gastropod, modioloid bivalves	564.95-564.97 mbsf: unidentified bivalve fragment
456.61-456.63 mbsf: modioloid? bivalve	565.48-565.49 mbsf: unidentified articulated bivalves (decalcified)
457.00-457.02 mbsf: unidentified small articulated bivalve	565.93-565.94 mbsf: unidentified bivalve fragment
459.15-459.19 mbsf: articulated modioloid bivalve	566.08-566.09 mbsf: unidentified bivalve fragment
459.28-459.32 mbsf: unidentified bivalve	567.27-567.29 mbsf: unidentified bivalve fragment
460.50-460.58 mbsf: articulated modioloid bivalves	567.81-567.82 mbsf: unidentified bivalve fragment
460.64-460.67 mbsf: two modioloid bivalves	567.87-567.89 mbsf: unidentified thin bivalve fragment
460.76-460.78 mbsf: modioloid bivalve	
461.53-461.57 mbsf: articulated modioloid bivalve and gastropod	<b>LSU 15.4</b>
462.47-462.50 mbsf: unidentified gastropod	585.24-585.25 mbsf: unidentified macrofossil fragment
462.58-462.65 mbsf: articulated modioloid bivalves	592.33-592.34 mbsf: unidentified bivalve fragment
461.65-461.69 mbsf: juvenile modioloid bivalves	594.75-594.76 mbsf: unidentified bivalve? fragment
461.80-461.83 mbsf: modioloid bivalve	595.90-595.91 mbsf: unidentified bivalve? fragment
463.36-463.38 mbsf: articulated modioloid bivalve	596.28-596.29 mbsf: unidentified macrofossil fragment
463.57-463.62 mbsf: juvenile modioloid bivalves, unidentified gastropod	596.52-596.53 mbsf: unidentified macrofossil fragment
463.98-464.00 mbsf: two articulated modioloid bivalves	596.87-596.88 mbsf: unidentified macrofossil fragment
464.40-464.42 mbsf: serpulid polychaete tube	597.28-597.30 mbsf: unidentified macrofossil fragment
464.44-464.47 mbsf: articulated modioloid bivalve	598.19-598.25 mbsf: unidentified bivalves (some articulated)
464.78-464.82 mbsf: three articulated modioloid bivalves	599.01-599.02 mbsf: unidentified bivalve fragment
464.85-464.87 mbsf: articulated (modioloid?) bivalve	599.04-599.05 mbsf: unidentified bivalve fragments
465.22-465.26 mbsf: articulated modioloid bivalve	599.16-599.21 mbsf: unidentified bivalves (pectinid?)
467.16-467.18 mbsf: serpulid polychaete tubes	599.21-599.24 mbsf: concretion with unidentified articulated bivalves
467.20-467.22 mbsf: unidentified small articulated bivalve	599.27-599.35 mbsf: concretion with unidentified bivalves (parallel to bedding, mostly dissolved)
467.34-467.40 mbsf: articulated modioloid bivalves	599.89-599.91 mbsf: concretion with unidentified bivalve
467.41-467.44 mbsf: unidentified bivalve (decalcified)	599.97-600.01 mbsf: large modioloid valve
467.71-467.75 mbsf: serpulid polychaete tubes (recrystallized)	
<b>LSU 13.2</b>	<b>LSU 15.6</b>
469.87-469.93 mbsf: modioloid bivalve	614.57-614.60 mbsf: concretion with unidentified bivalve
471.05-471.07 mbsf: modioloid bivalve	
482.60-482.64 mbsf: articulated modioloid bivalves	

9.7 and 11.3 (decalcified mould) have been tentatively ascribed to this group of pelagic gastropods previously unreported from the pre-Quaternary Antarctica. Benthic gastropods include at least four species. In particular, high-spined, turritiform shells occur in LSU 9.3 (199.56 mbsf), 9.4 (210.20 and 226.85 mbsf; Fig. 5.14e), 9.8 (285.15 mbsf), and 13.1 (454.45 mbsf); more than one taxon may be represented. Low-spined, subglobose shells possibly a naticid occur in LSU 9.3 (199.56 mbsf) and 9.4 (210.24 mbsf). Low-spined, small-sized gastropods occur in LSU 12.4 (444.09 mbsf), and 13.1 (448.51, 461.56, and 463.57 mbsf).

*Class Scaphopoda.* Smooth, tubular, thin, slightly angular shells occurring in LSU 8.4 may be scaphopods, but additional study of the sparse and fragmentary material available is needed to confirm this preliminary identification (Fig. 5.14f).

### Annelida

Annelida follow in order of abundance (two species at least) and are widely distributed in the core from top to bottom. The material comprises a number of calcareous tubes belonging to serpulid polychaetes. Serpulid tubes in

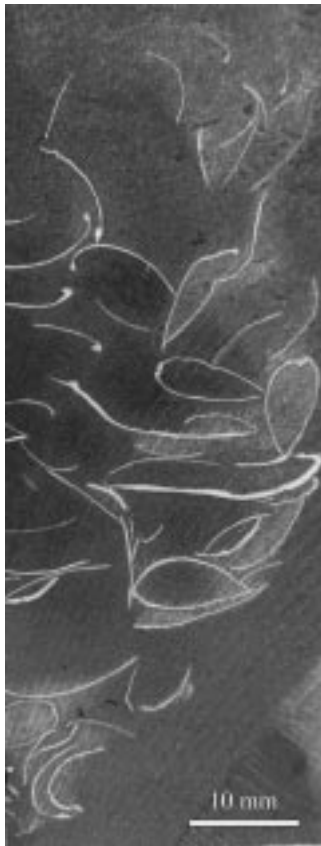


Fig. 5.13 - Fossiliferous "limestone" (coquina) from LSU 9.7 (249.65 mbsf). Note the great abundance of thin shelled bivalves, many still articulated; the assemblage is considered to be largely *in situ*.

various states of preservation occur in LSU 2.1, 3.1., 5.1, 6.1, 6.2, 7.2, 8.1, 8.3, 8.4, 9.2, 9.4, 9.6, 9.7, 11.3, 12.3, 12.4, 13.1, 15.1, and 15.2. Concentrations of serpulid polychaete tubes were observed at 114.00, 138.43, 141.74, 341.79, 342.07, and 467.71 mbsf. The most common serpulid is a simple, slender tube with annular ornamentation found almost ubiquitously in both the Miocene and Oligocene sections of the core. It strongly resembles the lower Miocene taxon reported from CRP-1 core (Jonkers & Taviani, 1998). The best preserved specimen shows a slightly arched shell (Fig. 5.14g). On shell characters alone, it is difficult to establish whether a single species of serpulid is involved from top to bottom of core CRP-2/2A. Another serpulid polychaete, characterized by a coiled and apparently smooth shell, has been observed attached to a bivalve fragment at 247.67 mbsf. The high level of bioturbation and a number of traces observed at specific levels of the CRP-2/2A core is probably linked to the action of soft-bodied worms which left no skeletal fossils.

### Bryozoa

Bryozoa are represented by only two occurrences (16.30 and 117.66 mbsf).

### Cnidaria

Cnidaria are represented by one species of coral s.l. (36.01, 36.21, 36.24, 36.50, and ?39.91 mbsf). It appears to have been a solitary species living on mixed sand-silty bottoms (Fig. 5.14h).

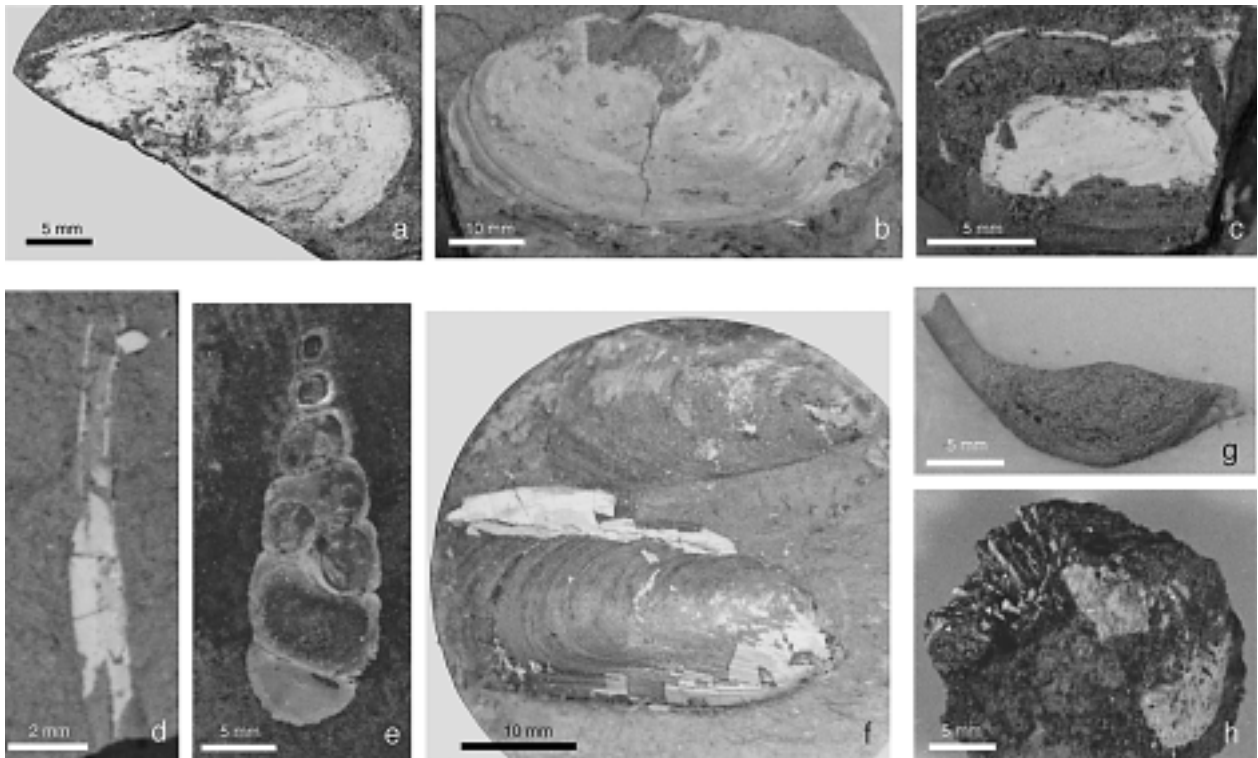


Fig. 5.14 - a) Relatively large protobranch bivalve (right valve) from LSU 9.4 (210.10 mbsf) showing an advanced state of decalcification. b) Protobranch bivalve *Yoldia?* sp., left valve from LSU 9.7 (260.83 mbsf). c) Imprint of a relatively large modioloid mussel from LSU 13.1 (447.43 mbsf). Note the presence of some original shell material and details of the external valve ornamentation (growth stages). d) Articulated bivalve (*Hiatella?* sp.) from LSU 6.2 (80.65 mbsf). Note the advanced state of decalcification. e) Unidentified turritiform, high-spired gastropod in a calcareous concretion from LSU 9.4 (226.85 mbsf). f) Fragmented shell of a thin and smooth scaphopod? from LSU 8.4 (165.41 mbsf). g) Well-preserved tube (partly embedded in matrix) of a serpulid polychaete from LSU 6.2 (80.65 mbsf). h) Solitary coral (s.l.) from LSU 3.1. (36.24 mbsf).

### **Echinodermata**

Echinodermata are represented by the rare occurrence of spines (16.30 and 19.84 mbsf) and fragmented tests (117.66, 230.22 and? 236.61 mbsf).

### **Porifera**

Porifera are documented by the recurrent presence of sponge spicules (see under Foraminifera) and by coherent spicule mats at 117.66 mbsf.

### **BIOSTRATIGRAPHICAL AND PALAEOENVIRONMENTAL REMARKS**

No precise age assessment can be derived from macrofossils identified in the CRP-2/2A core. Only some general and preliminary remarks are given here.

Most macrofossils appear to be taxa not encountered in other Oligo-Miocene records of Antarctica (*e.g.* Dell & Fleming, 1975; Beu & Dell R, 1989; Jonkers & Taviani,

1998). A possible exception is the common serpulid polychaete recovered throughout the CRP-2/2A core which appears to be very close to serpulids identified in the lower Miocene section of the CRP-1 drill hole (Jonkers & Taviani, 1998). Pectinids, which appear to be of some stratigraphical value (*e.g.* Jonkers & Taviani, 1998), are unfortunately rare in CRP-2/2A and only represented by incomplete valves that are difficult to interpret at present.

The occurrence of modioloid mussels in lower Oligocene sediments in CRP-2/2A is significant since the youngest documentation of similar bivalves in the Tertiary of Antarctica, is that from the Upper Eocene deposits of Seymour Island (Stilwell & Zinsmeister, 1992). These conspicuous bivalves have not been documented from sediments, presumed to be coeval with CRP-2/2A, in the CIROS-1 core.

All recognized macrofossils in CRP-2/2A are marine invertebrates and a preliminary interpretation of their possible palaeoenvironmental significance is summarized in figure 5.12.