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R. Scherer
Northern Illinois University, reed@geol.niu.edu

M. Hannah
Victoria University of Wellington

P. Maffioli
University of Milano-Bicocca

D. Persico
University of Parma

C. Sjunneskog
Louisiana State University

See next page for additional authors

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R. Scherer[1]*, M. Hannah[2], P. Maffioli[3], D. Persico[4], C. Sjunneskog[5], C.P. Strong[6], M. Taviani[7], D. Winter[8] & the ANDRILL-MIS Science Team[9]

[1]Department of Geology and Environmental Geosciences, 312 Davis Hall, Northern Illinois University, DeKalb, IL 60115 - USA
[2]School of Geography, Environment and Earth Sciences, PO Box 600, Victoria University of Wellington, Wellington - New Zealand
[3]Department of Geological Sciences and Geotechnologies, University of Milano-Bicocca, I-20126 Milan - Italy
[4]Department of Earth Sciences, University of Parma, 43100 Parma - Italy
[5]Department of Geology and Geophysics, Louisiana State University, Baton Rouge, LA 70803 - USA
[6]GNS Science, PO Box 30368, Lower Hutt - New Zealand
[7]Institute of Marine Sciences (ISMAR) - CNR, Via Gobetti 101, I-40129 Bologna - Italy
[8]Department of Geosciences, University of Nebraska–Lincoln, Lincoln, NE 68588-0340 - USA
[9]http://www.andrill.org/support/references/appendixc.html

**Corresponding author* (reed@geol.niu.edu)

Abstract - Fossils provide key data sets for the interpretation of the AND-1B core. Calcareous plankton and benthos provide the basis for palaeoenvironmental interpretations of both surface and bottom waters. Calcareous fossils are rare throughout, but occurrences noted are significant. Some calcareous fossils provide potential for age control via $^{86}Sr/^{87}Sr$, and palaeoenvironmental information may come from Mg/Ca ratios as well as oxygen and carbon isotopes. Organic-walled microfossils provide an index of reworking and transport, as well as the identification of a possible *in situ* Pliocene assemblage of previously unknown marine palynomorphs. Diatoms are abundant in the core, with diatom-rich sediments constituting nearly half the upper 600 m of core, subdivided into 13 diatomaceous units, ranging in thickness from under 1 m to nearly 100 m. Diatoms provide biostatigraphic age control, but calibration to the Southern Ocean zonation is limited by ecologic exclusion of many taxa and previously undocumented diachrony among other taxa. A new, high-resolution diatom biostratigraphy for the Antarctic continental shelf is now under development. Diatoms provide the basis for numerous palaeoenvironmental applications, including providing a proxy for palaeotemperature and palaeo-sea ice, as well as palaeoproductivity. All results presented here are preliminary, and interpretations should be considered tentative, pending quantitative and more detailed qualitative follow-up analyses.

INTRODUCTION

The ANDRILL McMurdo Ice Shelf Project drill core (AND-1B) includes a 1 285 m succession of variably fossiliferous marine, glacial, and volcanic sediments. Clast-rich diamictites interpreted as tillite or ice-proximal debris-flow deposits contain few fossils; the most notable group present being reworked marine and terrestrial palynomorphs. Some sandy and muddy diamictites contain foraminifera and, rarely, macrofossil fragments, plus variable occurrences of generally highly fragmented diatoms. There are also rare episodic occurrences of *Thoracosphaera* (calcareous dinoflagellates), radiolaria, ebridians, and siliceous flagellate phytoplankton, including silicoflagellates, chrysophytes, and parmales. Pure volcanic sequences contain virtually no fossil remains, but transported volcanic sands and muds may contain rare palynomorphs, foraminifera, sponge spicules, or macrofossil fragments.

Diatomites, which dominate several intervals in the drill core, correlate with low-density physical property measurements (see Niessen et al. this volume), and are characterised by a rich abundance of very highly fragmented diatoms. In general, calcareous microfossils are absent from diatomites, presumably a result of acidification of the sea bottom and pore waters due to degradation of organic carbon. There is evidence of sulphate reduction in most of the diatomites, as suggested by the widespread presence of apparent pyrite replacement of biogenic silica, plus occasional small framboids. The diatom assemblages in the diatomites are rich and generally of low diversity, often indicating very high primary productivity, especially in laminated intervals. The pervasive diatom fragmentation is likely due to compaction by sedimentary and glacial overburden. Below *c.* 580 metres below seafloor (mbsf) diatoms are rare and diagenetically altered. Other microfossil groups are sporadically present, in very low abundance.

Micro- and macrofossils provide a diverse set of information central to the ANDRILL mission. They provide age control, both relative and absolute. Diatoms provide the primary biostratigraphic age control on the drill core, but the diatom assemblages in AND-1B can only be broadly correlated directly with the Southern Ocean diatom biozonation, due to the fact that the environment of the Antarctic continental shelf differs from that of the Southern Ocean, where the zonation was established. Calcareous foraminifera and calcareous macrofossils provide the potential for absolute age control from the $^{87/86}$Sr method. Initial results from these analyses were anomalously old, suggesting pore-water contamination by volcanic-derived Sr, reworking from older sediments, or alteration due to recrystallisation. However, Sr results from calcareous foraminifera may prove useful in age determination in the lower section of drill core. Biostratigraphically useful palynomorphs in the core indicate intervals of reworking of Palaeogene sediments; however, it may be possible to develop a Pliocene organic-walled biostratigraphy based on this drill core. Diatoms and *Thoracosphaera* will help constrain surface-water temperatures and sea-ice history from the core.

On-ice diatom analysis focused on biostratigraphy, using qualitative and semi-quantitative approaches. Post-drilling research will focus on several goals besides development of an Antarctic continental-shelf Pliocene biostratigraphy. High sediment accumulation rates of diatom-rich intervals offer the opportunity for morphometric study of patterns and rates of evolution in diatom lineages, which will further help refine biostratigraphy. Diatoms also offer diverse opportunities for palaeoenvironmental interpretation of ANDRILL cores. For example, diatoms can be used to constrain relative water temperature, occurrence, extent and relative thickness of sea-ice environments, and a relative degree of palaeoproductivity through time.

CALCAREOUS AND AGGLUTINATED FORAMINIFERA

A total of 83 samples were examined from the intervals 1.82 to 10.10 mbsf in AND-1A and the 20.04 to 1 283.52 mbsf in AND-1B. Forty-two samples were productive, and contain a fauna comprising some 59 species, with 12 agglutinated, one planktic, and 46 calcareous benthic taxa represented. Foraminiferal assemblages typically were poorly developed throughout the cores, with most consisting of one or two species, each represented by one or two specimens. The maximum number of species recorded in a single sample was 11. This result is somewhat surprising in light of the rich fauna of some 75 species reported from the much thinner Late Neogene section drilled in the Cape Roberts Project (CRP)-1 drill core (Webb & Strong 1998).

'Microforaminifera' and foraminiferal chamber linings occur at numerous stratigraphic levels in both palynological samples and sedimentological smear slides, whereas foraminifera often were not observed in standard preparations at or near these levels. Examination of some of these specimens suggests that several taxa may be represented, including possible *Trochammina multiloculata* and *Nonionella* sp. Their absence in normal residues may be due to destruction of fragile tests during processing, non-retention on sieves due to small size, or both. Recovery and detailed study of these specimens may be possible with development of non-standard, specialised processing and recovery techniques; however, the utility of such efforts is uncertain.

Although foraminifera provided little palaeontological age control, it is likely that the intervals studied include Pleistocene, Pliocene and Upper Miocene strata. The former two intervals contain essentially modern faunas, and the latter, faunas similar to the CRP-1 drillhole and Deep Sea Drilling Project (DSDP) site 270. This faunal change occurs at about 600 mbsf. However, foraminifera may assist with future age determinations, especially in the lower half of the drill core, as foraminiferal tests from selected levels will be used for post-drilling $^{87/86}$Sr dating.

Because the foraminiferal record is poorly developed and discontinuous, especially above *c.* 600 mbsf, no foraminiferal-based biostratigraphic units were established for the drill core, and results for this report are referred to the lithostratigraphic units (LSUs) defined by the sedimentology team. Palaeoenvironmental interpretations are based mainly on studies by Kennett (1968), Fillon (1974), Osterman & Kellogg (1979), Bernhard (1987), and Violanti (1996).

MATERIALS AND METHODS

The overall sample suite (Tab. 1) consists of *c.* 246 samples, of which 73 were prepared and studied on ice, and a further 10 at GNS Science (GNS), Lower Hutt, New Zealand. All but the topmost two samples in this report are from AND-1B, as AND-1A was discontinued after coring for a short distance due to operational difficulties. Samples were taken mostly at *c.* 5 m intervals, or otherwise as indicated by favourable or unfavourable lithologies. Sample weights ranged from 20 g to 200 g, but most samples were between 40 g and 80 g.

All samples were prepared using Milli-Q ultrapure water and air-dried at room temperature, in anticipation of future geochemical study. Weakly consolidated samples from the upper drill core section were disaggregated in water by hand, followed by gentle rubbing and sequential wet sieving over 500, 125 and 63 µm sieves. Typical processing time for these samples was <30 minutes. More indurated samples were broken into <3 mm pieces with vice-grip pliers or a rock crusher (GNS; >101 mbsf) and were soaked for up to 24 hours. They then were further crushed using a pestle and washed as above. Sieves were cleaned with a fine wire brush and water-blasting and then dipped in methylene blue solution after each sample to identify contamination.

After drying, each size fraction was bagged, weighed and later examined with a stereo microscope. Although this study focused on the 125 µm size residue,

Tab. 1 - Foraminiferal sample log for AND-1A/1B showing the lithostratigraphic units (LSU). All samples listed; shaded samples were processed and examined on ice. Uppermost two samples from AND-1A, remainder from AND-1B. Results: NF=No Fauna; FR, FF, FC, FA=Foraminifera Rare, Few, Common, Abundant (see text for definitions); a=agglutinated, b=calcareous benthic, p=plankton.

CORE No.	FROM	TO	WEIGHT	RESULT
	LSU 1.1 (0-82.74 mbsf)			
1 (AND-1A)	1.82	1.87	76.75	NF
6 (AND-1A)	10.06	10.10	55.22	FRpb
16	20.04	20.10	58.56	FRb
16	2.40	20.45	59.92	FRb
18	24.95	25.00	50.36	FRb
19	26.03	26.08	32.92	FRba
20	26.55	26.60	44.98	
27	30.20	30.25	57.33	NF
27	32.19	32.24	57.93	
30	40.68	40.73	64.72	FRb
31	42.20	42.24	63.54	
31	42.32	42.36	43.87	NF
32	45.00	45.04		
33	47.60	47.65	82.66	NF
33	47.73	47.79	113.81	
34	49.92	49.97		
35	52.99	53.02	38.02	FRb
36	54.84	54.90	111.10	NF
36	56.61	56.66		
37	60.36	60.42	120.76	NF
35	60.62	60.67	89.98	FRba
37	65.02	65.06	100.08	
41	70.47	70.52	197.71	FRp
41	70.64	70.69	134.46	
42	72.52	72.56	74.05	NF
42	75.04	75.09	97.34	FRb
44	80.12	80.17	154.78	FRb
	LSU 2.1 (82.74-86.63 mbsf)			
45	83.11	83.16	99.31	
46	84.98	85.02	121.67	
46	86.08	86.13	75.97	NF
46	86.42	86.48	125.23	
	LSU 2.2 (86.63-92.24 mbsf)			
47	89.31	89.36	78.59	
47	90.08	90.13	94.90	
48	91.42	91.47	none	FApb
48	91.56	91.61	54.30	FApb
	LSU 2.3 (92.24-132.83 mbsf)			
48	93.00	93.05	69.77	NF
49	94.95	95.02	124.22	
50	96.67	96.71	86.19	FApba
51	99.60	99.67	160.70	FFpb
51	100.03	100.08	101.19	
51	100.42	100.47	105.60	
52	105.04	105.09	85.14	
54	110.09	110.14	80.28	
55	110.98	111.03	97.28	FFb
57	116.90	116.95	97.40	
57	117.29	117.34	94.52	FRb?
58	119.92	119.97	107.57	
60	125.07	125.12	61.51	
61	125.62	125.67	71.75	
61	126.50	126.55	110.57	NF
63	130.02	130.10	95.44	NF
63	131.86	132.00	89.69	
63	132.72	132.77	97.23	NF

CORE No.	FROM	TO	WEIGHT	RESULT
	LSU 2.4 (132.83-146.79 mbsf)			
64	134.97	135.02	103.47	NF
65	140.00	140.05	104.84	
66	142.00	142.05	136.80	
67	143.97	144.03	180.31	
67	144.82	144.87	116.83	
	LSU 3.1 (146.79-169.40 mbsf)			
69	149.73	149.78	130.56	
69	150.68	132.06	132.06	
71	154.52	154.57	97.58	NF
71	155.00	155.05	86.36	
71	156.00	156.05	79.28	
74	162.00	162.05	51.87	
74	162.38	162.42	75.82	FRp
75	165.00	165.05	99.55	
76	165.90	165.95	80.53	NF
76	167.10	167.15	58.94	
	LSU 3.2 (169.40-181.93 mbsf)			
77	170.05	170.10	85.00	
78	172.62	172.67	113.08	
79	174.89	174.94	89.85	
79	176.77	176.82	78.44	
80	180.10	189.15	131.62	
	LSU 3.3 (181.93-292.66 mbsf)			
82	183.99	184.04	90.20	
82	185.00	185.05	130.71	
84	190.06	190.11	91.94	
85	194.92	194.97	93.41	
87	200.08	200.13	70.38	NF
88	201.49	201.54	105.57	
89	205.00	205.05	113.76	
90	210.04	210.10	109.92	
93	214.83	214.88	71.90	
93	220.00	220.05	63.00	FAb
95	224.77	224.81	100.18	
97	230.00	230.05	126.71	
99	234.97	235.03	149.81	
99	235.51	235.56	127.41	
102	240.00	240.04	50.00	
103	244.94	244.98	47.55	NF
103	250.06	250.11	50.02	
104	255.01	255.05	34.86	
105	260.13	260.18	50.52	NF
106	264.83	264.87	62.40	
107	269.75	269.80	59.30	
108	275.11	275.15	60.52	
109	279.95	280.00	46.98	
109	282.27	282.32	50.02	NF
109	285.00	285.08	111.16	
110	290.05	290.10	42.27	
	LSU 3.4 (292.66-347.19 mbsf)			
111	292.68	292.73	50.35	
112	300.25	300.30	55.87	FRb
113	305.04	305.09	67.44	
114	309.95	310.00	68.01	
115	314.94	314.99	77.44	
115	319.96	320.01	74.36	
116	325.00	325.05	52.04	
117	330.11	330.16	52.84	NF

Tab. 1 - Continued.

CORE No.	FROM	TO	WEIGHT	RESULT
119	340.07	340.12	63.07	
120	345.19	345.24	57.76	
	LSU 3.5 (347.19-363.37 mbsf)			
120	347.27	347.31	52.82	
120/121	349.41	349.48	64.65	FRpb
122	355.06	355.11	54.71	
122	359.85	359.90	63.27	
	LSU 3.6 (363.37-382.98 mbsf)			
123	365.00	365.05	73.12	FFpb
124	370.03	370.08	78.70	
125	374.91	374.96	55.76	
125/126	378.02	378.07	52.37	FRb
126	379.98	380.03	54.71	
	LSU 4.1 (382.98-459.24 mbsf)			
127	385.18	385.23	53.89	
126	390.22	390.27	47.97	NF
128	395.03	395.08	49.83	
129	400.16	400.21	48.78	
130	404.87	404.92	52.25	
131	410.10	410.15	51.36	NF
131/132	414.95	415.00	53.57	
132	420.03	420.08	48.58	NF
134	430.07	430.12	48.30	
136	440.50	440.55	38.71	
137	450.24	450.29	57.25	
137	451.86	451.91	50.52	NF
	LSU 4.2 (459.24-511.18 mbsf)			
139	459.91	459.96	58.60	
140	464.10	464.15	74.06	
140	465.08	465.11	71.82	
141	469.77	469.82	84.63	NF
142	475.02	475.07	75.59	
142	480.35	480.40	76.15	
144	490.17	490.22	65.17	NF
146	499.93	499.98	49.97	
147	506.03	506.08	59.86	
147	510.07	510.12	62.27	FRb
	LSU 4.3 (511.18-575.11 mbsf)			
148	515.24	515.28	63.61	
149	520.15	520.20	82.81	
150	525.20	525.25	41.49	NF
152	535.52	535.56	49.67	
153	540.12	540.17	58.48	NF
153	545.56	545.61	48.08	
154	549.97	550.02	57.23	NF
157	565.22	565.27	67.96	
158	570.15	570.20	69.29	
158	574.94	574.99	67.87	
	LSU 4.4 (575.11-586.45 mbsf)			
159	578.34	578.39	61.58	FRb
159	580.06	580.11	55.27	
160	583.05	583.10	50.65	
	LSU 5.1 (586.45-646.49 mbsf)			
164	603.55	603.60	76.84	NF
165	609.92	609.98	77.66	
165	613.90	613.95	88.62	
166	615.16	615.21	66.61	FCa
167	624.09	624.15	71.57	
168	627.32	627.37	67.80	NF
168	629.80	629.85	80.88	

CORE No.	FROM	TO	WEIGHT	RESULT
	LSU 5.2 (646.49-649.30 mbsf)			
	LSU 5.3 (649.30-688.92 mbsf)			
172	650.79	650.84	73.91	FCpb
172	654.61	654.66	64.84	
173	661.47	661.52	68.65	
174	665.02	665.07	58.41	
174	665.89	665.94	72.25	NF
	LSU 5.4 (688.92-759.32 mbsf)			
178	692.06	692.11	75.66	FRb poor
183	705.05	705.10	48.12	
184	706.72	706.77	52.65	FR frag
184	710.24	710.29	48.79	
185	715.21	715.26	55.44	
187	725.10	725.15	53.26	
188	730.17	730.23	48.03	FFa
189	735.28	725.33	44.11	
189	740.23	740.25	19.45	FFab
190	745.07	745.15	54.65	
191	750.13	750.18	46.49	NF
192	754.95	755.00	38.73	FCb
	LSU 6.1 (759.32-897.95 mbsf)			
194	764.27	764.32	41.13	
196	775.08	775.13	46.45	FRb
197	779.90	779.49	29.05	
200	795.15	795.20	40.74	
201	800.27	800.32	28.49	FFb
202	805.10	805.15	42.28	
203	810.05	810.10	40.46	
204	814.99	815.05	45.59	FFb
207	826.34	826.39	35.96	
208	830.09	830.13	39.91	
209	835.00	835.04	38.93	
210	839.94	839.98	43.11	FFb
212	844.57	844.61	44.32	FRb
213	848.18	848.21	44.55	
215	855.06	855.11	39.39	
216	865.02	865.08	53.19	
218	875.03	875.10	61.30	
220	879.91	879.96	46.55	
221	890.03	890.08	42.30	
	LSU 6.2 (897.95-920.51 mbsf)			
	LSU 6.3 (920.51-1063.42 mbsf)			
227	920.72	920.78	42.32	
231	935.08	935.13	54.98	
232	944.42	944.47	38.31	FRb
234	950.66	950.71	42.12	
235	955.17	955.24	47.92	
235	960.17	960.22	60.49	
236	964.16	964.21	63.13	
237	970.05	970.10	41.93	
238	976.20	976.25	64.73	FRb
239	980.02	980.07	60.40	
241	990.40	990.45	50.40	
241	995.27	995.32	45.37	
242	1000.05	1000.10	63.68	FRb
243	1004.98	1005.03	60.55	
245	1010.13	1010.18	47.93	
246	1015.00	1015.05	58.58	NF

all size fractions were examined. Foraminifers were separated, slide-mounted and provisionally identified under a binocular microscope.

To standardise and expedite sample examination, the >500 μm residue typically was entirely scanned, and the >63 μm residue examined for 2–3 minutes. The >125 μm residue, containing the majority of the specimens, was subdivided (typically one-fourth to one-eighth) as required using a microsplitter to yield 2–3 trays of material. Approximate foraminiferal abundance (shown in Tab. 1) was determined as follows, based upon the number of specimens recovered from a well-strewn 55 mm x 100 mm picking tray:

NF: No foraminifera recovered.
R: Rare, one or fewer specimens per tray.
F: Few, 2–5 specimens per tray.
C: Common, 6–30 specimens per tray
A: Abundant, >30 specimens per tray.

Foraminiferal preservation (Tab. 1) is categorised as follows:

G: Good, original test texture well preserved, most specimens entire.
F: Fair, obvious dissolution damage, etching, recrystallisation or breakage.
P: Poor, specimens so altered or broken that identification is difficult or uncertain.

OCCURRENCES OF FORAMINIFERA BY LITHOSTRATIGRAPHIC UNIT (LSU)

Foraminiferal results are summarised in table 1, and sample-by-sample occurrences for all species are given in table 2.

LSU 1 (0–82.74 mbsf): The unit consists of 83 m of muddy diamictites, with interbedded mudstone and sandstone. It was relatively well sampled due to the slow drilling rate, with foraminifera being recovered from 11 of the 17 samples examined. Fossiliferous samples all contained only sparse but well-preserved faunas, commonly with extant species of either *Globocassidulina* or *Fissurina*; planktonic and agglutinated specimens each occurred in only one sample. Overall, the fauna is consistent with open-ocean conditions, and water depths of 300 m or more, with low specimen numbers perhaps reflecting very high sedimentation rates.

LSU 2 (82.74–146.79 mbsf): The 64 m-thick unit is mudstone-dominated, and also contains diamictite, diatomite, and volcanic sands. Mudstone-rich diatomaceous ooze and silty claystones of Subunits 2.2 and upper 2.3 yielded the most abundant and diverse (up to 12 species) assemblages found in the drill core; eight of 14 samples collected from LSU 2 were fossiliferous. Faunas contain modern species, with common to dominant *Ehrenbergina glabra, Globocassidulina crassa s.l., Globocassidulina subglobosa, Miliolinella subrotunda,* and *Cassidulinoides* spp. The planktonic *Neogloboquadrina pachyderma* accounts for up to 30% of total fauna, whereas agglutinates are uncommon.

Osterman & Kellogg (1979) note that *Ehrenbergina glabra* and *Globocassidulina* spp. are dominant faunal elements in the north-central Ross Sea, and also in the southern Ross Sea, proximal to the edge of the McMurdo Ice Shelf. Based on the associated sediments, which contain considerable ice-rafted debris, the latter environment may be the more likely.

LSU 3 (146.79–382.88 mbsf): Diatomite, variously interbedded with mudstone, diamictite, and biosiliceous-rich diamictites and mudstones, is the dominant lithology of the 236 m-thick unit. Only five of the 12 samples examined from the unit contained foraminifers, which were recorded in abundance from subunit 3.3 (220 mbsf), and rare through the remainder of the unit. Faunas are characterised mainly by *Globocassidulina* spp.; *Cibicides* spp. and *Cassidulinoides parkerianus* occur occasionally. The planktonic *Neogloboquadrina pachyderma* was recorded from a single sample near the base of the LSU. The faunas suggest open-water environments and depths of at least a few hundred metres.

The diatomite units of LSU 3 are partly correlative with the foram-rich lower Pleistocene sequence of carbonate and diamictite in CRP-1 (Webb & Strong 1998). In contrast, the diatomite contains a relatively impoverished assemblage, with few, versus common, planktonics. Diatom-rich waters apparently inhibit foraminifers, with few specimens recovered from pure diatomite. The fair to good preservation of these specimens, some of them diminutive, suggests that the sparse assemblages may be primary, rather than the result of post-depositional destruction.

LSU 4 (382.88–586.45 mbsf): Diatomite and interstratified volcanic-rich sandstones, mudstones and diamictites make up this 204 m-thick unit. The unit proved poorly fossiliferous: of 10 samples examined, rare foraminifera were present in two, and the remaining eight were non-fossiliferous. The only foraminifers recovered are single specimens of *Ehrenbergina glabra* and *Globocassidulina subglobosa*, which suggest open-water conditions and may mark the lowest occurrence of modern Ross Sea faunal assemblages.

LSU 5 (586.45–759.32 mbsf): Volcanic-rich sandstones, mudstones, and diamictites typifies this 173 m-thick unit, which contains a 2.8 m-thick phonolitic lava flow at *c.* 648 m. Foraminifera were recovered from six of 11 samples, and mark the beginning of an interval where most samples consistently contain small faunas. These assemblages represent a marked, permanent, taxonomic change from overlying faunas.

Entirely agglutinated assemblages characterised by various undetermined species of *Haplophragmoides, Cyclammina, Miliammina,* and *Trochammina* occur

Tab. 2 - Occurrence, abundance, and preservation of foraminifera in AND-1A/1B.

		LITHOSTRATIGRAPHIC UNIT 1: 0.00-82.74 mbsf. Muddy Diamictite																	LSU 2: 82.74-146.79 mbsf; Mudstone dominated							
DEPTH, TOP OF SAMPLE	1.82	10.06	20.04	20.40	24.95	26.03	30.20	40.68	42.32	47.60	52.99	54.84	60.36	60.62	70.47	72.52	75.04	80.12	86.08	91.42	91.56	93.00	96.67	99.60	110.98	117.29
DEPTH, BASE OF SAMPLE	1.87	10.10	20.10	20.45	25.00	26.08	30.25	40.73	42.36	47.65	53.02	54.90	60.42	60.67	70.52	72.56	75.09	80.17	86.13	91.47	91.61	93.05	96.71	99.67	111.03	117.34
ABUNDANCE: NF=0, R=1, F=2-5, C=6-30, A=>30	NF	R	R	R	R	R	NF	R	NF	NF	R	NF	NF	R	R	NF	R	R	NF	A	A	NF	A	A	F	R?
PRESERVATION: Good, **F**air, **P**oor		G	G	G	G	G		F			G			F	F		G	G		G	G		G	G	G	G
AGGLUTINATED																										
Ammodiscus spp.																							X			
Bathysiphon spp.																										
Cyclammina rotundata																										
Cyclammina sp.																										
Haplophragmoides spp.														?									X	X		
Miliammina sp.																										
Psammosphaera sp.																										
Pseudobolivina antarctica						X														X						
Recurvoides contortus																										
Rhizammina sp.																										
Trochammina quadracamerata																										
Trochammina sp.																										
CALCAREOUS BENTHICS																										
Angulogerina angulosa																					*X*					
Anomalinoides cf *parvumbilia*																								X		
Astrononion antarcticum																							X			
Cancris sp.																										
Cassidulinoides aequilatera																										
Cassidulinoides parkerianus																					X					
Cassidulinoides porrectus																				X				X		
Cibicides lobatulus																					X		X	X		
Cibicides refulgens																										
Cibicides temperatus																										
Cibicides spp.																										
Dentalina soluta																							X			
Discorbis sp.																										
Ehrenbergina glabra				X																X	X			X		
Ehrenbergina smooth sp.																										
Epistominella exigua																										
Fissurina bisulcata																										
Fissurina marginata																		X								
Fissurina spp.								X			X			X												
Fursenkoina fusiformis																										
Fursenkoina schreibersiana																										
Globocassidulina crassa s.l.																	X			X			X	X		
Globocassidulina subglobosa				X																			X	X	X	contam?
Globocassidulina sp.		X	X																							
Gyroidinoides sp.																										
Melonis sp.																								X		
Milionella subrotunda																							X	X	X	
Miliolidae, undiff.																										
Neodiscorbinella sp.																										
Nodosaria spp.					X	X																				
Nonionella bradyi																										
Nonionella iridea																										
Nonionella spp.																										
Oolina apheiloculata																										
Oolina apiopleura																										
Oolina sp.																							X	X		
Pullenia subcarinata																										
Pullenia sp.																										
Pyrgo subsphaerica																										
Pyrgo sp.																										
Quinqueloculina spp;																							X		X	
Rosalina sp.																							?			
Sigmoidellopsis sp.																										
Sphaeroidina bulloides																										
Stainforthia concava											X															
Trifarina earlandi																					X					
PLANKTIC																										
Neogloboquadrina pachyderma		X													X					X	X		X	X		
OTHER FOSSILS																										
Bryozoa																				X	X					
Diatoms																										
Echinoderm remains																					X					
Micromollusca		X																								
Ostracods						X																	X			
Radiolarians																										
Shell Fragments								X		X					X						X		X			
Spicules		X												X	X	X					X	X				X

at 615 mbsf and 730 mbsf. These agglutinated assemblages closely resemble Osterman & Kellog (1979) Assemblage 6, which occurs in shallow water on the continental shelf of the modern Ross Sea. LSU 5 contains the oldest record of *Neogloboquadrina pachyderma,* at *c.* 650 mbsf.

Globocassidulina subglobosa and *G. crassa* are the most characteristic taxa of the calcareous faunas, while other species recorded from the unit include *Nonionella bradyi, N. iridea,* and *Cibicides* spp. These probably reflect open water environments and water depth of at least several hundred metres, an interpretation supported by the persistent presence of recrystallised casts of large (up to 0.3 mm) coscinodiscid diatoms.

In general, the calcareous faunas of LSU 5 differ taxonomically and in overall character from overlying assemblages. Although their age cannot be closely determined, they show more affinity to the Miocene faunas in CRP-1 (Strong & Webb 1998) and DSDP site 270 (Leckie & Webb 1985) than to overlying faunas in the drill core. For example, *Ehrenbergina* smooth sp., first recorded near the base of LSU 5, appears identical to specimens figured as *Ehrenbergina glabra* (but lacking the spines typical of *E. glabra)* from the Oligocene-Miocene section of DSDP 270 (Leckie & Webb 1985).

LSU 6 (759.32–1220.15 mbsf): The lithologically variable unit consists of 461 m of diamictite, muddy sandstone, sandy mudstone and conglomerate. Only the uppermost 256 m were studied on ice, with good results–eight of 10 productive samples– continuing the trend noted in LSU 5, but increasing downhole induration and pyrite cementation from *c.* 1000 m presage progressively more difficult sampling through the remainder of the drill core.

Only calcareous benthic assemblages were recovered. They are similar to those found in LSU 5. They include the smooth *Ehrenbergina* species noted above, and also the youngest reported occurrence of *Cassidulinoides aequilatera,* which further strengthens the comparison of assemblages from the CRP-1 drill core and DSDP site 270 (recorded as *Cassidulinoides* cf. *parkerianus*; Leckie & Webb, 1985). A sample from 1000.05 mbsf, containing a single tiny specimen of *Fursenkoina schreibersiana*, marks the lowest observed occurrence of diatoms (one large, poorly preserved coscinodiscid) and may approximate the absolute diagenetic depth limit for the group. This

Tab. 2 - Continued.

	LSU 2: continued				LITHOSTRATIGRAPHIC UNIT 3: 146.79-382.88 mbsf. Diatomite												LSU4: 382.88-586.45 mbsf. Strongly volcanic						
DEPTH, TOP OF SAMPLE	126.50	130.02	132.72	134.97	154.52	165.90	200.08	220.00	244.94	260.13	282.27	300.25	349.41	350.11	365.00	378.02	390.22	410.10	420.03	451.86	469.77	490.17	510.07
DEPTH, BASE OF SAMPLE	126.55	130.10	132.77	135.02	154.57	165.95	200.13	220.05	244.98	260.18	282.32	300.30	349.47	350.15	365.05	378.07	390.27	410.15	420.08	451.91	469.82	490.22	510.12
ABUNDANCE: NF=0, R=1, F=2-5, C=6-30, A=>30	NF	NF	NF	NF	NF	NF	NF	F	NF	NF	NF	R	F	NF	F	R	NF	NF	NF	NF	NF	NF	R
PRESERVATION: Good, Fair, Poor								G				G	F		G	G							G
AGGLUTINATED																							
Ammodiscus spp.																							
Bathysiphon spp.																							
Cyclammina rotundata																							
Cyclammina sp.																							
Haplophragmoides spp.																							
Miliammina sp.																							
Psammosphaera sp.																							
Pseudobolivina antarctica																							
Recurvoides contortus																							
Rhizammina sp.																							
Trochammina quadracamerata																							
Trochammina sp.																							
CALCAREOUS BENTHICS																							
Angulogerina angulosa																							
Anomalinoides cf *parvumbilia*																							
Astrononion antarcticum																							
Cancris sp.								?															
Cassidulinoides aequilatera																							
Cassidulinoides parkerianus								X															
Cassidulinoides porrectus																							
Cibicides lobatulus																							
Cibicides refulgens													X										
Cibicides temperatus															X	X							
Cibicides spp.																							
Dentalina soluta																							
Discorbis sp.																							
Ehrenbergina glabra																							
Ehrenbergina smooth sp.																							
Epistominella exigua								X															
Fissurina bisulcata																							
Fissurina marginata																							
Fissurina spp.																							
Fursenkoina fusiformis								X															
Fursenkoina schreibersiana																							
Globocassidulina crassa s.l.								X															
Globocassidulina subglobosa								X				X											X
Globocassidulina sp.															X								
Gyroidinoides sp.													?										
Melonis sp.																							
Milionella subrotunda																							
Miliolidae, undiff.																							
Neodiscorbinella sp.																							
Nodosaria spp.																							
Nonionella bradyi																							
Nonionella iridea																							
Nonionella spp.								X															
Oolina apheiloculata																							
Oolina apiopleura															X								
Oolina sp.																							
Pullenia subcarinata																							
Pullenia sp.																							
Pyrgo subsphaerica																							
Pyrgo sp.																							
Quinqueloculina spp;																							
Rosalina sp.																							
Sigmoidellopsis sp.																							
Sphaeroidina bulloides																							
Stainforthia concava																							
Trifarina earlandi																							
PLANKTIC																							
Neogloboquadrina pachyderma													?		X								
OTHER FOSSILS																							
Bryozoa														X									
Diatoms										X													
Echinoderm remains														X									
Micromollusca																							
Ostracods																							
Radiolarians					X	X	X			X					X	X		X					
Shell Fragments									X		X				X	X							
Spicules	X				X		X		X	X	X	X	X	X	X	X	X	X	X				X

occurrence suggests that the finer-grained intervals within LSU 5 and LSU 6 accumulated in a similar, open-ocean environment.

Seven additional samples from the lower part of LSU 6 were processed and examined at GNS, with four yielding calcareous benthic foraminifers similar to those higher in the unit. The lowest fossiliferous sample found to date occurs about 5 m above the base of the unit. Abundance was sparse to low, and specimens were in general noticeably less well preserved than in the upper part of the unit. Strata between 1090–1110 mbsf may have the best potential for yielding enough foraminiferal carbonate for $^{87}Sr/^{86}Sr$ dating. Based on observed lithologic textures, some samples from LSU 6 may be altered diatomites.

LSU 7 (1220.15–1275.24 mbsf): Volcanic sandstone and mudstone dominate the 55 m-thick unit. The single sample examined, possibly an altered diatomite, was non-fossiliferous.

LSU 8 (1275.24–1284.87 mbsf TD): The lowermost unit of the cored section consists of diamictite with interstratified mudstone (possibly altered diatomite). Two samples were examined, the lower from about 1.4 m above the base of the drill core. Both are well indurated, disaggregated poorly, and are non-fossiliferous.

THORACOSPHAERA AND CALCISPONGES

Calcareous nannofossils from the AND-1B drill core were present in 31 samples, out of approximately 529 examined (Fig. 1). Productive intervals were recognised at different depths of the stratigraphic sequence in relation to the lithology and the estimate of $CaCO_3$ concentration.

Preliminary analysis of the smear slides did not revealed any coccolithophores, discoasters, or other calcareous nannofossils. However, calcareous dinoflagellates and other calcareous microfossils occur with variable concentrations. Fragments of calcareous dinoflagellate cysts in smear slides probably belong to the species *Thoracosphaera saxea* (Stradner 1961), and *Thoracosphaera heimi* (Kamptner 1941) and other, potentially undescribed species (Villa & Wise 1998). These thoracospheres often occur with calcareous spicule fragments (*Calciospongia*), and occasionally

Tab. 2 - Continued.

	LSU4: continued			LITHOSTRATIGRAPHIC UNIT 5: 586.45--759.32 mbsf. Volcanic.											LSU6: See next page.				
DEPTH, TOP OF SAMPLE	525.20	540.12	578.34	603.55	615.16	627.32	650.79	665.89	692.06	706.72	730.17	740.23	750.13	754.95	775.08	800.27	814.97	839.94	844.57
DEPTH, BASE OF SAMPLE	525.25	540.17	578.39	603.60	615.21	627.37	650.84	665.94	692.11	706.77	730.23	740.25	750.18	755	775.13	800.32	815.05	839.96	844.61
ABUNDANCE: NF=0, R=1, F=2-5, C=6-30, A=>30	NF	NF	R	NF	F	NF	C	NF	R	NF	F	F	NF	C	R	F	F	R	R
PRESERVATION: Good, **F**air, **P**oor			G		F		G		P		F	P-F		G	G-F	G	F-G	F-G	G
AGGLUTINATED																			
Ammodiscus spp.																			
Bathysiphon spp.					X						X								
Cyclammina rotundata												X							
Cyclammina sp.					X														
Haplophragmoides spp.					X						X	X							
Miliammina sp.					X														
Psammosphaera sp.											X								
Pseudobolivina antarctica																			
Recurvoides contortus																			
Rhizammina sp.											X								
Trochammina quadracamerata											X								
Trochammina sp.					X														
CALCAREOUS BENTHICS																			
Angulogerina angulosa																			
Anomalinoides cf *parvumbilia*																			
Astrononion antarcticum																			
Cancris sp.																			
Cassidulinoides aequilatera																X		X	
Cassidulinoides parkerianus																			
Cassidulinoides porrectus																			
Cibicides lobatulus																			
Cibicides refulgens																			
Cibicides temperatus																			
Cibicides spp.							X								X				
Dentalina soluta																			
Discorbis sp.														X					
Ehrenbergina glabra			X																
Ehrenbergina smooth sp.														X	X	X			
Epistominella exiqua																			
Fissurina bisulcata												cf							
Fissurina marginata							X												
Fissurina spp.																			
Fursenkoina fusiformis																			
Fursenkoina schreibersiana																			
Globocassidulina crassa s.l.														X					
Globocassidulina subglobosa							X					X		X		X	X		
Globocassidulina sp.									X			X							
Gyroidinoides sp.																			
Melonis sp.																			
Milionella subrotunda																			
Miliolidae, undiff.																X			
Neodiscorbinella sp.																			
Nodosaria spp.																X			
Nonionella bradyi											X								
Nonionella iridea															X				
Nonionella spp.																			
Oolina apheiloculata							X												
Oolina apiopleura																			
Oolina sp.																			
Pullenia subcarinata												cf							
Pullenia sp.																	X		
Pyrgo subsphaerica											cf								
Pyrgo sp.																		X	
Quinqueloculina spp.																			
Rosalina sp.																			
Sigmoidellopsis sp.																X			
Sphaeroidina bulloides																			
Stainforthia concava																			
Trifarina earlandi																			
PLANKTIC																			
Neogloboquadrina pachyderma							X												
OTHER FOSSILS																			
Bryozoa																	X		
Diatoms				X	X	X		X	X	X	X	X				X	X		
Echinoderm remains										X									
Micromollusca																			
Ostracods																			
Radiolarians						X													
Shell Fragments																			
Spicules	X		X	X	X	X	X				X	X		X					

with fragments or complete specimens of foraminifera and fragments of ostracoda. Illustrations of some of the specimens are in figure 2.

Thoracosphaerids provide useful information for the palaeoenvironmental reconstruction of the Quaternary (Villa & Wise 1998). The presence of thoracosphaerids in the Quaternary suggests either a peculiar adaptation to this environment, due to their ability to develop cysts, warmer conditions at the time of their deposition, or a combination of both. However, they represent an additional element to use with the other proxies for inferring palaeoenvironmental conditions reflected in the core.

Semiquantitative analyses permit the characterisation of presence or absence of thoracosphaerids in the studied samples, and identified biogenic carbonate intervals at about 27 and 31 mbsf, between 91 and 98 mbsf, scattered samples between 98 and 426 mbsf and between 554 to 558 mbsf. From 558 mbsf to the bottom of the core, the prevalence of volcanic lithologies does not allow these microfossils to be recognised without SEM analysis. Future studies, in particular on the structural morphology of thoracosphaerid walls and the crystalline volcanic clasts (*e.g.* microgeodes) will allow differentiation between them.

CALCAREOUS MACROFOSSILS

Macrofossils are present, and at times relatively common, at discrete levels of AND-1B down to *c.* 380 mbsf; however, below that depth macrofossils are exceedingly rare. Macrofossils occurr in as many as *c.* 100 horizons through the core. Specimens visible in the sampled half-core were all extracted for further inspection under a microscope. Although their preservation varies greatly, most macrofossils are very poorly preserved and represented by minute and worn fragments insufficient for a taxonomic assignment. Macrofossils identified from the AND-1B drill core consist of entire or fragmented calcareous hard parts belonging to marine invertebrates, including benthic molluscs (bivalves, gastropods), cirriped crustaceans, serpulid polychaetes, bryozoans, echinoids, brachiopods, and sponges.

AND-1B and AND-1SS (1) (GC) cores have been carefully inspected for calcareous

Tab. 2 - Continued.

	LITHOSTRATIGRAPHIC UNIT 6: 759.32-1220.15 mbsf. Diamictite & mudstone												LSU 7	LSU 8: Diamict	
DEPTH, TOP OF SAMPLE	875.05	944.42	976.20	1000.05	1015.00	1030.03	1054.78	1093.76	1110.29	1155.47	1180.11	1215.79	1235.38	1275.35	1283.47
DEPTH, BASE OF SAMPLE	875.10	944.47	976.25	1000.10	1015.05	1030.08	1054.83	1093.83	1110.34	1155.52	1180.16	1215.84	1235.43	1275.40	1283.52
ABUNDANCE: NF=0, R=1, F=2-5, C=6-30, A=>30	NF	R	R	R	NF	NF	NF	F	R	NF	R	F	NF	NF	NF
PRESERVATION: Good, Fair, Poor		G	F	F				P	F-G		F	F			
AGGLUTINATED															
Ammodiscus spp.															
Bathysiphon spp.												?			
Cyclammina rotundata															
Cyclammina sp.															
Haplophragmoides spp.															
Miliammina sp.															
Psammosphaera sp.															
Pseudobolivina antarctica															
Recurvoides contortus															
Rhizammina sp.															
Trochammina quadracamerata															
Trochammina sp.															
CALCAREOUS BENTHICS															
Angulogerina angulosa															
Anomalinoides cf. *parvumbilia*															
Astrononion antarcticum															
Cancris sp.															
Cassidulinoides aequilatera		X	X												
Cassidulinoides parkerianus															
Cassidulinoides porrectus								X			X				
Cibicides lobatulus															
Cibicides refulgens															
Cibicides temperatus									cf			cf			
Cibicides spp.															
Dentalina soluta															
Discorbis sp.			?					X							
Ehrenbergina glabra															
Ehrenbergina smooth sp.															
Epistominella exigua								X							
Fissurina bisulcata															
Fissurina marginata															
Fissurina spp.															
Fursenkoina fusiformis															
Fursenkoina schreibersiana				X											
Globocassidulina crassa s.l.															
Globocassidulina subglobosa								X	X						
Globocassidulina sp.															
Gyroidinoides sp.															
Melonis sp.															
Milionella subrotunda															
Miliolidae, undiff.															
Neodiscorbinella sp.								X							
Nodosaria spp.		X						X							
Nonionella bradyi															
Nonionella iridea												X			
Nonionella spp.															
Oolina apheiloculata															
Oolina apiopleura															
Oolina sp.															
Pullenia subcarinata															
Pullenia sp.															
Pyrgo subsphaerica															
Pyrgo sp.															
Quinqueloculina spp;															
Rosalina sp.												X			
Sigmoidellopsis sp.															
Sphaeroidina bulloides															
Stainforthia concava															
Trifarina earlandi															
PLANKTIC															
Neogloboquadrina pachyderma															
OTHER FOSSILS															
Bryozoa															
Diatoms				X											
Echinoderm remains															
Micromollusca															
Ostracods															
Radiolarians															
Shell Fragments	?		X												
Spicules															

macrofossils suitable for Sr dating. Although unevenly distributed, carbonate macrofossils have been identified at many levels in the upper 360 mbsf. However, with very few exceptions (notably the carbonate-enriched unit at *c.* 91–92 mbsf), most macrofossil material is represented by worn and indeterminant fragments, likely pertaining to cirriped crustaceans (barnacles) or bivalves. They often occur as calcitic allochthonous bioclasts incorporated in various types of marine sediments. Accordingly, and depending upon the degree of diagenetic alteration, ages obtained from such bioclasts should be considered with prudence, providing at best a maximum age for the sedimentary unit bearing them. The carbonate macrofossil occurrences, including specimens submitted for Sr dating and other potential candidates are listed in table 3.

MACROFOSSIL OCCURRENCES BY AGE

Pleistocene: Macrofossils from the interval between 91 and 92 mbsf represent a relatively diverse assemblage of calcareous skeletonised invertebrates resembling Early Pleistocene to Recent Ross Sea counterparts (Dell 1990; Taviani et al. 1998) and are the richest macrofossil fauna recovered in the AND-1B drill core. The preservation of the macrofossils is generally good and includes thin aragonitic shells. Fossils are all small and appear size sorted, suggesting downslope displacement by gravity flows. Diatoms, magnetostratigraphy, and $^{40}Ar/^{39}Ar$ dating above this interval suggest an early Pleistocene age, similar to the carbonate unit recovered in CRP-1 (Lithostratigraphic Unit 3.2) (Taviani & Claps 1998).

Pliocene: When present, macrofossils from the Pliocene section are largely represented by calcitic bioclasts likely pertaining in most cases to cirriped crustaceans (barnacle plates). Their minute size, weathered surfaces, and fragmentation impede further taxonomic evaluation with very few exceptions (*e.g.* 370 mbsf). Most macrofossil fragments appear to be reworked from older marine units. Various lithostratigraphic units are interpreted as deep marine and are considerably bioturbated, an indication that bottom conditions were not necessarily prohibitive to benthic life. The paucity of skeletal remains may be a consequence of the

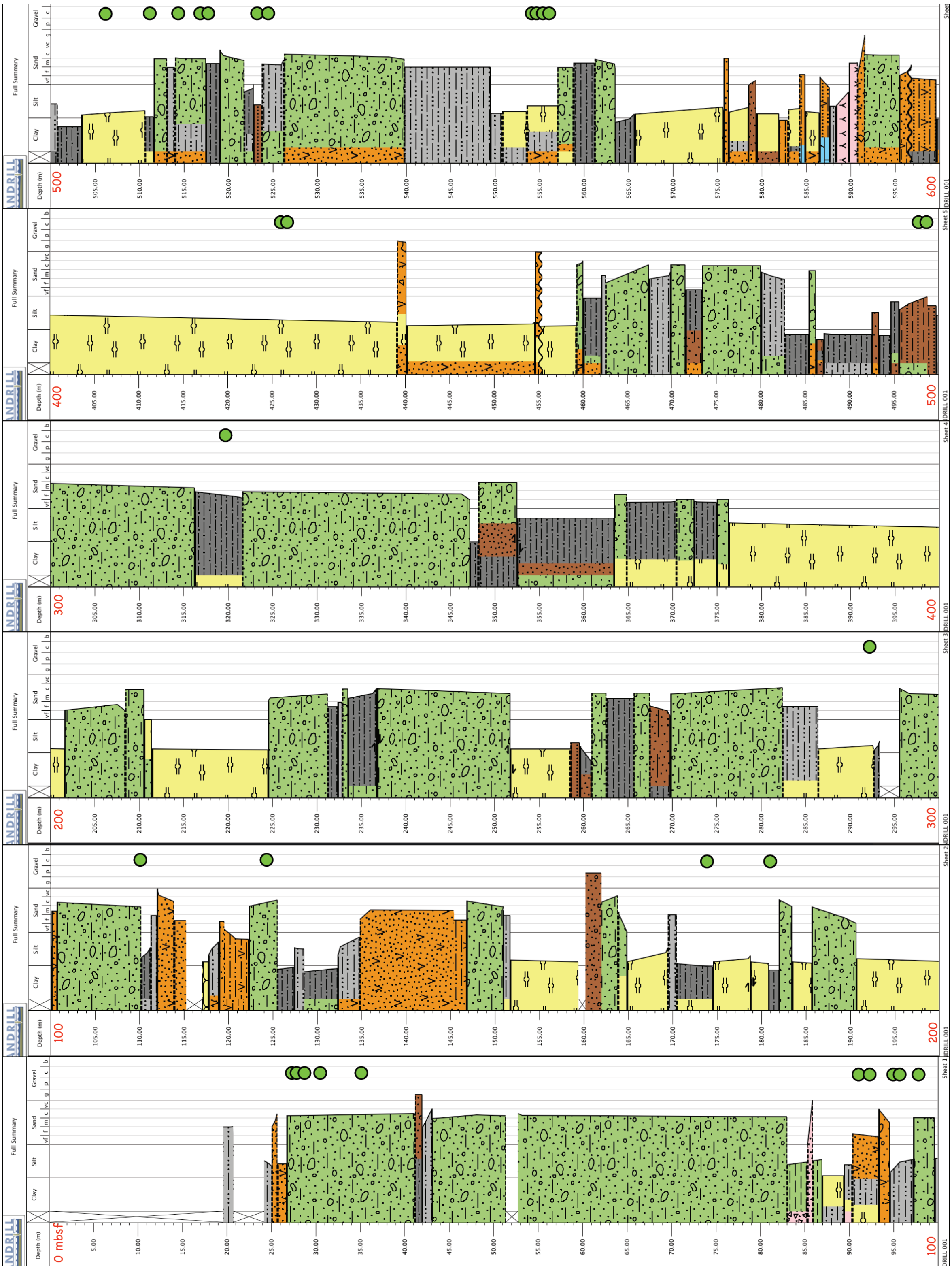


Fig. 1 – Calcareous nannofossil occurrences: stratigraphic position of the 31 fossili-bearing samples.

rarity of calcareous organisms at bathyal depths but could also represent *post-mortem* dissolution of their skeletons.

Miocene: There are only a few records of macrofossils in the Miocene section, mostly worn, fragmented, and recrystallised cirriped plates. As with the Pliocene section, the occasional presence of macrobenthos is documented by the intense bioturbation observed at many levels. The observed lack of mineralised durable parts may, therefore, more likely reflect a situation of *post-mortem* dissolution rather than original bottom conditions that were hostile to benthic life. A well-preserved calcareous serpulid polychaete tube, indicating open-marine conditions, was recovered from LSU-6 at 1 179.65 mbsf (Fig. 3). This specimen has been sampled for $^{87}Sr/^{86}Sr$ dating.

MARINE AND TERRESTRIAL ORGANIC-WALLED FOSSILS

Palynology, the study of the acid-insoluble remains of microscopic marine flora and fauna (palynomorphs) includes marine fossils such as dinoflagellate cysts, acritarchs, prasinophyte algae, and zooplankton, as well as terrestrial palynomorphs such as spores and pollen. Although a taxonomically diverse group, palynomorphs have proven useful for biostratigraphic and environmental studies at various high-latitude sites including the CRP and Ocean Drilling Programme (ODP) in Prydz Bay (for example, see Hannah et al. 2000; Macphail & Truswell 2004; Hannah 2006).

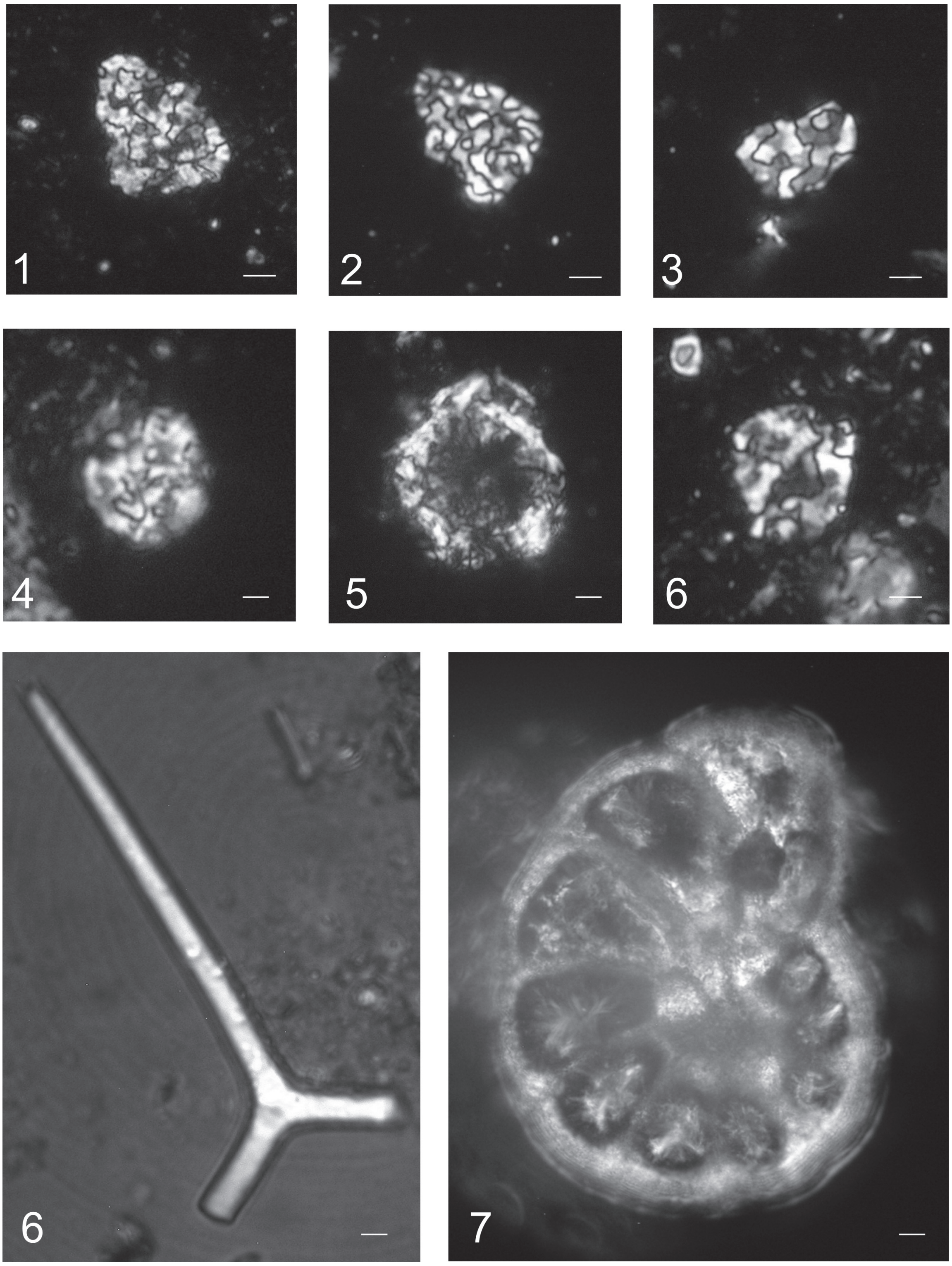


Fig. 2 – Micrographs of calcareous fossils in smear slides. 1. *Thoracosphaera* fragment, sample 95.95 mbsf, LM X-nicols. 2. *Thoracosphaera* fragment, sample 124.32 mbsf, LM X-nicols. 3. *Thoracosphaera* fragment, sample 110.07 mbsf, LM X-nicols. 4. *Thoracosphaera* complete specimen, sample 95.95 mbsf, LM X-nicols. 5. *Thoracosphaera* complete specimen, sample 96.02 mbsf, LM X-nicols. 6. *Thoracosphaera* fragment, sample 124.32 mbsf, LM X-nicols; 7. *Calciosponge* spicule, sample 95.95 mbsf, LM X-nicols. 7. Benthic foram, sample 95.95 mbsf, LM X-nicols. (Scale bar = 1 µm).

Tab. 3 - Occurrence of macrofossils in AND-1B, including selected calcareous macrofossils submitted for Sr and identification of other potential candidates.

Macrofossils in AND-1B		
Depth mbsf	**Remarks**	**Sr-dating**
91.06-91.10	diverse benthic assemblage with bryozoans, gastropods (i.a. *Anatoma* sp.), bivalves frag, serpulid polychaete, echinoid spines	
91.13-91.17	relatively well preserved benthic assemblage with bryozoans, serpulid polychaetes	
91.26-91.31	diverse benthic assemblage with bryozoans, gastropods (include fresh frag of costate *Onoba* sp.), bivalves, brachiopod? frag., serpulid polychaete, echinoid spines, sponge spicules	
91.42-91.47	diverse and relatively well preserved benthic assemblage, bryozoans, bivalves, gastropods (trochid?, fresh frags of *Eumetula* sp., *Pusillina*? sp.), serpulid polychaete, echinoid spines	
91.52-91.55	relatively large bryozoan colony, echinoid spines	
91.55-91.61	1 barnacle plate (*Bathylasma*? sp.), well preserved bivalves, brachiopod frag., 2 bivalve frags (*Pseudokellya* cf *gradata*, bivalve gen. sp. indet.)	dated
91.71-91.73	various frags of thin well preserved indet. bivalves, serpulid polychaete, brachiopod frag, bryozoan, echinoid spines	dated
150.28-150.29	1 relatively large indet. frag (bivalve or barnacle)	to be done
150.34-150.35	1 small frag (bivalve or barnacle)	dated
150.71-150.72	1 small frag indet. (bivalve?)	
156.76-156.76	1 chalky frag, indet.	
164.65-164.65	chalky frags (barnacles?)	
187.10-187.12	thin, small, chalky frag indet. (bivalve or barnacle)	
188.65-188.67	1 small frag indet. (bivalve or barnacle)	
189.17-189.19	1 small frag indet (bivalve or barnacle)	
189.50-189.52	thin frags indet. (bivalve or barnacle)	
190.85-190.87	1 small thick frag indet. (bivalve or barnacle)	
206.57-206.59	1 frag indet. (bivalve or barnacle)	
206.61-206.64	1 frag indet. (bivalve or barnacle)	
207.58-207.59	1 small frag indet. (bivalve or barnacle)	
208.77-208.80	1 frag indet. (bivalve or barnacle)	
208.98-209.01	relatively thick frags (bivalves or barnacles)	
210.25-210.27	1 tubular shell, incomplete (serpulid polychaete?)	
211.32-211.35	frags indet. (barnacles?)	dated
250.71-250.74	1 small frag indet. (bivalve or barnacle)	
251.29-251.31	1 small frag indet.	
255.37-255.42	1 small doubtful frag indet.	
256.05-256.07	1 indet. frag	
261.73-261.75	1 small frag indet. (bivalve or barnacle)	
265.48-265.51	1 frag indet. (barnacle?)	dated
269.51-269.54	2 small bivalve frags	
270.54-270.54	1 small frag indet. relatively fresh (barnacle?)	dated
270.58-270.60	1 chalky frag (bivalve?)	
274.80-274.83	small frags indet.	
274.96-274.99	various small frags indet.	
276.20-276.23	1 relatively large frag (barnacle?)	dated
277.59-277.61	small, tiny frags indet.	
279.21-279.23	1 chalky frag (bivalve?) broken during preparation	
279.37-279.38	small frags indet. (bivalves or barnacles)	
279.68-279.70	1 small frag (bivalve?)	
279.84-279.87	very small frags indet.	
280.17-280.19	2 small frags indet.	
281.16-281.18	1 small frag indet,	
281.31-281.34	2 small worn frags indet.	
281.67-281.69	1 small frag indet. (bivalve? or barnacle)	
284.16-284.19	2 small frags indet. (bivalves?)	
284.97-285.00	1 relatively large frag (barnacle)	dated
285.08-285.12	1 relatively large frag (bivalve?)	
285.25-285.27	1 barnacle frag	
285.37-285.37	1 relatively large frag of barnacle plate (worn but some ornamentation still visible)	
285.85-285.85	1 barnacle plate, relatively well preserved (costate ornamentation present)	dated
286.28-286.28	shell frag indet. (bivalve?)	
288.13-288.16	bivalve, incomplete, chalky, exfoliated, originary nacred (Mytilidae or *Laternula* or other)	
290.75-290.78	1 small frag indet. (bivalve?)	
300.70-300.72	1 small frag indet.	
308.47-308.49	1 small frag indet.	
310.22-310.24	1 frag indet. (bivalve or barnacle)	
325.05-325.07	1 thin-shelled bivalve, indet.	dated
326.26-326.27	1 small frag, thick (bivalve? or barnacle)	dated
328.33-328.35	1 small frag indet. (bivalve? or barnacle)	
329.28-329.30	1 small frag (bivalve?)	dated
330.11-330.16	worn bryozoan, echinoid spine	

Tab. 3 - Continued.

Depth mbsf	Remarks	Sr-dating
330.97-330.99	1 recrystallised bryozoan	
332.32-332.34	1 bryozoan	
332.63-332.65	1 small frag indet. (bivalve? or barnacle)	
333.32-333.34	1 bryozoan? (sectioned)	
334.28-334.30	1 small frag indet.	
335.15-335.17	1 frag indet. (bivalve or barnacle)	dated
337.66-337.68	1 frag relatively fresh, indet. bivalve?	dated
338.57-338.59	1 small chalky frag indet.	
341.07-341.08	1 small worn frag indet. (bivalve or barnacle)	dated
345.05-345.08	1 small frag indet.	dated
345.75-345.77	1 small chalky frag indet.	
346.81-346.82	1 small frag indet.	
350.86-350.89	some frags (barnacle?)	
351.22-351.23	1 small frag (barnacle?)	
358.28-358.29	1 indet. bivalve, fragmented but about 1 cm in size	
361.53-361.54	small frags indet.	
365.00-365.05	small frags (barnacle?)	
365.91-365.92	1 small frag (barnacle?)	
368.92-368.93	1 frag indet. (barnacle?)	
369.73-369.64	1 small frag (barnacle?)	
369.98-370.01	1worn barnacle frag (some ornamentation still visible)	
370.45-370.47	1 small frag (barnacle?)	
370.76-370.77	small frags (barnacle?)	
371.24-371.25	very small carbonate particle, possibly indet. macrofossil	
371.36-371.37	1 very small frag (barnacle?)	
374.17-374.18	1 frag indet. (barnacle?)	
374.21-374.23	2 worn barnacle frags, one relatively large	to be done
374.62-374.63	1 tiny frag indet. (barnacle?)	
375.08-375.09	1 frag indet. (barnacle?)	
375.47-375.48	1 frag indet. (barnacle?)	
376.08-376.11	various frags, including a relatively large but worn barnacle plate	to be done
378.02-378.07	relatively large (c. 1 cm) barnacle frag	to be done
381.17-381.19	1 frag indet. (barnacle?)	
473.61-473.62	1 small frag indet. (barnacle?)	to be done
1179.62-1179.66	Serpulid worm tube, well-preserved	to be done
652.78-652.81	1 plate, relatively large, probably recrystallised barnacle	to be done

SAMPLES FOR Sr DATING

Depth mbsf	Remarks	Sr-dating
91.55-91.61	2 bivalve frags (*Pseudokellya* cf *gradata*, bivalve gen. sp. indet.)	dated
91.71-91.73	thin well preserved indet. bivalve frags	dated
150.28-150.29	1 relatively large indet. frag (bivalve or barnacle)	to be done
150.34-150.35	1 small frag (bivalve or barnacle)	dated
211.32-211.35	frags indet. (barnacles?)	dated
265.48-265.51	1 frag indet. (barnacle?)	dated
270.54-270.54	1 small frag indet. relatively fresh (barnacle?)	dated
276.20-276.23	1 relatively large frag (barnacle?)	dated
284.97-285.00	1 relatively large frag (barnacle)	dated
285.85-285.85	1 barnacle plate, relatively well preserved	dated
325.05-325.07	1 thin-shelled bivalve, indet.	dated
326.26-326.27	1 small frag, thick (bivalve? or barnacle)	dated
329.28-329.30	1 small frag (bivalve?)	dated
335.15-335.17	1 frag indet. (bivalve or barnacle)	dated
337.66-337.68	1 frag relatively fresh, indet. bivalve?	dated
341.07-341.08	1 small worn frag indet. (bivalve or barnacle)	dated
345.05-345.08	1 small frag indet.	dated
374.21-374.23	1 worn relatively large barnacle frag	to be done
376.08-376.11	relatively large but worn barnacle plate	to be done
378.02-378.07	relatively large (c. 1 cm) barnacle frag	to be done
473.61-473.62	1 small frag indet. (barnacle?)	to be done
652.78-652.81	1 plate, relatively large, probably recrystallised barnacle	to be done
1179.62-1179.66	Serpulid worm tube, well-preserved	to be done

MATERIALS AND METHODS

A total of 242 samples for palynological analysis were collected from AND-1 push core SS011, AND-1A, and AND-1B from about every 5 metres below 24.88 mbsf. Preferentially, fined-grained lithologies were collected, but on many occasions this was not possible and coarser material was chosen. For on-ice palynology, sample processing was carried out at the Gracefield Campus of GNS Science in Lower Hutt, New Zealand. On average during drilling, one package of samples was freighted to the laboratory per week.

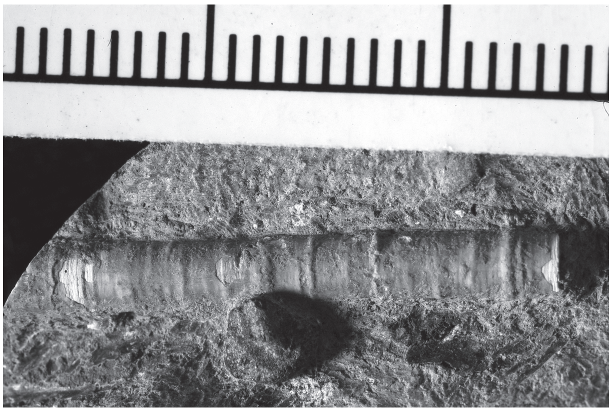


Fig. 3 – Well preserved calcareous serpulid polychaete tube from 1179.65 mbsf. Specimen is >21 mm long, and was cut by the drill. The image is of the upper part of a bedding plane. The edge of the core is visible at the upper left, where the specimen is cut.

The completed slides were returned about 10 days after the samples left McMurdo Station. Because of the time constraints resulting from this process, at the end of drilling only 24 samples at *c.* 20 m sample spacing had been processed and examined, from between 60.42 and 540 mbsf, and this report is based solely on these samples.

Processing procedures were based on those developed for the CRP, outlined in Simes & Wrenn (1998), but without the use of a microwave digester. Up to about 30 g of dry sample was treated with dilute HCl to remove any carbonates. Silicates were removed by placing the sample in HF (50%) until the reaction stopped, followed by treatment with hot HCl and water washes.

If, after inspection, oxidation was considered necessary, the residues were oxidised for 5 minutes in 10% HNO_3. The residues were then floated using sodium polytungstate solution (specific gravity 1.6), and the float fraction was then sieved at 6 µm. The entire residue after sieving was mounted in glycerine jelly. In most cases the entire residue was examined and counted, allowing the numbers of grains per gram to be estimated. In two cases (441.0 and 522.97 mbsf) only one-half of the residue was counted. Yields for these samples were estimated based on half the dry weight possessed. As a check on the recovery of palynomorphs, after the float was taken, slides were made up of the heavy fraction. After examination of the first few samples, it was decided to discontinue this practice as no palynomorphs were encountered in these slides.

Palynomorph yields for each sample are listed in table 4. All samples yielded palynomorphs except for one at 145.46 mbsf, which was barren. The yield is variable, however, with the highest yields tending to come from the diatomite units (up to 28.43 grains per gram). Other than this, it is difficult to see any direct link between lithology and yield. For example, samples described as muddy diamictite contain floras ranging from 0.08 to 5.39 grains per gram. The upper levels of this range are associated with clast-poor diamictites.

MARINE PALYNOMORPHS

Both marine and terrestrial palynomorphs were recovered from most samples. Representative specimens are illustrated in figure 4. A range chart of all the palynomorphs found in this initial study is provided in figure 5. Palynomorphs are separated into marine and terrestrial species. The marine flora is further subdivided into what is considered to be (1) a probably *in situ* flora and (2) an assemblage of reworked Eocene marine palynomorphs of the well-known Transantarctic Flora (Wrenn & Hart 1988).

In the case of the marine floras an attempt was made to identify to species level, and where this was impossible an open nomenclature is used. In a few cases where identification to even genus level was impossible an informal name such as 'grey spheres' is used. It is hoped that with further analysis taxonomic resolution will improve. Terrestrial palynomorphs are assigned to very broad groups pending off-ice investigation by a specialist. Plotted down the left-hand side of the figure 5 are graphs of the raw counts of each of the three groups (*in situ* marine, Transantarctic Flora, and terrestrial palynomorphs). The same data are shown in table 3 as grains per gram. It is clear from the range chart that the core, down to 540.52 mbsf, can be subdivided into two intervals based on their palynomorph content. The palynomorph assemblages recovered from these intervals are discussed separately below.

60.42–169.60 mbsf: Excluding the barren sample at 145.46 mbsf, this interval is dominated by reworked elements of the Eocene Transantarctic Flora with yields between 0.45 and 3.87 grains per gram. The most common species present is *Vozzhennikovia apertura,* with *Enneadocysta partridgei, Spinidinium macmurdoense,* and *Deflandrea antarctica* also making significant contributions to the assemblage, presumably, because of the reworking. Most specimens are poorly preserved. This interval also contains several specimens of what is considered to be an *in situ* marine flora (see below). The yield in most samples was very low, between 0.12 and 1.21 grains per gram. The assemblage in this interval consists largely of leiospheres and acanthomorph acritarchs. The yield rises sharply to 2.61 grains per gram at 169.60 mbsf, with the appearance of significant numbers of the organic chamber linings of microforaminifera. The delicate nature of these palynomorphs suggests that they are not part of the reworked group.

184.70–540.52 mbsf: Eocene marine palynomorphs are almost totally absent from this lower interval, with only sporadic appearances of single specimens of *Vozzhennikovia apertura.* The yield of Transantarctic Flora over most of this interval is 0 to 0.45 grains per gram. There is a small peak in numbers of several species at about 500 mbsf (Fig. 5) where the yield rises to 1.3 grains per gram. The lack of substantial numbers of Eocene palynomorphs through this interval suggests that reworking is minimal and that the non-Eocene marine assemblage recorded from this interval is *in situ*.

Palynomorph yield is very variable throughout this interval, ranging from 28.43 and 20.64 grains per gram from diatomites at 441.0 and 201.25 mbsf down to 0.07 in the silty claystone at 260.45 mbsf. The high numbers of marine palynomorphs recovered from the diatomite units, which show no indication of diatom reworking, also suggests that the marine palynomorph assemblage is not reworked.

Major components of the *in situ* marine flora are microforaminiferal linings, leiospheres and a group referred to here as 'grey spheres'–many of which are probably poorly preserved protoperidinioid cysts, but archaeopyles and other diagnostic features were impossible to see. Marine floras from the upper part of this interval (between about 184.70 and 224.38 mbsf) are slightly more diverse than those from lower in the interval, and contain at least two species of *Lejeunecysta,* a single specimen identified as *Batiacasphaera* sp., and several species of *Cymatiosphaera*. One of these species, *Cymatiosphaera* sp. 2, strongly dominates the sample at 224.38 mbsf. Reasonably common through this interval are cysts tentatively assigned to *Eatonicysta*, which often have a complete ectophragm.

TERRESTRIAL PALYNOMORPHS

Pending investigation by specialist, terrestrial palynomorphs have been assigned to broad categories only. Permian/Triassic spores and taeniate bisaccate pollen are found throughout the drill core, and are obviously recycled. Cenozoic spores and pollen are similarly found throughout the drill core, but further study will be required to determine the amount and nature of the recycling. In general the amount of terrestrial input to the assemblages increases downsection, reaching a peak of 8.99 grains per gram at 502.72 mbsf. There seems to be no direct correlation between numbers of terrestrial and marine palynomorphs that are not part of the Transantarctic Flora, again supporting the possibility that these marine species are *in situ.*

SUMMARY OF AND-1B PALYNOLOGY

This preliminary study has demonstrated the presence of significant assemblages of palynomorphs in AND-1B. Most of the marine assemblage appears to be *in situ*. In the short term it is unlikely that these marine palynomorphs can add to the chronostratigraphy; however, the mix of dinoflagellate cysts, prasinophyte algae and acritarchs reported should provide important palaeoclimate information.

Tab. 4 - Yield data in grains per gram. Calculation based on a count of the entire residue, except for samples at 441.0 and 522.97 smbsf, where only half was counted. For these samples the yield was calculated using half of the dry weight.

Depth	Sample dry weight	Lithology	Total Abundance -Grains per gram	Marine - Grains per gram	Transantarctic Flora - Grains per gram	Terrestrial - Grains per gram
60.42-60-45	28	Muddy diamictite	3.04	1.21	1.68	0.07
80.00-80.03	40.75	Muddy diamictite	1.45	0.12	1.10	0.20
99.97-100.02	25.87	Silty claystone to clayey siltstone	4.60	0.43	3.87	0.23
119.97-199.99	39.34	Volcanic sltstone	0.56	0.20	0.28	0.08
145.46-145.48	38.2	Volcanic sand / siltstone	0.00	0.00	0.00	0.00
169.60-169.62	32.17	Mudstone with dispersed clasts	1.01	0.38	0.45	0.10
184.7-184.72	24.52	Volcanic siltstone	2.73	2.61	0.00	0.12
201.25-201.27	23.21	Diatomite	21.03	20.64	0.00	0.26
224.38-224.4	27.1	Diatomite	11.14	11.11	0.00	0.04
243.78-243.81	24.47	Muddy diamictite	1.27	0.29	0.04	0.94
260.45-260.48	28.57	Silty claystone	1.05	0.07	0.00	0.98
280.95-280.97	13.13	Clast rich muddy diamictite	0.69	0.15	0.00	0.53
300.39-300.41	21	Clast poor muddy diamictite	2.10	0.57	0.00	1.52
321.18-321.22	31.1	Sandy mudstone with dispersed clasts	2.15	0.93	0.00	1.22
343.00-343.02	16.99	Clast poor muddy diamictite	3.18	2.47	0.00	0.71
360.23-320.25	23.16	Volcanic siltstone	1.17	0.35	0.00	0.82
379.20-379.22	17.87	Diatomite	10.18	8.79	0.06	1.34
401.24-401.26	14.12	Diatomite	2.55	1.84	0.00	0.71
418.95-418.97	17.68	Diatomite	10.01	9.11	0.00	0.90
441.0-441.06	18.22	Diatomite	28.43	28.43	0.00	0.00
460.68-460.70	17.06	Silty claystone	1.00	0.41	0.00	0.59
478.02-478.05	31.19	Clast poor muddy diamictite	5.39	4.07	0.10	1.22
502.72-502.74	21.59	Silty claystone	24.18	13.80	1.30	8.99
522.97-522.99	20.73	Silty claystone / very fine sandstone	7.24	5.26	0.05	1.93
540.52 - 540.54	21.39	Mudstone with dispersed clasts	3.27	1.64	0.14	1.50

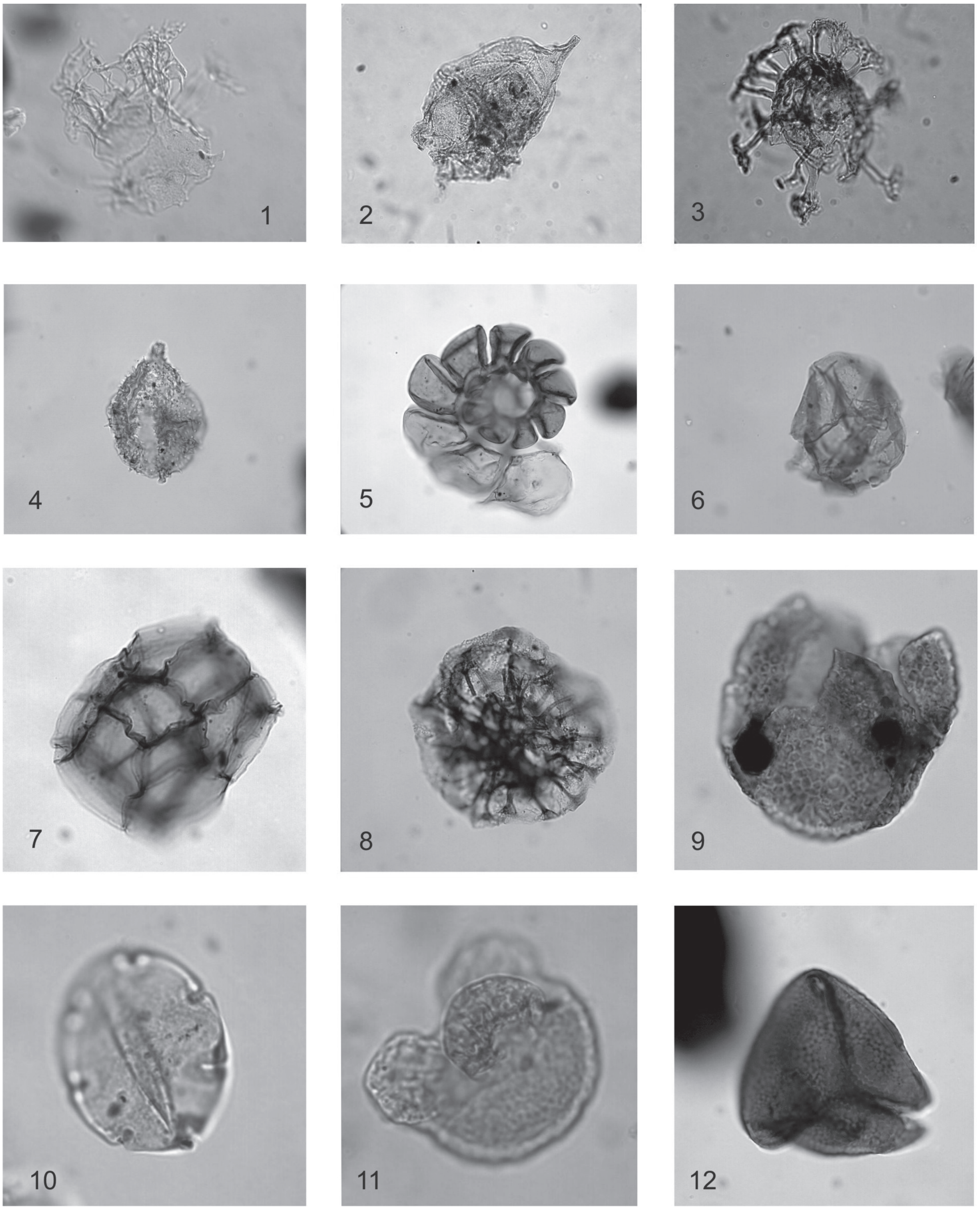
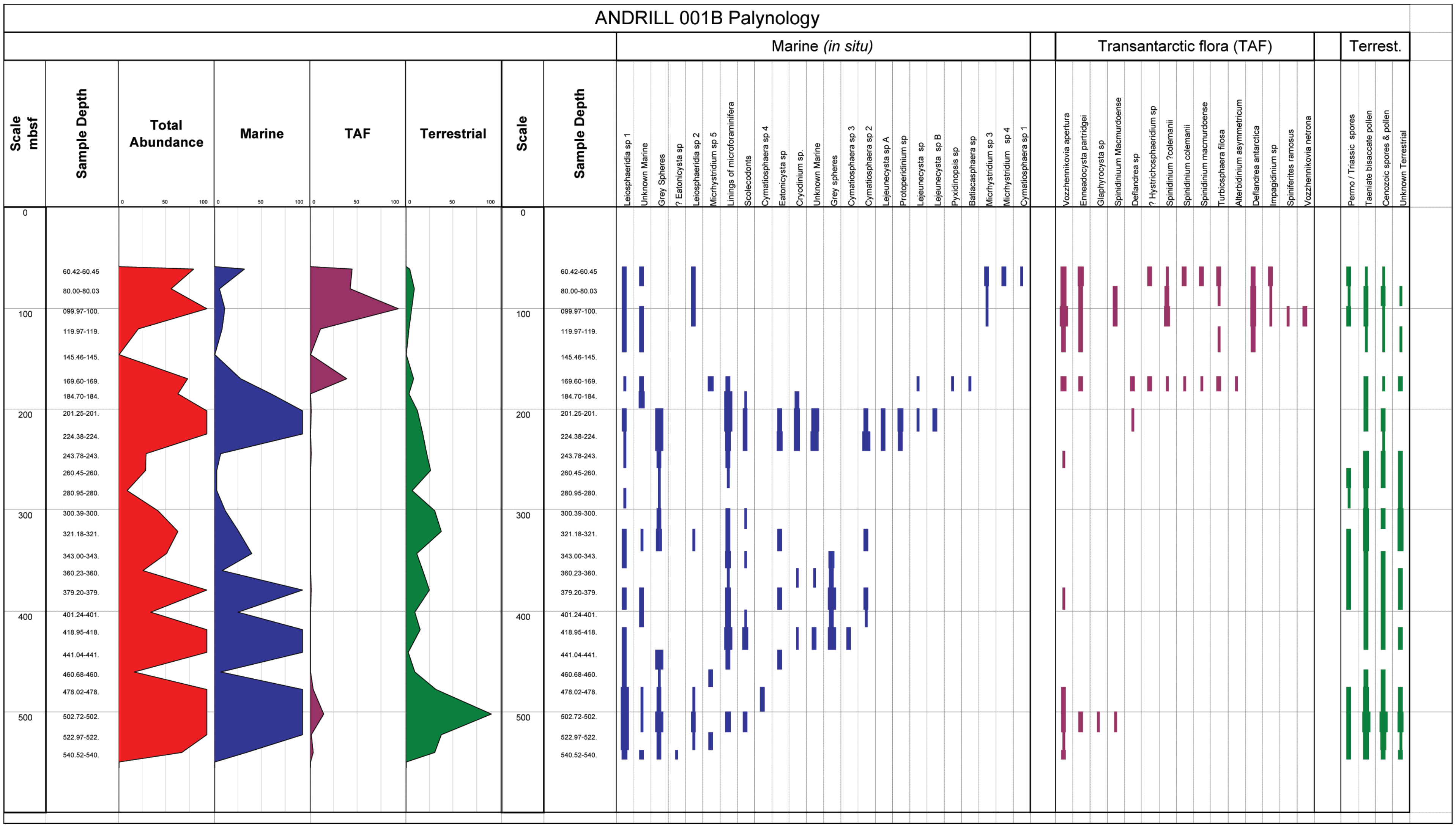


Fig. 4 – Representative palynomorphs from AND-1B. 1–4 Transantarctic flora: 1. *Glaphyrocysta sp*: depth = 502.72-502.74 mbsf, slide number = L23218/1, England finder co-ordinates = O51, diameter of central body = 32 µm. 2. *Alterbidinium asymmetricum*: 169.6-169.3 mbsf, L23198/1, N46/3, length = 80 µm. 3. *Enneadocysta partridgei*: 169.6-169.62 mbsf, L23198/1, S47/2, diameter of central body = 41 µm. 4. *Vozzhennikovia apertura*: 169.6-169.62 mbsf, L23207/1, F33/3, Length = 45 µm. 5–9 *In situ* marine palynomorphs. 5. Lining of microforaminifera: 184.7-184.72 mbsf, L23100/1, D52, diameter = 77 µm. 6. 'Grey sphere': 418.95–418.97 mbsf, L23214/2, P48/3, 37 µm. 7. *Cymatiosphaera* sp 2: 224.38-224.40, L23201/1, O45/2, 45 µm. 8. *Eatonicysta* sp, 224.38–224.4 mbsf, L23201, R36/3, 65 µm. 9. *Batiacasphaera* sp: 169.6–169.62 mbsf, L23198, O47, 43 µm. 10–12 Terrestrial palynomorphs. 10. *Nothofagidites* cf. *flemingii*: 478.02–478.03 mbsf, L23217/2, x=66, y=113.4 (England finder co-ordinates unavailable), 21 µm. 11. *Microcachryidites antarcticus*, 478.02–478.03 mbsf, L23217/2, F38/3, 24 µm. 12. *Granulatisporites micronodosus,* 260.45–260.48 mbsf, L23212/1, M42/3, 40 µm.

MARINE DIATOMS AND OTHER SILICEOUS FOSSILS

Marine diatoms are the only common siliceous fossil in AND-1B. Occurrences of radiolarians, ebridians, parmales, sponge spicules, and other siliceous microfossils are rare. Silicoflagellates are common members of the assemblage in diatom unit (DU)-XI but occur only intermittently throughout the rest of the core. Representative samples characterising

Fig. 5 – Range chart of palynomorphs. The graphs on the left hand side are based on the raw counts. Note that any count over 100 is clipped. Counts from 441.0 and 522.52 mbsf are based on one-half of the residue available.



the different facies, with a focus on fine-grained sediments, were selected for diatom analysis. Sample preparation included several distinct methods.

MATERIALS AND METHODS

Smear slides were prepared following lithostratigraphic description of the drill core, and at sample intervals down to millimetre scale, offering the possibility of microstratigraphic analysis of key intervals. Duplicate sets of smear slides representing more than 715 distinct levels in the drill core were prepared during on-ice core characterisation. A total of 108 interval samples were processed for on- and initial off-ice examination for Core Characterisation and this Initial Report. These were prepared using several distinct methods in order to achieve clean slides for detailed analysis. Most samples disaggregated quickly with mili-Q water alone, making chemical digestion unnecessary. As needed, some organic carbon and clay-rich samples were oxidised with 10% H_2O_2, and some were sieved, using a 20 µm mesh stainless steel sieve. Other samples were sieved with a 10 µm mesh nylon sieve. Strewn slides were prepared from both unsieved and sieved material. For sieved samples, fine as well as coarse fractions were prepared. Permanent microscope slides were prepared using Norland Optical Adhesive #63 or #81 (R.I. 1.56) and analysed using ×40 (dry), ×60 (dry), ×63 (oil) and ×100 (oil) objectives. At least four transects were examined for each slide in order to initially characterise the diatom assemblage and abundance. Abundance estimates were produced using methods standardised through many ODP cruises and the CRP.

Diatom biostratigraphy follows established schemes developed during previous drilling/coring programs in the Antarctic nearshore zone (Cenozoic Investigations in the Ross Sea [CIROS], McMurdo Sound Sediment & Tectonic Studies [MSSTS], Dry Valley Drilling Project [DVDP], Shallow Drilling Project (US) [SHALDRIL], CRP) and the pelagic realm (ODP Legs 114, 119, 120, 177, 178, 183, DSDP Leg 28, etc.). Datums were analysed using previously published results from these other nearshore and open-ocean sites with the assistance of the Constrained Optimisation (CONOP) database (Cody et al. in press), which provides Southern Ocean age constraints using all published ages for species reported within the sample (Tab. 6). Analysis for core characterisation was focused on identification of biostratigraphically useful species.

DIATOM OCCURRENCES

Continuous coring of AND-1B began at 24.17 mbsf. Thick successions of diamictite and volcanic sands and muds were recovered, containing few diatoms and, more frequently, no trace of diatoms (Fig. 6). It has been shown that grounded ice degrades diatoms but that diatoms can be transported in a subglacial setting and retain an identifiable character (Scherer et al. 2004; Sjunneskog & Scherer 2005). Nevertheless, significant thicknesses of diamictite in AND-1B are completely barren of diatoms. Typically, even highly sheared Pleistocene diamictites contain reworked diatom fragments (Scherer 1991; Scherer et al. 2004), but virtually no trace of even small fragments of diatoms can be found in most core samples down to 53 mbsf, with few exceptions. The absence of biosiliceous fragments is interpreted as reflecting not only mechanical degradation, but dissolution of finely ground diatom fragments under significant shear strain.

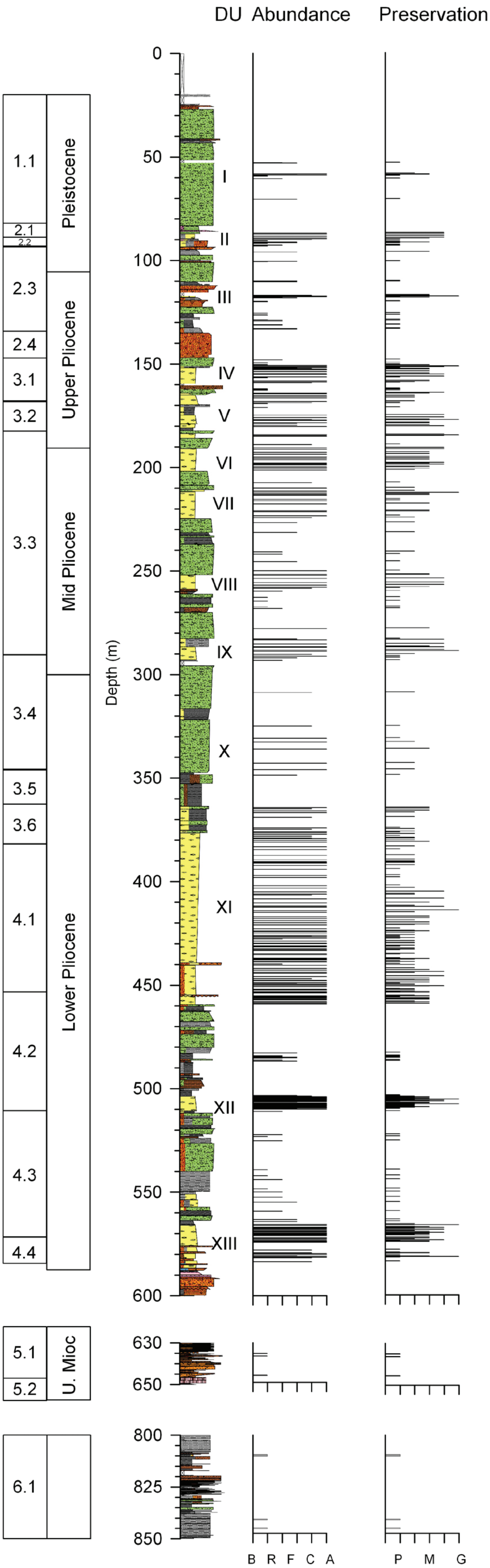
As diatoms are very rare or absent in most diamictites and volcanic sediments, the focus in the Initial Reports is on the diatom assemblages within diatomites and diatomaceous muds. In the upper *c.* 580 m of core, most recovered sedimentary facies interpreted as representing open water contain a rich and abundant diatom assemblage (Fig. 6, range chart of diatoms is downloadable at the internet site http://www.mna.it/english/Publications/TAP/terranta.html). These diatom-rich intervals are also recognised by their characteristic low density and low seismic velocity (see Niessen et al. this volume). Diatoms are largely absent below 580 mbsf.

Preservation of diatoms within the diatomites varies from well preserved to poor, sometimes with intense fragmentation, most likely due to sediment and episodic glacial loading. Fragmentation cuts across all species types, implying compaction rather than shear or grazing (Scherer et al. 2004). Muds interpreted as representing grounding-line proximal/outwash facies contain few, rare, or no diatoms. In some cases diatom fragments are well sorted in the fine silt range, implying winnowing, transport, and redeposition of diatom remains. No diatom assemblages within this facies are interpreted as representing primary deposition.

Below 580 mbsf diatom occurrences are rare and they are diagenetically altered, limiting their utility. Replacement of diatom silica with pyrite can allow identification, but abundance within these facies is always lower than in samples with primary silica preservation. Diatoms in the lower half of AND-1B are generally preserved as recrystallised fragments or siliceous casts, most likely representing the transition from opal-A to opal-CT. In only a few cases can these be identified with moderate confidence and applied toward a biostratigraphy.

DEFINITION AND DESCRIPTION OF DIATOMACEOUS UNITS (DU)

Below we define 13 stratigraphic intervals of diatomaceous sediment and characterise their diatom content. The details for each unit are summarised in table 5. DU-I through DU-III are characterised by an *in situ* diatom assemblage with common reworked older diatoms. DU-III is thin, and is interpreted as bound by unconformities, with time missing between both overlying and underlying diatomaceous units



(see Krissek et al.; G. Wilson et al. this volume). DU-IV through DU- IX are characterised by clear cycles of diatomite and diamictite deposition. The well-defined diatomaceous units are interpreted as interglacial periods, possibly Milankovitch-paced. Diatomaceous unit X is a thick succession of diatom-bearing glacially influenced sediment and underlies a major unconformity. DU-XI defines the longest and most continuous diatomite of AND-1B, nearly 100 m thick, and, unlike many of the overlying diatomites, appears to include the transition from open-marine diatomite to glacial diamictite. DU-XII and DU-XIII are similar in character and provide the oldest well-defined biostratigraphic age control in the core. First and last stratigraphic occurrences of key diatoms in AND-1B are illustrated on figures 7 & 8. Datums identified are in table 6.

Although the diatom assemblages examined generally contain a well-known flora, numerous taxa examined will require additional examination to allow positive identification to the species level. Some taxa are unknown or indeterminate species; others are transitional forms between described species. Notable lineages requiring additional examination and morphometrics include *Fragilariopsis* and the *Thalassiosira oestrupii/tetraoestrupii* lineage, and the relationship between *Thalassiosira inura* and the *T. oliverana* group. Figure 9 illustrates a range of morphologies seen in the genus *Fragilariopsis*, which dominates the assemblage in numerous intervals. Figure 10 shows a range of morphology seen in *Rouxia*. Figure 11 illustrates a very rare example of a *Thalassiosira tetraoestrupii* that can be distinguished from *T. oestrupii* in the light microscope. Throughout this document, in tables and figures, we use the name *T. oestrupii* in reference to a group of taxa with morphologic criteria broadly ascribed to *T. oestrupii* (*i.e. sensu lato*). Typically the key morphologic feature can only be seen in the electron microscope. Further taxonomic analysis will follow in the science documentation phase of this project, including appropriate transfer of several *Thalassiosira* species that should be ascribed to the newly erected genus *Shionodiscus,* including *T. oestrupii*, *T. tetraoestrupii, T. gracilis, T. gracilis var. expecta, T. trifulta, T. inura, T. complicata,* and possibly others (Alverson et al. 2006).

DU-I: Mid- to Lower Pleistocene, 58.15–58.90 mbsf: This unit contains several biostratigraphically useful diatom species. Extant species *Actinocyclus actinochilus* (0–3.02 Ma), *Thalassiosira gracilis* (0–2.14 Ma) (scarce), and

Fig. 6 (left) – Diatom abundance and preservation for the upper 585 m is plotted against core log and lithologic units. Diatom abundance categories (B = barren; R = rare; F = few; C = common; A = abundant) and preservation categories (P = poor; M = moderate; G = good) are based on transect counts using smear and strewn slides. Also presented are stratigraphically lower intervals containing rare and poorly preserved diatoms. The remainder of the core is effectively barren of diatoms.

Thalassiosira antarctica (0–1.1? Ma), along with extinct taxa such as *Thalassiosira elliptipora* (acme 0.73–1.08 Ma), *Actinocyclus ingens* (last common occurrence (LCO) in Antarctic 0.67 Ma), and *Rouxia leventerae* (0.14–2.08 Ma), point to an age range of 0.14 to 1.08 Ma for this assemblage. Many specimens in this assemblage provide anomalously old ages and are therefore judged to be reworked. These include *Actinocyclus karstenii*, *Thalassiosira vulnifica*, and *Denticuplopsis* spp. Some heavily silicified and long-ranging taxa present, such as *Paralia sulcata* and *Stephanopyxis* spp., are typical of samples that include significant reworking (Sjunneskog & Scherer, 2005). Bohaty et al. (1998) showed that *Thalassiosira torokina* ranges to at least the early Pleistocene on the in the Antarctic continental shelf. We cannot determine with certainty whether occurrences of *T. torokina* are in place or reworked in DU-I.

DU-II: Lower Pleistocene, 86.92–97.08 mbsf: This interval is a diatom-rich silty clay/mudstone

Tab. 5 - Diatomaceous units by depth for AND-1B; species providing biostratigraphic age control given with their age range following in parenthesis for each unit. The age range possible for each unit is based on the diatom species present in the assemblage. Other species characteristic of the assemblage for each unit is also shown, with the general abundances for each species as is the overall abundance and preservation for the samples within the unit. General comments on species present in each assemblage, or their first or last occurrences are discussed in the last column. Species age references as follows: (a) Harwood & Maruyama, 1992; (b) Bohaty *et al.*, 1998; (c) Leg 188 Explanatory Notes; (d) Zielinski & Gersonde; (e) Winter & Iwai, 2002; (f) Whitehead & Bohaty, 2003; (g) Censarek & Gersonde, 2002; (h) Cody et al. in press. Includes some informal taxonomy.

Diatom Units	Depth (mbsf)	Biostratigraphic indicators	Age Range (Ma)	Abundance/ Preservation	Characterisic assemblage	Comments
I	58.15 - 58.90	*A. actinochilus* (0-3.02h), *A. ingens* (LO 0.39/LCO 0.67d), ***R. leventerae* (0.14d-2.08h)**, *T. antarctica* (0-1.1b), ***T. elliptipora* (0.73-FCO 1.07d)**, *T. lentiginosa* (0-3.8e), *T. torokina* - late form (1.0b-9.0a)	0.14 - 1.07	F/M-P	*A. karstenii*(X-F), *Thalassiothrix/ Thalassionema*(F-A), *P. sulcata*(X-F), *S. microtrias*(X), *S. recta*(X)	Includes abundant reworked Pliocene and Miocene diatoms: *Denticulopsis* spp., *Trinacria* spp., *A. karstenii*, *T. vulnifica*. Contains few *Fragilariopsis* spp. Possible that entire assemblage is moderately reworked.
II	86.92 - 97.08	*A. actinochilus* (0-3.02h), *A. ingens* (LO 0.39/LCO 0.67d), *R. leventerae* (0.14d-2.08h), *T. antarctica* (0-1.1b), ***T. elliptipora* (0.73-FCO 1.07d)**, *T. lentiginosa* (0-3.8e), *T. torokina* (1.0b-9.0a)	0.73 - 1.07	A/G-M	*A. karstenii*(X), *Chaetoceros spp.(X), Denticulopsis* spp.(X), *E. antarctica*(R), *F. sublinearis*(X), *P. sulcata*(X-R), *S. microtrias*(X), *Thalassionema/ Thalassiothrix*(C-A), *T. tumida*(X)	High productivity assemblage with reduced summer sea ice. Includes some reworked species, including *Denticulopsis* spp., *T. inura*, *T. kolbei*, *T. vulnifica*.
III	116.75 - 118.70	*A. actinochilus* (0-3.02h), *A. ingens* (LC 0.39/LCO 0.67d), ***R. leventerae* (0.14d-2.08h)**, *T. antarctica* (0-1.1b), *T. elliptipora* (0.73-FCO1.07d), ***T. fasciculata* (0.84d-4.2a)**, *T. lentiginosa* (0-3.8e), *T. torokina* (1.0b-9.0a)	0.84 - 2.5	C/M	*E. antarctica*(X), *F. obliquicostata* (X-F), *P. sulcata*(X-R), *R. antarctica* (X-C), *S. microtrias*(X-R), *Thalassionema/Thalassiothrix*(X-R)	Some reworked species present, top of rare occurrences of *T. vulnifica* at 110.39 mbsf, LAD of *R. antarctica* at 116.93.
IV	150.87 - 159.33	*A. actinochilus* (0-3.02h) (rare), *R. diploneides* (2.31-4.67h), *T. elliptipora* (0.73-FCO 1.07d), *T. inura* (2.37-5.06d), *T. kolbei* (1.98d-4.1a), *T. oestrupii/ tetraoestrupii* (0-5.7c), ***T. tetraoestrupii* var. *reimerii* (1.46-2.55d)**, *T. torokina* (1.0b-9.0a)	1.46-2.55	A/M - fragmented	*A. karstenii*(X-R), *E. antarctica*(X), *Fragilariopsis* spp. complex, *Rhizosolenia* sp. D (X-R), *R. antarctica*(F-A), *R. diploneides*(X-C), *S. microtrias*(R)	FAD of *A. actinochilus*, LAD of *R. dipolneides*, *T. inura*, *T. kolbei*, and *Rhizosolenia* sp. D (of H&M92) occur within this unit. *T. tetraoestrupii* var. *reimeri* common almost exclusively in this package. Sea-ice related assemblage present.
V	164.1 - 180.73	***A. fasciculatus* (2.25-2.92h)**, ***A. maccollumii* (2.54-2.9d)**, *R. diploneides* (2.31-4.67h), *T. elliptipora* (0.73-FCO 1.07d), *T. fasciculata* (0.84d-4.2a), *T. inura* (2.37-5.06d), *T. kolbei* (1.98d-4.1a), *T. oestrupii/ tetraoestrupii* (0-5.7c), *T. oliverana* (0-6.4d), *T. torokina* (1.0b-9.0a), *T. vulnifica* (2.41d-3.12f)	2.25-2.9	A/M - fragmented	*A. karstenii*(R-F), *Coscinodiscus* spp. (X), *D. antarcticus*(X-A), *E. antarctica*(X-F), *F. curta*(X-R), *Rhiz.* sp. D (X), *R. antarctica*(X-C), *S. microtrias*(X-R), *Fragilariopsis* spp. complex	Top of consistant/abundant *T. vulnifica*, LAD of *T. fasciculata*, *A. maccollumii*, and *A. fasciculataus* occur within this unit. Last common occurrence of *Synedropsis creanii*. Sea-ice related assemblage present with high primary productivity. Parts finely laminated
VI	183.42 - 201.59	***A. maccollumii* (2.54-2.9d)**, *R. diploneides* (2.31-4.67h), *T. elliptipora* (0.73-FCO 1.07d) (rare), *T. fasciculata* (0.84d-4.2a), *T. inura* (2.37-5.06d), *T. kolbei* (1.98d-4.1a), *T. oestrupii/tetraoestrupii* (0-5.7c), *T. oliverana* (0-6.4d), *T. torokina* (1.0b-9.0a), ***T. vulifica* (2.41d-3.12f)**	2.54-3.12	A/M - fragmented	*A. karstenii*(F), *F. curta*(X), *F. praecurta*(R), *R. antarctica*(R-C), *S. microtrias*(X-F), *Fragilariopsis* spp. complex. Laminae with *C. criophilum* and *D. antarcticus*	FAD of *T. elliptipora* just below the bottom sample, FAD of *A. maccollumii* and *T. vulnifica* at bottom of interval. Sea-ice related assemblage present. *Fragilariopsis* stratigraphic markers to be established.
VII	209.96 - 224.44	***T. fasciculata* (0.84d-4.2a)**, *T. elliptipora* (0.73-FCO 1.07d) (rare), ***T. inura* (2.37-5.06d)**, *T. oestrupii/tetraoestrupii* (0-5.7c), *T. torokina* (1.0b-9.0a)	2.37-4.2	A/M - fragmented	*A. karstenii,*(X-F), *D. antarcticus*(X-R), *E. antarctica*(X-R), *F. curta*(X-R), *F. praecurta*(X-F), *R. antarctica*(X-F), *S. microtrias*(X-F), *S. creani*(X-R), *Fragilariopsis* spp. complex	Sea-ice related assemblage present. *Fragilariopsis* stratigraphic markers to be established.
VIII	250.02 - 258.32	***T. fasciculata* (0.84d-4.2a)**, ***T. inura* (2.37-5.06d)**, *T. oestrupii/tetraoestrupii* (0-5.7c), *T. torokina* (1.0b-9.0a)	2.37-4.2	A/M - fragmented	*Chaetoceros* spp.(X-A), *F. curta*(R), *F. praecurta*(R), *R. antarctica*(R-C), *Fragilariopsis* spp. complex, *Thalassionema/ Thalassiothrix* (R-C)	High productivity assemblage
IX	283.35 - 292.66	*F. barronii* (1.39d-4.16f), *F. praeinterfrigidaria* (2.93d-5.09g), ***F. weaveri* (2.6-3.42a)**, *R. diploneides* (2.31-4.8h), *T. fasciculata* (0.84d-4.2a), *T. inura* (2.37-5.06d), *T. oestrupii/tetraoestrupii* (0-5.7c), *T. oliverana* (0-6.4d), *T. striata* (2.65d-4.5a), *T. torokina* (1.0b-9.0a)	2.6-3.42	A/M - very fragmented	*A. karstenii*(X-F), *Chaetoceros* spp. (X-F), *E. antarctica*(X-R), *R. antarctica*(X-F), *S. microtrias*(X-R), *S. creanii*(X-F), *Thalassionema/ Thalassiothrix* spp. (R-F), *Fragilariopsis* spp. complex	LAD of *F. praeinterfrigidaria*, all occurences of *F. weaverii* confined to this interval, *F. barronii* more common than higher in core. Consistent occurrences of *T. striata* observed.
X	295.46 - 346.94	***F. barronii* (1.39d-4.16f)**, *F. praeinterfrigidaria* (2.93d-5.09g), *R. diploneides* (2.31-4.67h), ***T. complicata* (3.12d-4.6a)**, *T. fasciculata* (0.84d-4.2a), *T. inura* (2.37-5.06d), *T. oestrupii/tetraoestrupii* (0-5.7c), *T. striata* (2.65d-4.5a), *T. torokina* (1.0b-9.0a)	3.12-4.16	A/M - very fragmented	*A. karstenii*(X-F), *E. antarctica*(X-R), *R. antarctica*(X-F), *S. microtrias*(R), *Thalassionema/ Thalassiothrix* (R-F)., *Fragilariopsis* spp., *Stephanopyxis* spp..	High and variable primary productivity. LAD of *T. complicata* at top of unit. FAD of *F. barronii* at bottom of unit.
XI	363.37-459.24	*F. praeinterfrigidaria* (2.93d-5.09g), *R. diploneides* (2.31-4.67h), *T. complicata* (3.12d-4.6a), *T. fasciculata* (0.84d-4.2a), ***T. inura* (2.37-5.06d)**, *T. oestrupii/tetraoestrupii* (0-5.7c), *T. striata* (2.65d-4.5a), *T. torokina* (1.0b-9.0a)	4.16-5.06	A/M - fragmented	*A. karstenii*(X-R), *Chaetoceros* spp. (X-C), *D. antarcticus*(X-R), *D.* sp. 1 MIS (X-F), *E. antarctica*(X-F), *P. barboi*(X-C), *R. antarctica*(X-F), *S. microtrias*(R), *T. nitzschioides*(R-C), *Thalassiothrix* spp. (R-C), *Fragilariopsis* spp., *Stephanopyxis* spp. (X-F). Fine laminations common. Silicoflagellates are common in some samples.	Very high productivity/accumulation rate. The FAD of *T. fasciculata* and *T. striata* and LAD of Denticulopsis sp. 1 (cf. delicata) MIS occur within unit. Lowest consistent occurrence (FAAD) of *F. praeinterfrigidaria* within unit, but it continues to be rare in the upper part of DU XII. Also lowest occurrance of consistent *T. inura* at base of unit.
XII	503.42-511.56	*R. diploneides* (2.31-4.67h), *T. inura* (2.37-5.06d), ***T. oestrupii/tetraoestrupii* (0-5.7c)**, *T. complicata* (3.12d-4.6a), *T. oliverana* (0-6.4d), *T. torokina* (1.0b-9.0a)	4.5-5.7	A/M - fragmented	*A. karstenii*(X-F), *A octonarius*(X-R), *Coscinodiscus* spp. (R), *D. delicata* (X), *E. antarctica*(X-R), *F. curta*(X-F), *R. antarctica*(X-F), *S. microtrias* (R), *S. creanii*(X), *Thalassionema/ Thalassiothrix*(R-C), *Chaetoceros*	No *T. fasciculata*, *T. striata* in assemblage. Moderate to high productivity. Youngest possible age of 4.5 Ma based on the lack of *T. striata* in the assemblage. FAD of *T. inura* occurs within this unit.
XIII	550.78-586.45	*R. diploneides*(2.31-4.67h), *T. complicata* (3.12d-4.6a), **T. oestrupii/tetraoestrupii (0-5.7c)**, *T. oliverana* (0-6.4a), *T. torokina* (1.0b-9.0a), *T. tumida* (rare) (0-4.55h)	5.06-5.7	A/M-G	*A. karstenii*(X-F), *A. octonarius*(X-R), *Chaetoceros* spp. (R-A), *D. antarcticus*(X-F), *D. delicata*(X-F), *D.* sp. 1 MIS (X-F), *E. antarctica*(X-C), *S. microtrias*(X-F), *S. cheethamii* and *S. creanii*(x-R), *T. nitzschioides*(R-A), *Thalassiothrix* spp. (R-C)	*T. torokina* large and flat. Abundant pyritization, moderate recrystalization of siliceus diatom. Assemblage very similar to unit above with the exception that *T. inura* is not part of the assemblage. Youngest possible age based on FAD of *T. inura.*

Tab. 6 - Chart of diatom events and ages from prior published work and CONOP (Cody et al., in press)modelling for the Southern Ocean.

Datum	Species	Depth (mbsf)	Conop age (average min)	Conop age (average max)	Published age (min)	Published age (max)
LO	*Rouxia leventerae* Bohaty	52.98	0.07	0.35	0.13	0.14
LO	*Thalassiosira elliptipora* (Donahue) Fenner	58.15	0.64	0.71	0.30	1.81
LO	*Actinocyclus ingens* Rattray	86.90	0.50	0.57	0.30	1.99
FO	*Rouxia leventerae* Bohaty	89.20 (255.70)	2.00	2.08	-	-
LO	*Thalassiosira vulnifica* (Gombos) Fenner	(58.88) 110.39	2.14	2.18	2.38	2.43
LO	*Thalassiosira fasciculata* Harwood and Maruyama	(58.49) 125.6	0.89	0.89	0.75	2.19
LO	*Actinocyclus karstenii* Van Heurck	(86.90) 126.39	2.13	2.16	1.72	2.82
LO	*Thalassiosira inura* Gersonde	(52.98) 150.7	2.53	2.55	1.62	3.12
LO	*Thalassiosira kolbei* (Jousé) Gersonde	(86.96) 150.7	1.98	1.98	1.62	3.01
LO	*Thalassiosira tetraoestrupii* var. *reimeri Mahood & Barron*	150.80	1.31	1.34	1.32	1.61
LO	*Rhizosolenia* sp. D Harwood & Maruyama	150.80	-	-	-	-
LO	*Rouxia diploneides* Schrader	151.21	2.55	2.69	1.62	3.23
FO	*Actinocyclus actinochilus* (Ehrenberg) Simonsen	153.80	2.72	2.81	1.81	3.23
FO	*Thalassiosira tetraoestrupii* var. *reimeri* Mahood & Barron	159.25 (190.65)	2.35	2.37	2.43	2.66
LO	*Actinocyclus fasciculatus* Harwood & Maruyama	164.40	2.65	2.77	-	-
LO	*Actinocyclus maccollumii* Harwood and Maruyama	177.00	2.79	2.84	1.72	2.82
FO	*Actinocyclus fasciculatus* Harwood & Maruyama	185.05	2.65	2.77	-	-
LO	*Synedropsis creanii* Olney	189.00	-	-	-	-
FO	*Actinocyclus maccollumii* Harwood and Maruyama	201.40	2.79	2.84	2.50	3.30
FO	*Thalassiosira vulnifica* (Gombos) Fenner	201.40 (256.90)	3.12	3.18	3.20	3.21
FO	*Thalassiosira elliptipora* (Donahue) Fenner	207.40 (286.60)	2.00	2.06	1.51	3.51
LO	*Fragilariopsis barronii* (Gersonde) Gersonde et Bárcena	(156.35) 285.36	1.19	1.29	0.80	2.60
LO	*Thalassiosira striata* Harwood and Maruyama	(209.96) 285.36	2.89	2.96	1.81	3.51
LO	*Fragilariopsis praeinterfrigidaria* (McCollum) Gersonde et Bárcena	(259.83) 287.05	3.45	3.49	2.09	4.61
LO	*Fragilariopsis weaveri* (Ciesielski) Gersonde et Bárcena	288.33	2.45	2.53	1.81	3.71
LO	*Thalassiosira complicata* Gersonde	(245.46) 288.80	3.36	3.44	2.61	4.51
FO	*Fragilariopsis weaveri* (Ciesielski) Gersonde et Bárcena	291.22	3.51	3.55	3.10	4.31
FO	*Fragilariopsis barronii* (Gersonde) Gersonde et Bárcena	345.95	4.28	4.52	4.01	4.71
LO	*Fragilariopsis interfrigidaria* (McCollum) Gersonde et Bárcena	364.38	2.40	2.45	1.81	3.30
FO	*Thalassiosira fasciculata* Harwood and Maruyama	429.9 (450.83)	4.25	4.42	4.21	4.49
FO	*Thalassiosira kolbei* (Jousé) Gersonde	435.02	3.80	4.02	2.60	4.93
FO	*Fragilariopsis interfrigidaria* (McCollum) Gersonde et Bárcena	437.59	3.93	4.19	3.30	4.34
LO	*Denticulopsis* sp. 1 MIS	(364.89) 448.90	-	-	-	-
FO	*Thalassiosira striata* Harwood and Maruyama	452.25	4.30	4.64	3.48	4.49
LO	*Denticulopsis delicata* Yangasawa and Akiba	(348.75) 424.9	-	-	-	-
FO	*Thalassiosira inura* Gersonde	507 (565.67)	4.71	4.77	4.59	6.82
FO	*Fragilariopsis praeinterfrigidaria* (McCollum) Gersonde et Bárcena	508.95 (566.16)	4.72	4.78	4.51	5.97
FO	*Rouxia antarctica* Heiden, in Heiden and Kolbe	509.10	4.43	4.57	-	-
FO	*Rouxia diploneides* Schrader	581.84	4.61	4.70	3.72	4.49
FO	*Denticulopsis* sp 1 MIS	581.84	-	-	-	-
FO	*Rhizosolenia* sp. D Harwood & Maruyama	581.84	-	-	4.50	-
FO	*Thalassiosira complicata* Gersonde	583.64	4.64	4.71	4.51	4.80
FO	*Thalassiosira oestrupii* (Ostenfeld) Proschkina-Lavrenko	583.64	4.48	4.95	4.31	6.34
FO	*Denticulopsis delicata* Yangasawa and Akiba	583.64	-	-	-	-

Note: depths represent the tops and bottoms of consistent occurrences and higher abundances for each species, those proceeding or following in parenthesis are less consistent occurrences and lower in number.

grading up into a silty diatomite. Diatoms are abundant and generally well preserved. The diatom assemblage is nearly identical to that recognised in the early Pleistocene recovered at Cape Roberts Project 1 (CRP-1 Unit 3.2; Bohaty et al., 1998). The assemblage is similar to that above; however, the abundance and preservation is better. The overall age range assigned to this unit is 0.73–1.07 Ma, due to the more consistent presence of *T. elliptipora*. The assemblage is dominated by *Thalassionema* and *Thalassiothrix* fragments and *Chaetoceros* spores are consistently observed. The assemblage includes biostratigraphic markers *T. elliptipora*, *Actinocyclus ingens*, *Rouxia leventerae*, and the late form of *Thalassiosira torokina* (Bohaty et al. 1998). There are rare occurrences of older species, such as *Thalassiosira complicata*, *T. inura*, and *Denticulopsis* species, but the concentration of reworked specimens observed in this unit is lower than the previous one. The presence of consistent

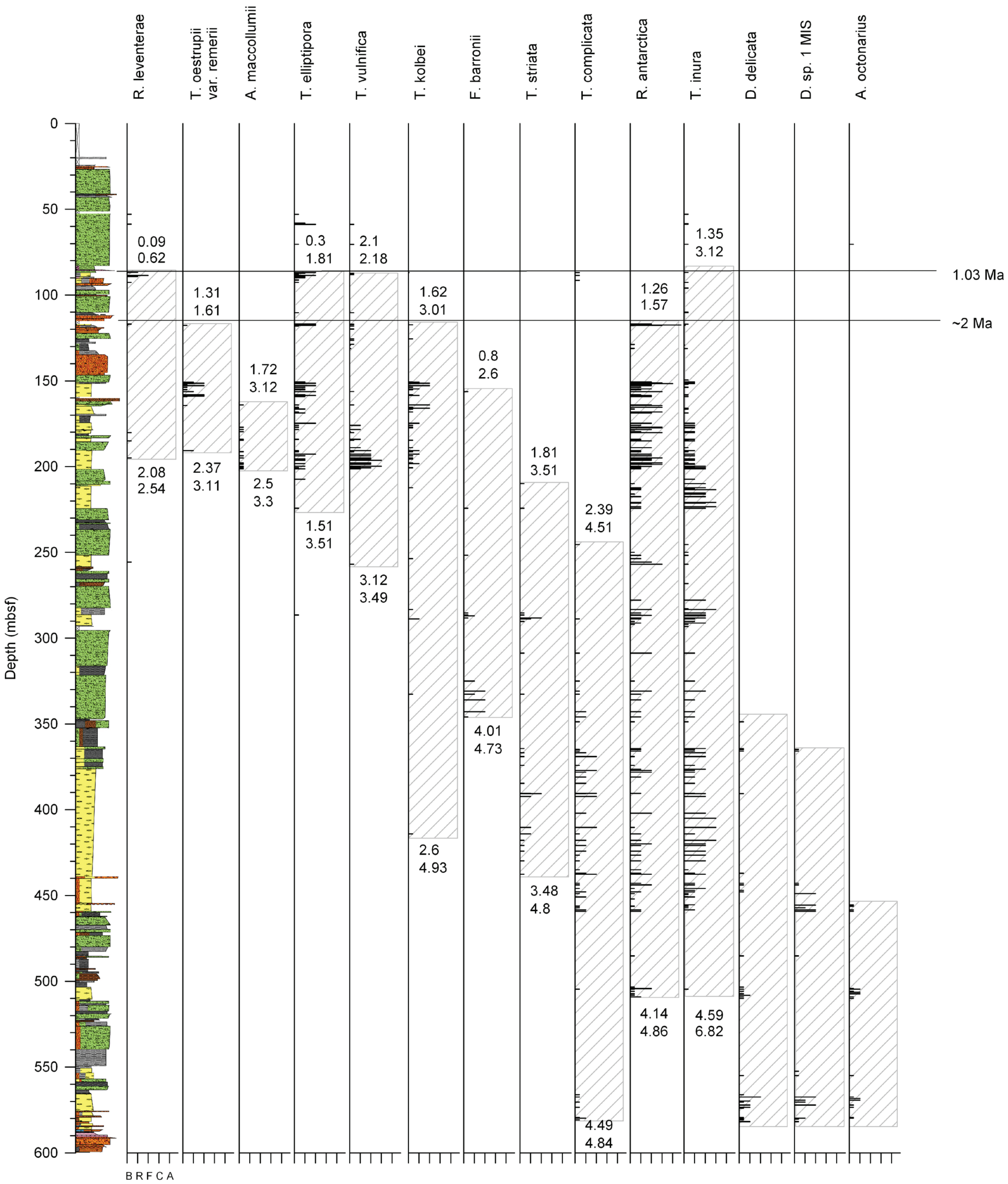


Fig. 7 – Abundance of biostratigraphic and potential biostratigraphic markers are plotted against core log. Shaded box shows the whole range of (confirmed) occurrence of the species in the core. Indicated above and below the box are the last occurrence and first occurrence age ranges based on literature and CONOP (Cody et al. in press). The preliminary ages from $^{40}Ar/^{39}Ar$ dating of volcanic material at ~84 and ~114 mbsf are also shown (G. Wilson et al., this volume).

T. elliptipora in this unit would indicate that it should be placed into the *A. ingens* Zone. The age of this deposit is constrained by an $^{40}Ar/^{39}Ar$ age from a pumice at 85.53–85.85 mbsf as older than 1.03 Ma, and a palaeomagnetic normal interval, interpreted as the Jaramillo Subchron (see G. Wilson et al., this volume), confirming the age of DU-II as the interglacial Marine Isotope Stage 31. Similar to the assemblage reported by Bohaty et al. (1998), this assemblage contains little evidence of a significant summer sea-ice diatom flora. True diatomites of DU-II are restricted to 86.9 to 89.7 mbsf. The remainder of DU-II includes variable diatom abundance with coarse-grained intervals characterised by volcanic sands and episodic redeposited biogenic carbonate.

DU-III: Upper Pliocene 116.75–118.70 mbsf: This thin interval is slightly different from the overlying one in that *A. ingens* is more abundant and

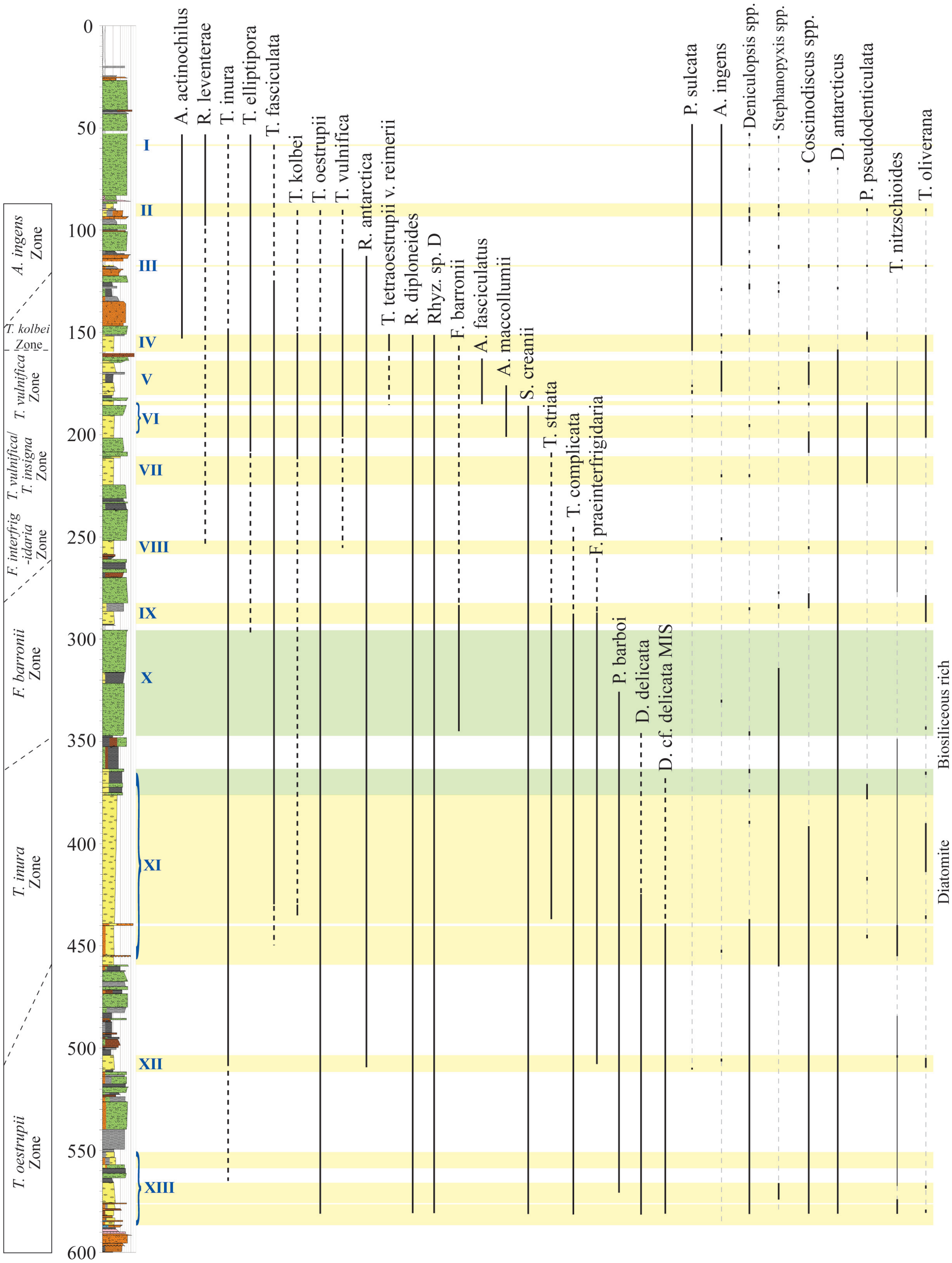


Fig. 8 – Biostratigraphic ranges of useful age-diagnostic diatom species, as well as those with more intermittent occurrences, illustrating variations in the environment and amount of reworking. Roman numerals denote the depth intervals of the diatomaceous units, indicated by the yellow bars. The green bars indicate diatom-rich units that are not diatomites. Solid vertical bars show consistent occurrences of each species; dashed lines illustrate sporadic or rare occurrences. *T. oestrupii* is used *sensu lato* (see text).

is observed consistently in nearly all the samples. The last common occurrence of this species is recorded from other sites around the Antarctic as 0.67 Ma, which provides the upper age limit for this unit. The age of this unit is constrained by the presence of an ash at 114.47–114.51 mbsf with a $^{40/39}$Ar age of approximately 2 Ma (G. Wilson et al., this volume). The assemblage also includes *T. elliptopora*, but in

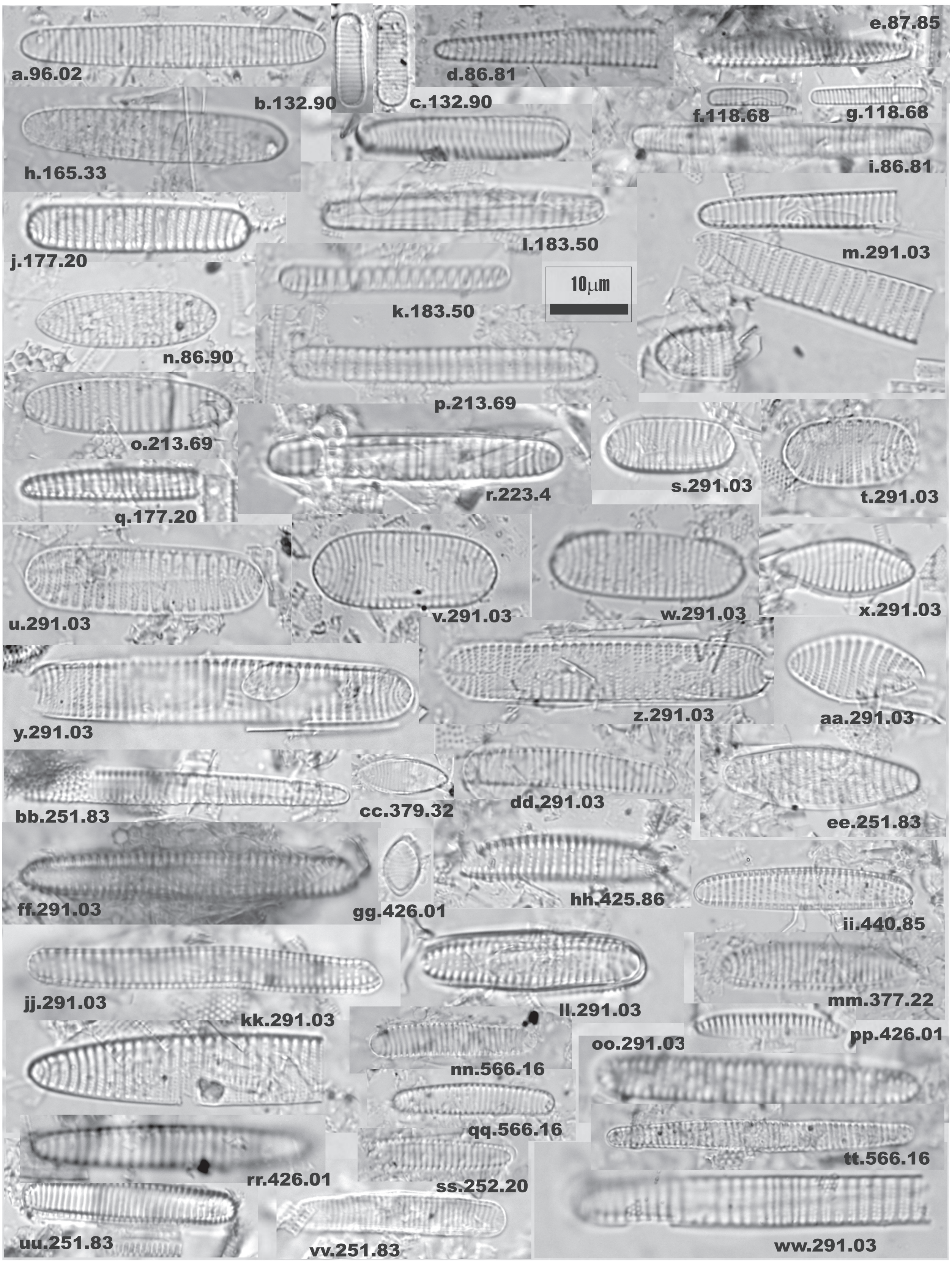


Fig. 9 – Suite of common specimens of *Fragilariopsis* between 86.81 and 566.16 mbsf, illustrating the diversity of morphology. Many of these taxa can be confidently identified to the species level, but there remains a range of intermediate and/or transitional forms, and others that are unknown. We present this plate in the AND-1B Initial Report without identification to the species level or assignment of informal names, pending further study. Labels are depths in metres below seafloor. Scale bar (10 μm) applies to all micrographs.

lower abundance than in DU-II, and *R. leventerae* whose first appearance datum (FAD) is published as 2.08 Ma, providing the oldest possible age for DU-III. There are rare occurrences of *Thalassiosira vulnifica* throughout this unit, ending in the mudstones above the top of the diatomaceous ooze. This assemblage would be placed into the traditional open-ocean *A. ingens* Zone.

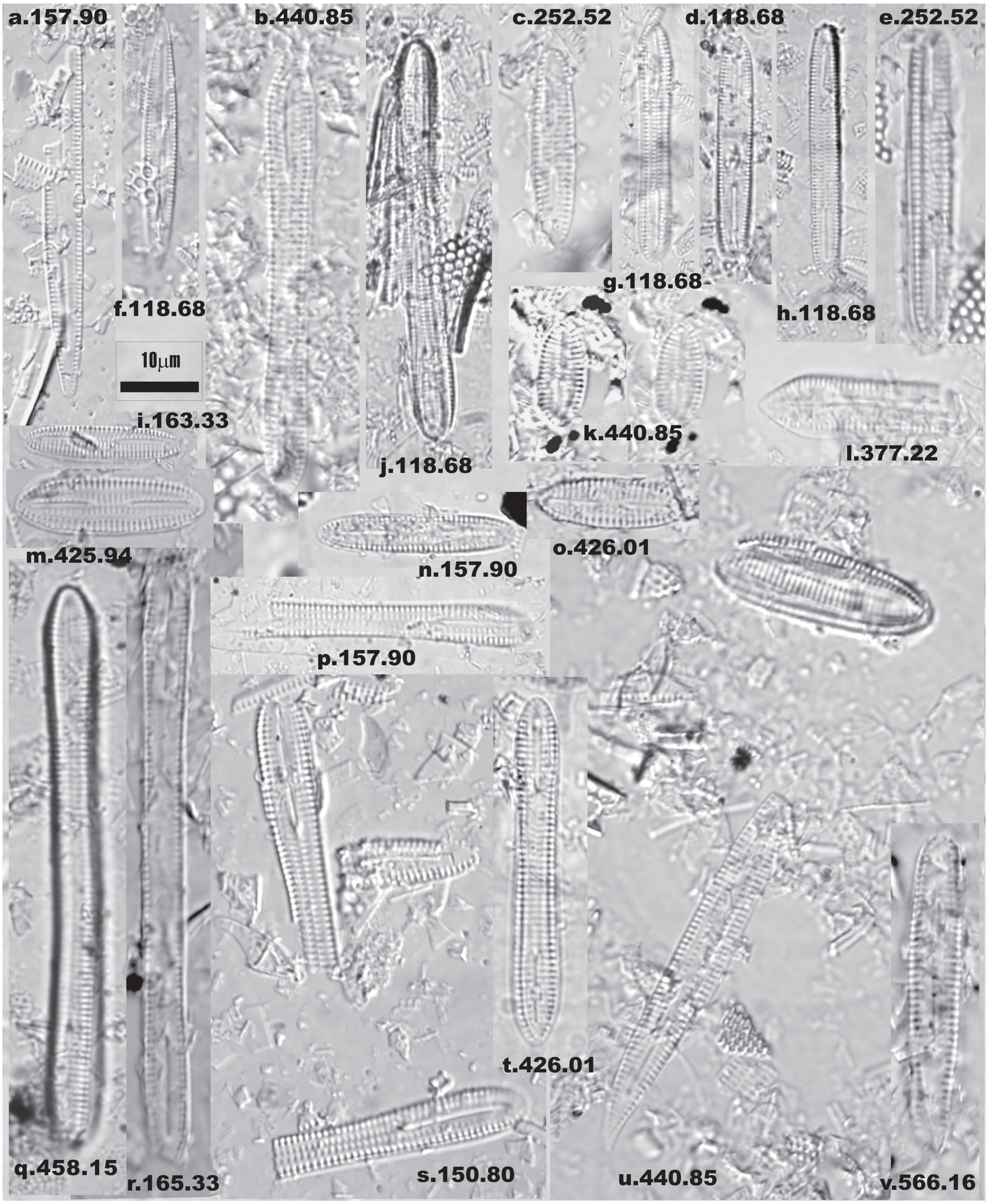


Fig. 10 – Suite of common specimens of *Rouxia* between 118.68 and 566.16 mbsf, illustrating the diversity of morphology. Many of these taxa can be easily identified to the species level, but there remains a range of intermediate and/or transitional forms, and others that are completely unknown. We present this plate in the AND-1B Initial Report without identification to the species level or assignment of informal names, pending further study. Labels are depths in metres below seafloor. Scale bar (10 µm) applies to all micrographs.

DU-IV: Upper Pliocene, 150.87–159.33 mbsf: This interval is separated from the overlying units by a thick diamictite unit. The diatom assemblage in DU-IV differs significantly from the overlying assemblages, suggesting that a considerable unconformity exists above. The assemblage is dominated by diverse *Fragilariopsis* species (Fig. 9), including those indicative of the presence of sea ice, and *Rouxia antarctica* (Fig. 10). *T. elliptipora* is a consistent part of the assemblage but occurs in lower abundances than above. Some species present in the assemblage that support the age range for this unit of 1.46–2.55 Ma are *T. kolbei*, *Rouxia diploneides*, and *T. inura.* One species with a very tight age constraint at other sites is *Thalassiosira tetraoestrupii* var. *reimerii*, whose

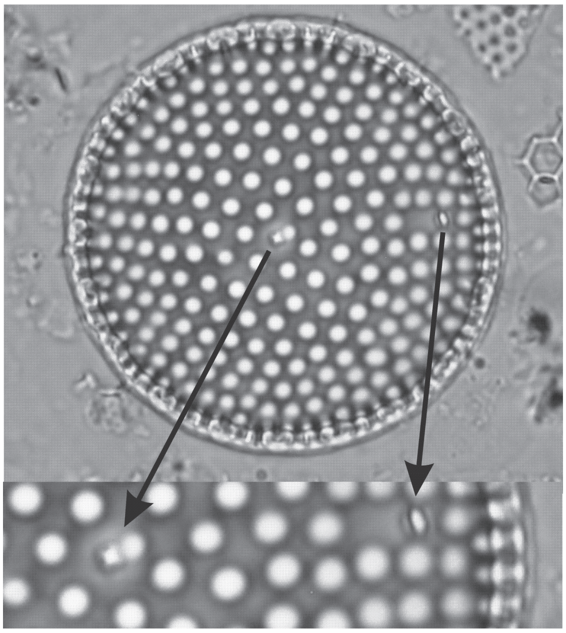


Fig. 11 – Thalassiosira tetraoestrupii, 118.68 mbsf. This unusually robust specimen illustrates that the central strutted process (detail) is quatriporate, accurately identifying *T. tetraoestrupii*. The precise age of the transition from a quadripored process to the tripored process of the modern *T. oestrupii* is unknown because this feature is generally not visible in the light microscope.

occurrence is almost entirely contained within this sedimentary unit. This allows us to use the entire range of this species to define the upper and lower ages for this unit. Reworking of older species is almost non-existent in the samples examined. The tops of *T. kolbei* and *T. inura* at the top of this unit would place it in the *Thalassiosira kolbei* Zone.

DU-V: Upper Pliocene, 164.1–180.73 mbsf: The diatom assemblage in this unit has several species with somewhat short age ranges, both in the genus *Actinocyclus*. They are *Actinocyclus fasciculatus* and *A. maccollumii*, and both have distinct and easily recognisable morphological features. The last appearance of datum (LAD) age of the first of the two is used to define the upper age limit for this unit (2.25 Ma) and the stratigraphic last occurrence (LO) of the second is recorded within this unit at 177.0 mbsf, whose age is reported as 2.54 Ma at other sites. The oldest possible age for this unit is constrained by the first appearance datum (FAD) of *A. maccollumii*, which is 2.9 Ma. This unit is in fact younger than this, as this species is still observed in samples from the underlying diatomaceous package (DU-VI). *Thalassiosira vulnifica* begins to be consistently and more abundantly observed in samples in the lower part of this unit. This species could conservatively have its LO depth in the hole at 176.0 mbsf, which has an age of 2.4 Ma, or it could be placed back at 110.39 mbsf where the last of the consistent rare occurrences were. This will need to be further evaluated. The top of consistent *T. vulnifica* and the presence of *R. diploneides* in the assemblage could place this unit in either the *T. vulnifica* or the *Thalassiosira insigna/vulnifica* Zones.

DU-VI: Mid-Pliocene, 183.42–201.59 mbsf: This unit is a combination of two small diatomite units separated by a diamictite; they are discussed together as the diatom assemblages are very similar in both. The two *Actinocyclus* species mentioned above continue to help define the possible age range for this unit; *A. fasciculatus* does not occur below the base of the small upper diatomite and *A. maccollumii* does not occur below the base of the lower one. The youngest these sediments could be, then, can be defined as the LAD age for *A. maccollumii* (2.54 Ma), which is the older of the two. The oldest possible age for this unit is provided by the FAD age of *T. vulnifica*, which was not observed below the base of this unit, and has an age of 3.12 Ma. *T. elliptipora* continues to be consistently present in this assemblage in scarce and rare abundances, but then disappears, apart from very rare occurrences, in lower samples. As *T. vulnifica* has its base in this hole at the bottom of this sedimentary unit, this diatomaceous unit is placed into the *Thalassiosira insigna/vulnifica* Zone. *R. antarctica* is common in some samples and there are some laminae present within this unit containing *Corethron pennatum*, *Dactyliosolen antarcticus* or *Thalassiothrix antarctica.*

DU-VII: Mid-Pliocene, 209.96–224.44 mbsf: The diatom assemblages present in this unit do not provide a strong age constraint at this time. *Thalassiosira inura* is present in consistent and moderately high abundance and gives us the youngest possible age of 2.37 Ma. This species is also present in equal numbers in the overlying unit, which ties in well with the estimated age for that unit. The definition of the oldest possible age for this unit is provided by the FAD of *Thalassiosira fasciculata*, which is given in the literature as being 4.2 Ma. This datum does not occur within this unit; rather it is the youngest first occurrence among the other species within the assemblage. The *Actinocyclus* species that helped define the age of DU-VI are not present in the assemblage, supporting this older age. As the assemblage in this unit is rather nondescript, and as the age of the unit is constrained by the two species mentioned above and the absence of the ones discussed in DU-VI, this unit conforms with the definition of several Southern Ocean diatom zones: the *Thalassiosira insigna/vulnifica* Zone, the *Fragilariopsis interfrigidaria* Zone, the *Fragilariopsis barronii* Zone.

DU-VIII: Mid-Pliocene, 250.02 – 258.32 mbsf: This unit has an assemblage similar to the overlying one, and has been given the same possible upper and lower age constraints. A non-age-diagnostic difference between this unit and DU-VII is the relative scarcity of *Rhizosolenia* spp., in comparison with the overlying unit; they were not observed in high numbers but were somewhat consistent in their presence above. DU-VIII has been divided out as a separate unit due to the 25 m or so of diamictite and muds between these two. They may actually reflect passing of relatively little geologic time (*e.g.* a Milankovitch-paced glacial-interglacial cycle). This unit has the same open-ocean zonal placement issues as DU-VII.

DU-IX: Mid-Pliocene, 283.35–292.66 mbsf: The species *Fragilariopsis praeinterfrigidaria, F. barronii*, and *Thalassiosira striata* all are consistently observed (*i.e.* LADs) and constitute an important component in the assemblage. Another species has its entire observed range of occurrences within this unit, and serves to provide the upper and lower age constraints for DU-IX. *Fragilariopsis weaverii* occurs between 288.33 and 291.22 mbsf and its published age range is 2.6–3.42 Ma. This species occurs in only scarce and rare abundances, so the entire unit is confined to this age range instead of only the depths in which it is observed. This unit is the lowermost one containing the diverse assemblage of the *Fragilariopsis* complex (Fig. 9); below this the assemblages begin to have higher numbers of species more commonly observed in other sites from around the Antarctic continent. The top of *F. praeinterfrigidaria* and the presence of *F. barronii* place this unit into the *F. barronii* Zone.

DU-X: Lower Pliocene, 295.46–346.94 mbsf: This unit is unique in that it is entirely composed, sedimentologically, of diatom-rich diamictites and muds, rather than true diatomite. Most diamictites down to this point have had reduced assemblages with poor preservation, indicating their reworked nature. Samples from this diamictite have common to abundant diatoms, implying a glacimarine setting. Diatom preservation is always poor to moderate, but the fragmentation is not enough to prohibit identification to the species level. The assemblages appear to be diverse and not just composed of heavily silicified species and fragments. The maximum age definition for this unit of 4.16 Ma is provided by the FAD age of *F. barronii*, which occurs consistently in DU-X. The upper age comes from the LAD age of *Thalassiosira complicata* (3.12 Ma), which is observed in DU-X in low but consistent numbers and was absent from samples in the overlying unit. The base of *F. barronii* at the bottom of this interval places it in the *F. barronii* Zone as well. *Stephanopyxis* spp. are common in this unit and appear to be in place within the assemblage.

DU-XI: Lower Pliocene, 363.37–459.24 mbsf: This unit is the longest of the diatomite units of AND-1B. The upper part is composed of diatom-rich diamictites and mudstones, overlying diatomite that contains a biostratigraphically identical assemblage. This transition may represent the most detailed climatic deterioration preserved in the core. The upper age constraint is provided by the absence of *F. barronii*, which is present in the overlying unit. The oldest possible age is provided by the FAD of *Thalassiosira inura* (5.06 Ma). *T. complicata* is observed throughout this hole, which will greatly increase its FAD age as compared to other published ages and thus makes it unsuitable for use as an age-defining species for any of these lower units. Several species change from being consistently observed to having only rare occurrences in samples towards the base of this unit. The FAD of *Thalassiosira striata* is defined within this unit at 452.25 mbsf. The age given to this event in the literature is 4.5 Ma, which agrees with the stratigraphy of this large diatomite unit. Another FAD occurring within this unit is that of *T. fasciculata* (429.9 mbsf), this species does not currently have a published age reference, so this drill core may be able to provide one for this species. The presence of consistent and abundant *T. inura* through to the bottom of this long interval would place this entire unit in the *T. inura* Zone. *Chaetoceros* species, *Proboscia barboi, Thalassionema nitzschioides*, and *Thalassiothrix* species are common or abundant in some samples. Silicoflagellates, while having a more sporadic and rare occurrence throughout the rest of the drill core, are observed in higher abundances from 364.38 to 453.85 mbsf. This unit likely reflects deposition under notably warmer than present surface waters; conditions that persisted for an extended period of time, likely reflecting at least several contiguous Milankovitch cycles.

DU-XII: Lower Pliocene, 503.42–511.56 mbsf: This diatomite unit is another partially defined by the absence of species present in samples at higher levels but not observed here. *Thalassiosira fasciculata* and *T. striata* are not observed in the DU-XII assemblage. Thus the definition for the uppermost possible age is 4.5 Ma, the FAD of *T. striata*. The FAD of *T. inura* (5.06 Ma) occurs at 507 mbsf. The age for the FAAD of *T. inura* is 4.9 Ma, and this is likely observed at the erosional base of DU XI, but it is also possible that this datum is represented within this unit at 507 mbsf. The oldest possible age for this unit is constrained by the presence of *Thalassiosira oestrupii* whose FAD is defined as 5.7 Ma. Other species observed in the assemblage that are known to co-occur with *T. oestrupii* at other sites are *Actinocyclus octonarius, Thalassiosira oliverana,* and *T. torokina*. *Rouxia antarctica* occurs to the base of this unit, but is not observed below. The FO datum for this species is not known at this time. The absence of *T. fasciculata*, *T. inura* and *T. striata* and the continued occurrence of *T. oestrupii* and *F. praeinterfrigidaria* indicate that this unit may be placed into the *T. oestrupii* Zone. DU-XII is also characterised by the consistent occurence of *Denticulopsis delicata* and a related form.

DU-XIII: Lower Pliocene, 565.67–586.45 mbsf: This, the oldest defined diatomaceous unit in AND-1B, has an assemblage composition similar to the overlying one, but has an older youngest possible age based on the lack of *T. inura* in the assemblage. The age of its FAD is 5.06 Ma. Rare occurrences of *Fragilariopsis praeinterfrigidaria* occur in sample 566.16S. The published age for the FAD of this species is 5.09 Ma, which would seem to correlate well with the youngest possible age for this unit. As mentioned above, *R. antarctica* is not present in the samples from this lower-most unit, but the lack of information regarding the FAD for this species prohibits its biostratigraphic utility at this time. *Chaetoceros* species are rare to abundant throughout this unit while *T. nitzschioides* have higher abundances in the lower part of this unit. *Dactyliozolen antarcticus, E. antarctica, Rouxia diploneides*, and *Stellarima microtrias* increase in abundance from the bottom to the top of this unit. We interpret this unit to be very similar to DU-XII and also place it within the *T. oestrupii* Zone. As with the overlying unit, DU-XIII is also characterised by the consistent occurence of *Denticulopsis delicata* and a related form.

Upper Miocene (?): No diatomaceous units are defined beneath DU-XIII, because diatoms are very rare in the lower 700 m of core in all lithologies. However, the rare occurrences allow some speculative biostratigraphic characterisation. Mudstones barren of diatoms may either reflect an absence of a primary diatomaceous component or removal of diatoms by diagenetic effects. Because the skeletons are made of amorphous silica, they are especially susceptible to the effects of low-grade metamorphism. It is rare for diatoms to be preserved beneath more than *c.* 500 m of sediment, because as the opal-A alters to more crystalline forms (ranging from opal-CT to chert) morphologic detail is lost. Nevertheless, several thin horizons within the lower half of AND-1B were found to contain very poorly preserved remains identifiable as diatoms fragments. Small diatom fragments were recognised in 15 samples, but fewer than five samples contained diatoms that can be even tentatively identified. The occurrences of these are generally in the form of zeolite (?) casts, most of which are unidentifiable. Although pyritised diatoms occur in varying concentrations throughout the core, these too are not present in identifiable form in the lower half of the core.

Diatoms very tentatively identified (Fig. 12) as *Actinocyclus ingens* (FAD 14 Ma), *Denticulopsis dimorpha, D. lauta, D. simonsenii*, and questionable identification of *Thalassiosira oliverana* var. *sparsa* suggest an upper Miocene age. No fragments of the distinctive central area of the easily identifiable, robust, and rather ubiquitous *Thalassiosira torokina* (FAD *c.* 7-8 Ma) have been recognised. These tentative observations provide very weak biostratigraphic arguments, but these constraints, if accurate, indicate an age range of younger than *c.* 13–14 Ma and possibly older than 7–8 Ma. Casts of large (>63 µm) centric diatoms occur, rarely, in foraminiferal preparations down to at least 1050 mbsf. Such large centric diatoms (typically *Coscinodiscus* spp. but impossible to identify here) are generally restricted to open-ocean settings, suggesting that these mudstones were deposited under open-water conditions. Similar diatom-free deposits were described from Miocene sediments of the central Ross Sea, from DSDP site 272 (Hayes & Frakes 1975). These deposits were shown by X-ray diffraction to be rich in cristobalite, a diagenetic product of altered opal.

FUTURE RESEARCH ON AND-1B DIATOMS

REFINEMENT OF THE ANTARCTIC CONTINENTAL SHELF DIATOM BIOSTRATIGRAPHY

AND-1B provides an opportunity to establish a far more detailed Antarctic diatom biostratigraphy than previously possible. Due to the absence of prior recovery of upper Miocene through lower Pleistocene drill core, several taxa previously known from continental shelf and offshore deposits have had unknown stratigraphic ranges. Some of these occurrences are known only from glacially transported diamictons, with an age inference by association with biostratigraphically constrained forms. *Denticulopsis delicata* may be the most notable of these. With the AND-1B core, the first or last occurrences of other taxa previously known from discontinuous Antarctic diamictons or incomplete ranges in drill core can be established. These include the first occurrence of extant taxa *Thalassiosira gracilis* var. *expecta* and *Synedropsis recta*, and the last occurrences of *S. cheethamii* and *S. creanii* (Olney et al. in press a), which had their first occurrences in the Ross Sea during the late Oligocene (Olney et al. in press b). These and other FADs and LADs will be established and well constrained, and a new biozonation for the Antarctic continental shelf will be established during the post-drilling phase.

PALAEOENVIRONMENTAL RECONSTRUCTION

Many parts of the diatomite units contain evidence of bioturbation, but there are numerous sections that preserve fine laminae, indicating reduced mixing by benthic communities. Typically, these laminated intervals comprise alternating layers of moderately diverse diatom assemblages and those with monospecific dominance, though few layers in AND-1B are true monospecific layers. Discrete monospecific layers, which may form mats on the seafloor, are generally interpreted as indicating rapid deposition and high surface water productivity associated with surface-water stratification and seasonal events. Some diatomite units contain relatively abundant ice-rafted detritus (IRD) (*e.g.* DU-II), whereas others (DU-XI) contain little evidence of ice rafting.

A full palaeoenvironmental interpretation must take into account the changes in geography caused

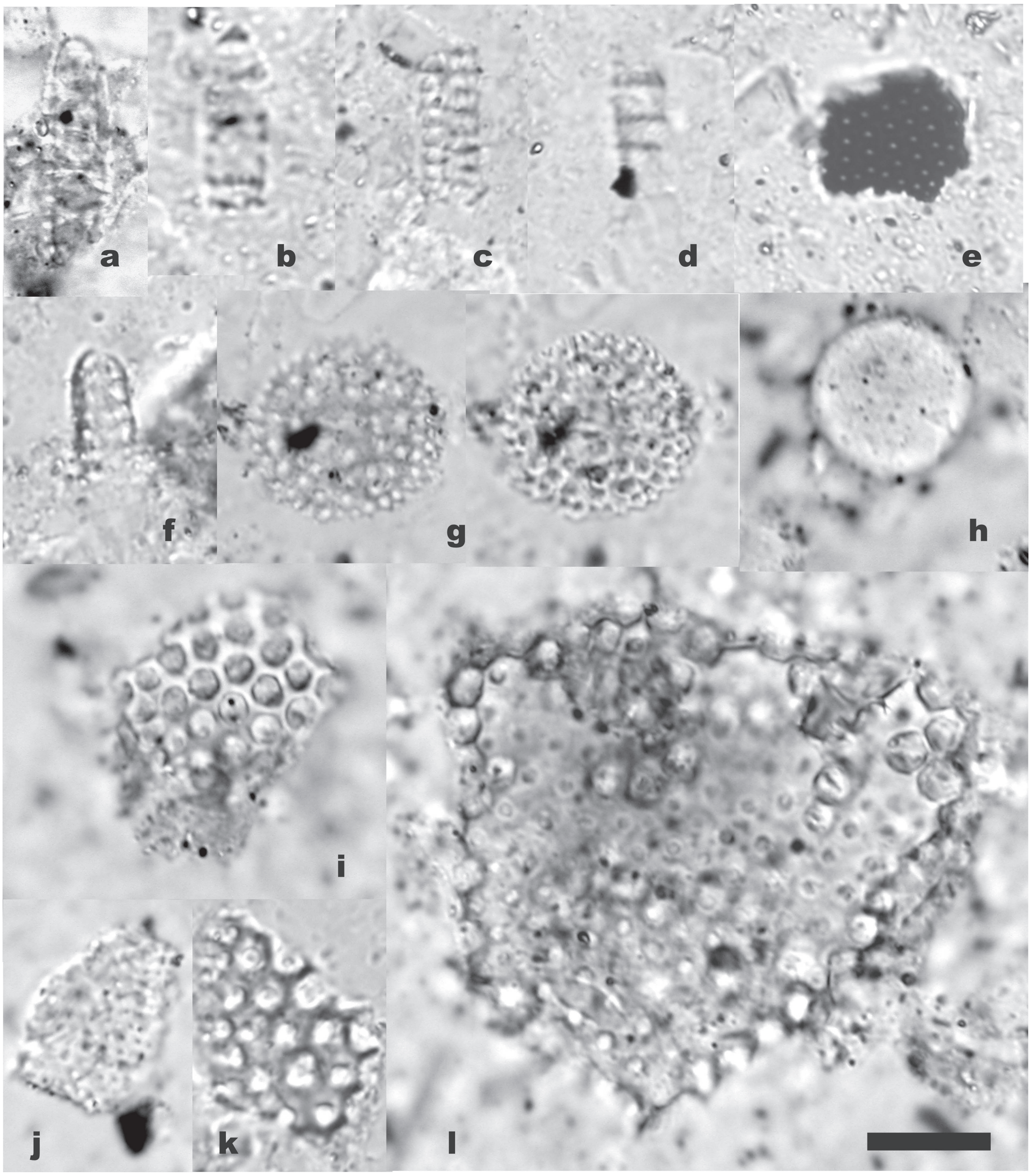


Fig. 12 – Diatoms from the lower 700 m of core. All are recrystallised, but tentative identification is possible for some. (A) *Denticulopsis dimorpha* (?), 810.04 mbsf. (B) *Denticulopsis simonsenii* (?), 981.61 mbsf. (C) *Denticulopsis maccollumii* (?), 981.61 mbsf. (D) *Denticulopsis lauta* (?), 981.61 mbsf. (E) Unidentified pyritised fragment, 880.87 mbsf. (F) *Denticulopsis* (?) 981.61 mbsf. (G) *Actinocyclus ingens* (?), two planes of focus, 981.61 mbsf. (H) Zeolite (?) cast of a small centric diatom, 880.87 mbsf. (I) Diatom fragment, 880.87 mbsf. (J) Diatom fragment, 880.87 mbsf. (K) Diatom fragment, 880.87 mbsf. (L) Diatom fragment, 880.87 mbsf. Scale bar = 10 μm.

by volcanism and the creation of Ross Island. In addition to altering ice-flow patterns during glacial advance, the development of these features would have changed currents and circulation on the shelf during marine phases, and influenced water-mass exchange with the open ocean. Significant in the record is the near absence of redeposited terrestrial diatoms, which suggests that at least the upper 580 m of the AND-1B core was deposited in deep water (> *c.* 100 m) with little direct terrigenous input.

Relative water temperatures and the extent and style of sea ice through time may be inferred from the diatom assemblages. Figure 13 shows the stratigraphic distribution of selected taxa, and figure 14 shows the temperature range documented for extant species. The initial diatom record is grouped into environmental assemblages, calibrated to modern ecological constraints: (1) sea-ice-related taxa, (2) cold open-water taxa and (3) cool-temperate open-water taxa. Results are presented in figure 15 as a ternary diagram. We acknowledge that taxonomy and environmental constraints may have changed from the Pliocene to the Recent, so this diagram should be viewed as indicative of more general trends

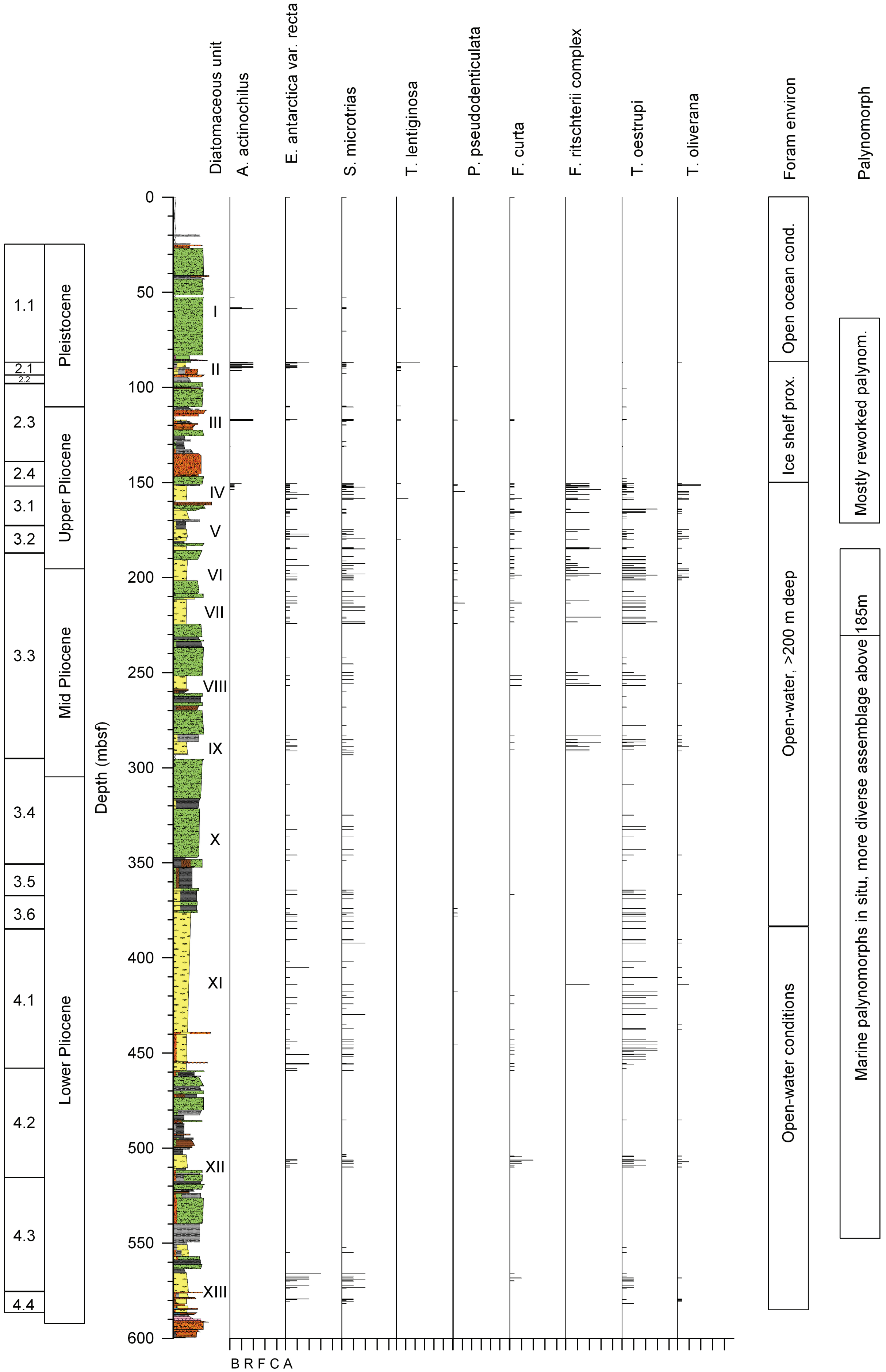


Fig. 13 – Abundance of important diatom species as environmental indicators, indicating a shift from cold to warm water masses in association with a disconformity at 150 mbsf. *T. oestrupii* is identified *sensu lato* (see text).

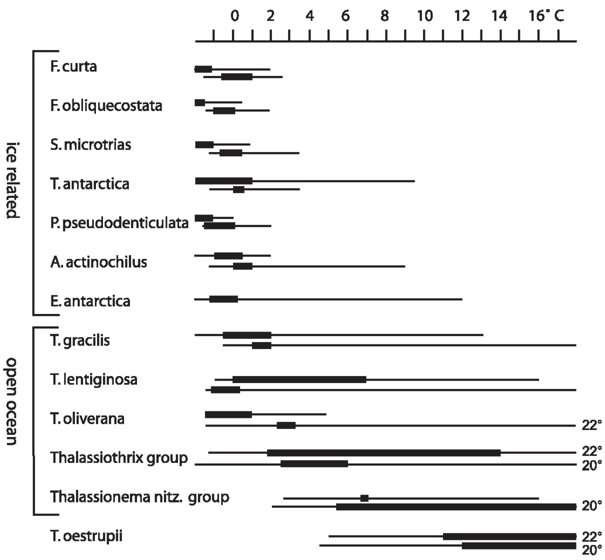


Fig. 14 – Compilation of sea surface temperature (SST) data for key diatoms species represented in the AND-1 cores including push core (PU) and gravity core (GC). The heavy lines show the temperature of seawater where the maximum occurrence of diatom species in the underlying sediment; the thin lines indicate the temperature range where species are encountered. The species are grouped according to environment: ice related, open ocean, and subtropical (*T. oestrupii*). References used are Zielinski & Gersonde (1997), Armand et al. (2005), Crosta et al. (2005) & Romero et al. (2005). Note that mosta taxa related to *T. oestrupii* in AND-1B are the ancestral *T. tetraoestrupii sensu lato* (see text).

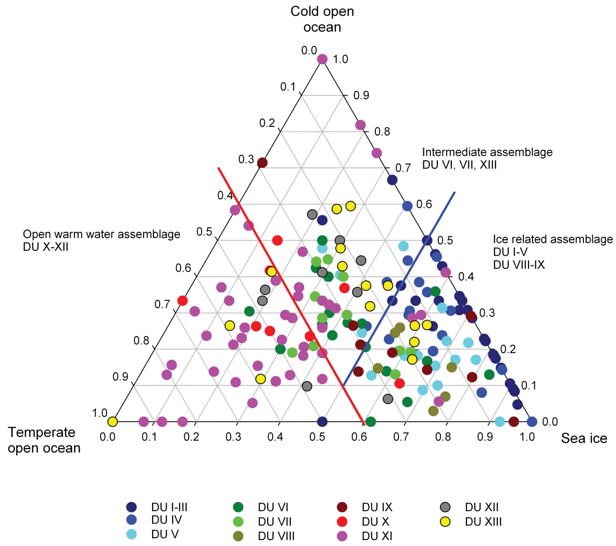


Fig. 15 – Ternary diagram showing the environmental trends of the 13 diatomaceous units, on the basis of occurrences of environmentally constrained extant taxa. Diatoms are classified as related to sea ice, cold open water, or cool-temperate water. The diagram indicates a transition from cold to warm back to cold conditions, but also environmental change within diatom units. Tentative lines are drawn in the diagram to separate the different assemblages. Included in sea-ice assemblage are *A. actinochilus, F. curta, F. obliquecostata, F. ritscherii complex, E. antarctica,* and *P. pseudodenticulata*; the temperate to subpolar open-water assemblage includes *T. nitzschioides* and *T. oestrupii*; the cold open water includes *S. microtrias, T. gracilis, Coscinodiscus* spp., *Rhizosolenia* spp., *Thalassiothrix antarctica* and *Thalassiosira antarctica*. We acknowledge that some taxa have evolved from the Pliocene to the Recent (notably *T. oestrupii/tetraoestrupii* and certain *Fragilariopsis* spp.), so this plot should be considered as providing tentative and broad interpretations.

than as a quantitative transfer function. The plot indicates a transition from a sea-ice characterised environment to an assemblage indicative of cooler, more temperate conditions, with DU-XI indicating the warmest conditions and the lowest concentration of sea-ice related taxa.

Detailed analyses of community structure, palaeoproductivity, genesis, and oceanographic significance of laminated diatomites, and sediment accumulation rates are possible, as well as analysis of glacial-interglacial and interglacial-glacial transitions. Other palaeoenvironmental goals include analysis of Milankovitch-paced diatom assemblage changes, and tracing sea-ice proxies, both in the diatom assemblages and in diatom-bound nitrogen isotopes. Studies of stratigraphic mixing and provenance of diatoms in diamictite, following Sjunneskog & Scherer (2005), are also worthy of detailed investigation during the post-drilling phase.

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