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Palaeontological Characterisation and Analysis of the AND-2A Core, ANDRILL Southern McMurdo Sound Project, Antarctica

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Abstract – The palaeontological yield of the 1138.54 metre-long AND-2A sedimentary rock core provides unique documentation of Neogene environments in the Ross Sea region of Antarctica. Especially important is the biological legacy of the climatically crucial 'mild' middle Miocene phase. Diatom-bearing units provide key information for stratigraphic intervals never previously recovered from locations proximal to the Antarctic continent and constrain the age model for the AND-2A core. Benthic calcareous (and agglutinated) foraminifera were present at many levels; remarkable is the occurrence of planktonic taxa only seldom found in the Neogene nearshore record of the Ross Sea region. The sporadic occurrence of calcareous dinoflagellate remains (thoracosphaerids) is consistent with warmer-than-present seawater during the Miocene. Marine palynomorphs are almost ubiquitous, although their abundance and diversity are variable. Pollen and spores from the middle Miocene section suggest a mossy tundra vegetation and represent the first stratigraphically-constrained record of terrestrial vegetation in Victoria Land during this time. Fragments of lignin-rich organic matter (huminite-vitrinite and inertinite groups) are particularly predominant during the Miocene climatic optimum, and continue into the Pliocene. Macrofossils are reasonably common throughout the core. Polychaete worm tubes ~~were almost ubiquitous~~. Especially remarkable is the bivalve record (mainly pectinids), with 4-5 different taxa pointing out a mild climatic situation in the Miocene nearshore.

INTRODUCTION

Drilling operations for the Southern McMurdo Sound (SMS) Project were conducted in the austral spring 2007 to recover the AND-2A core at 77°44.27'.76"S and 165°17'18.24"E. This core comprises 1138.54 metres of various types of sedimentary rocks with some volcanics encompassing lower Miocene to Quaternary successions (Fielding et al., Fig. 1, pp.78-89, this volume; Acton et al., this volume, b).

The Core Characterisation Phase of the SMS Project was conducted by an on-ice Palaeontology Team that included seven specialists of taxonomic groups of recognised biostratigraphic and environmental utility in the Antarctic Cenozoic, and an off-ice team who produced results reported herein after the drilling phase was completed. The palaeontologic record of the AND-2A core is highly remarkable in terms of quality and quantity of fossils, with over 1200 samples collected on-ice, including those for off-ice specialists. The on-ice treatment of such a large set of samples was possible through the collaborative work of additional SMS on-ice personnel (J. Carnes, R. Frisch-Gleason, J. Hamre, L. Jovane, K. Mankhoff, K. Pound, J. Reed, E. Strada, P.-N. Webb, and R. Williams). It is worth mentioning the important role provided by using thin-sections (Fig. 2) to identify fossils in the AND-2A core, that were otherwise undetectable through visual inspection or washing; these on-ice thin sections were provided by S. Petrushak. Sample aliquots from intervals of presumptive critical palaeoclimatic significance were

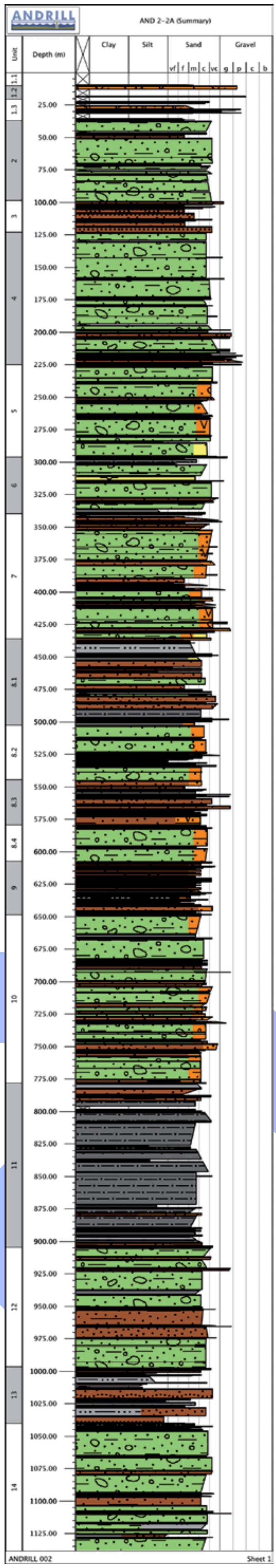


Fig. 1 - Lithostratigraphic log of the AND-2A drillcore (from Fielding et al., this volume).

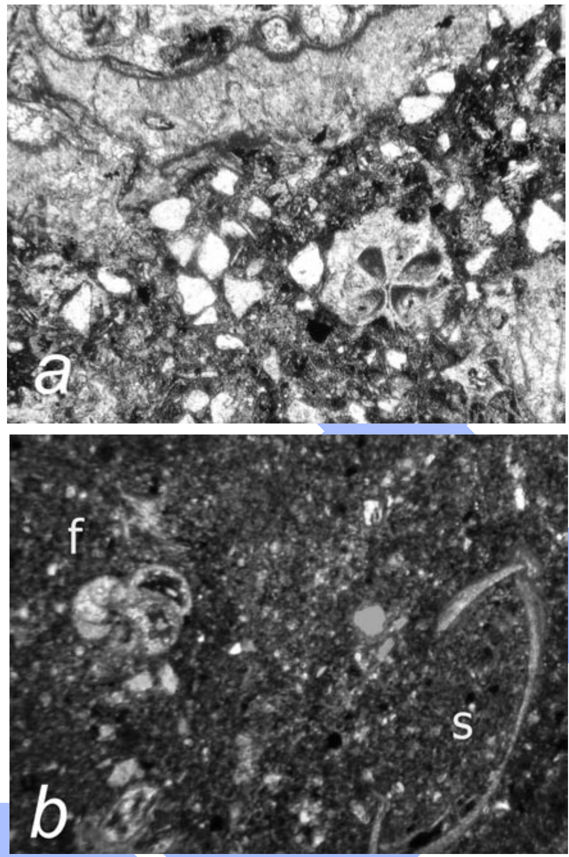


Fig. 2 - Thin sections showing calcareous fossils in the AND-2A drillcore from a carbonate-rich unit within LSU 4 at 377.71 mbsf (x20); (a) various biogenic allochems; (b) deformed polychaete tube 's' and recrystallized benthic foraminifer 'f'.

distributed among the palaeontologists in order to achieve a more comprehensive view of the Neogene palaeobiota.

Major issues to which palaeontology contributes an independent and often unique view are biostratigraphy (dating) and palaeoenvironments. Equally important is the contribution of palaeontology in supplying, whenever possible, suitable material for isotopic dating (in the specific case of AND-2A, Sr isotopes on carbonates), and diagenetic- and palaeoclimatic-oriented studies.

The present contribution follows the style of similar reports from drillcores in Southern Victoria Land (Cape Roberts Science Team 1998, 1999, 2000; Naish et al., 2007) and has been arranged in the following subsections: Marine diatoms and other siliceous microfossils, Calcareous nannofossils, Calcareous and agglutinated foraminifera, Marine and terrestrial organic-walled fossils, Terrestrial lignin-rich organic-walled fossils, and Macrofossils. Although highly innovative and promising, microbial studies related to AND-2A sediments and fluids conducted by M. Lenczewski and colleagues are not included here, since they are still in progress and unavailable at this stage of the core characterisation. Additionally, TEX_{86} palaeotemperature studies by F. Sangiorgi are not included here, see the "Explanatory Notes" section (Florindo et al., this volume) for procedures and promise of this approach.

citing Fielding pp. 78-89 figure 1 can be omitted and gives space for a "summary" of table 5.

Information presented herein is intended as the basic palaeontologic characterization of the AND-2A drillcore, thus the interpretation of data is deliberately limited, as the data are still developing. Depths in core are expressed as metres below seafloor (mbsf).

MARINE DIATOMS AND OTHER SILICEOUS MICROFOSSILS

GENERAL

Biosiliceous microfossils in the AND-2A core are sparse. Sponge spicules comprise a large fraction of the biosiliceous component. Diatoms are generally rare but occur in high abundance and moderately diverse assemblages in short intervals of the core (Fig. 3). Ebridians, silicoflagellates and other siliceous microfossils are also present, but generally rare to absent. Intervals containing useful diatom assemblages occur between 47.00-48.24 mbsf, 225.38-312.02 mbsf, 430.26-432.34 mbsf, 536.42-546.06 mbsf, and 736.20-771.50 mbsf.

Overall, preservation of the biosiliceous material is good. Fragmentation is moderate to high. As in the MIS Project AND-1B core (Scherer et al., 2007), the level of fragmentation is comparable across all morphologies, implying compaction rather than shearing or grazing is responsible for the fragmentation (Scherer et al., 2004). There is little to no sign of significant dissolution or diagenetic alteration of the biosiliceous microfossils, even beyond the generally accepted (expected) ~600 mbsf depth level, at which point alteration and diagenetic processes rendered siliceous microfossils unworkable in previous nearshore Antarctic drillcores. Indeed, fragments of reasonably well-preserved diatom specimens were found down to 1120.94 mbsf (Fig. 3).

METHODS

Biostratigraphic analyses were performed on smear slides mounted with Norland optical adhesive #61 (refractive index = 1.56). Slides are labelled AND-2-2A and specific depth in mbsf. Diatom identifications were carried out using Olympus CH-2, Olympus BH-2, Zeiss travelling and Leica Laborlux S transmitted light microscopes.

Total slide abundance assessments were made from smear slides at 788x using the Zeiss travelling microscope by the on-ice diatom team and ARISE (ANDRILL Research Immersion for Science Educators) Program participants K. Mankoff and K. Pound (see Huffman et al., this volume). A rubric with the categorical system used to determine values in figure 3 is presented below:

Total slide abundance
A = abundant (>10 valves per field-of-view)
C = common (≥ 1 valve per field-of-view)
F = few (≥1 valve in at least every 5 fields-of-view)
R = rare (≥1 valve per twenty fields-of-view)
X = present (≥ 1 fragment per twenty fields-of-view)
B = barren (no fragments observed in twenty fields-of-view)

Slide preparation and examination for on-ice biostratigraphy and assemblage assessment was carried out in the Crary Science and Engineering Centre (CSEC) at 400x, 600x and 1000x (oil-immersion objective) magnification. Diatom datum and zonal boundaries were then constrained using detailed smear-slide sample intervals at ~1 m increments, where possible. Samples with rare to common overall abundance of diatoms were either disaggregated in distilled water, or processed with hydrogen peroxide and 10% hydrochloric acid. Strewn slides were prepared from the samples, and when necessary, the cleaned material was also sieved at >20 micrometres (μm) to improve recovery of identifiable, more complete, diatom specimens. The slides were systematically scanned, and qualitative diatom occurrence data were collected, to be presented in subsequent reports. The abundance of individual diatom taxa was based on the number of specimens observed per field of view at 400x, 600x, and 1 000x and recorded as follows:
A = abundant (>10 valves per field-of-view)
C = common (1–10 valves per field-of-view)
F = few (≥1 valve per 10 fields-of-view and <1 valve per field-of-view)
R = rare (≥3 valves per traverse of coverslip and <1 valve per 10 fields-of-view)
X = present (<3 valves per traverse of coverslip, incl. an appearance as fragments)
B = barren (no diatoms observed in one traverse of a 40 millimetre coverslip)

Preservation of diatoms was determined qualitatively, both in terms of dissolution and fragmentation, and reported as follows:
G = good (slight to no fragmentation or dissolution)
M = moderate (moderate fragmentation or dissolution)
P = poor (severe effects of fragmentation or dissolution)

DISTRIBUTION IN CORE

Total diatom abundance and species richness bar charts are presented against the lithological log in figure 3. Diatom occurrence is grouped into 9 units (designated by Roman numerals I to IX) based on inferred ages, preservation/abundance, and relative depths. A summary of palaeoenvironmental inferences drawn from the diatom data alongside the lithological log and the inferred age of each unit based on Cody et al. (2008) and Olney et al. (2007) are given in figure 4. Light micrograph images of representative diatom taxa are presented in figure 5, and figure 6 provides a summary occurrence chart of key diatom taxa in the AND-2A core. Diatom events utilized for

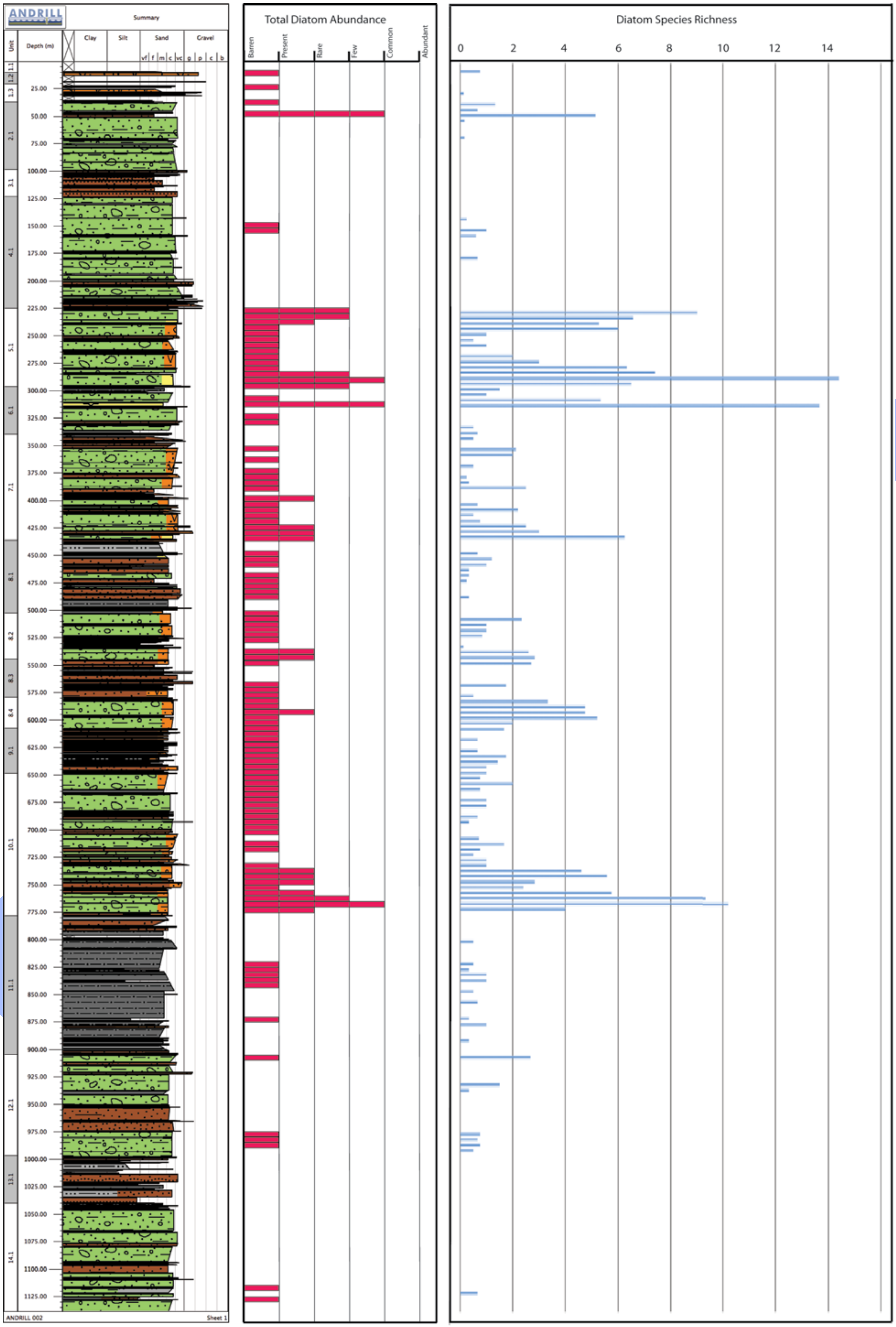


Fig. 3 - Total diatom abundance and diatom species richness bar charts generated from averages over five meter bins, plotted against the lithological log at the left. Species richness values are for the number of species and several informal species groups, thus these numbers are probably an underestimate of the true species richness.

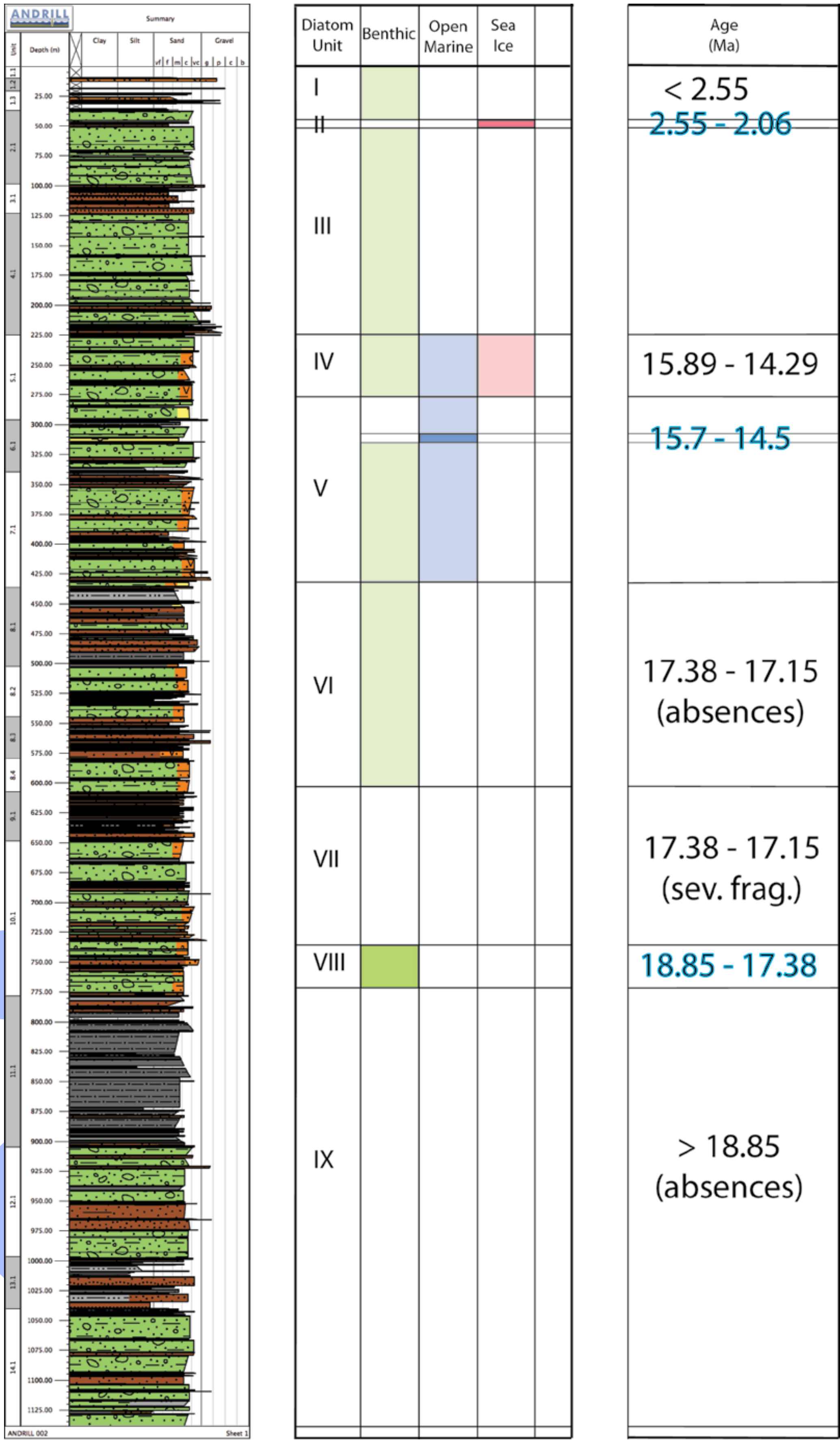


Fig. 4 - Diatom units, their assigned ages and palaeoenvironmental interpretations displayed against the lithological log. Ages in lighter tones (*e.g.*, 2.55 – 2.06 Ma) are considered to be more reliable than the ages associated with "absences", which indicates an age assignment based entirely or almost entirely on absences rather than occurrences. the abbreviation "sev. frag" indicates a zone of severe fragmentation of diatom remains. The central column - Palaeoenvironmental interpretation - is presented in terms of major influences; lighter shades indicate zones of limited evidence, while deeper shades indicate zones of more certain paleoenvironmental interpretation.

Tab. 1 - Diatom events utilized for biostratigraphic interpretation of the AND-2A drillcore in bold. All ages are from the average age model of Cody et al. (2008) unless indicated by an asterisk (*) where sources include Harwood et al. (1999), Scherer et al. (2001) and Olney et al. (2007). Diatom age ranges are further discussed in the chronostratigraphy chapter (Acton et al., this volume). FO = First Occurrence; LO = Last Occurrence; FCO = First Common Occurrence.

Datum	*Species*	*Depth (mbsf)*	*CONOP age (average min)*	*CONOP age (average max)*	*Published age (min)*	*Published age (max)*
LO	*T. elliptipora*	47.00	0.64	0.71	0.3	1.18
FO	*T. elliptipora*	48.22	2.00	2.06	1.07	3.51
LO	*T. vulnifica*	44.06	2.15	2.19	0.6	3.1
LO	*T. torokina*	45.05	2.20	2.27	1.88	2.18
LO	*A. maccollumii*	47.00	2.40	2.45	1.81	2.91
LO	*T. inura*	47.00	2.53	2.55	1.88	3.1
FO	*A. maccollumii*	48.24	2.79	2.84	2.5	3.3
FO	*T. vulnifica*	49.83	3.12	3.18	2.2	3.51
FO	*T. inura*	49.78	4.71	4.77	4.8	6.83
FO	*T. torokina*	49.78	6.43	8.03	8.56	10.07
LO	*D. lauta sensu latu*	234.15	12.46	13.73	9.53	-
LO	*D. maccollumii*	225.38	14.29	14.36	12.32	14.36
LO	*N. sp. 17 Schrader*	310.1 or ~ 225? on fig 6	15.50	15.52	-	-
FO	*D. lauta sensu latu*	312.03	15.67	15.70	15.79	-
FO	*A. ingens*	278.55 or ~310? on fig. 6	15.89	15.89	15.79	-
FO	*D. maccollumii*	432.34 or ~300? on fig 6	16.87	17.15	16.34	16.91
FO	*N. sp. 17 Schrader*	431.98	16.35	17.15	-	-
LO	*T. praefraga*	736.20	17.38	17.88	15.96	18.17
LO	*T. nansenii*1*	763.84	-	-	17.50	-
FO	*T. praefraga*	771.50	18.68	18.85	19.37	21.81
FO	*A. octonarius2*	432.34	17.89	19.20	-	-
FO	*T. nansenii**	770.50	-	-	24.98	-
FCO	*R. fidicularis*3*	741.30	-	-	20.30	-

1. Very rare occurrences (?) to 738.2 mbsf
2. Very rare occurrences (?) from 604.84 mbsf
3. Taxon identification tentative; single specimen identified

this initial reporting (ages from Cody et al., 2008; Harwood et al., 1999; Scherer et al., 2001; Olney et al., 2007 are given in table 1.

UNIT I (44.06 mbsf to top of section): Late Pliocene to Recent (< 2.55 Ma)

Thirty-five samples were examined between 44.06 to 0.0mbsf. Lithologies include volcanic-rich sedimentary rocks and lava. The lower 6 metres is a diamictite with minor sandstone, conglomerate and clayey siltstone. Diatoms occur at abundances of less than 3 specimens per traverse of a 40 mm coverslip, and are not considered indicative of an *in-situ* assemblage. No age-diagnostic taxa were noted. The presence of *Paralia sulcata* and a single fragment of *Cocconeis fasciolata* may indicate a shallow water (<100 m depth) environment, but any interpretation based on such sparse occurrences is tentative at best.

UNIT II (50.50-44.06 mbsf): Late Pliocene (2.55-2.06 Ma)

Fifteen smear and strewn slides were examined from this interval, which is dominated by diamictite. Productive diatom-bearing samples were taken from reddish-colored, wispy, clayey siltstone laminae within clast-poor, greenish grey, sandy diamictite between 47.00 and 48.24 mbsf. Two relatively rich diatomaceous intervals (at 47.00 mbsf and between 48.20-48.24 mbsf) contain comparatively diverse and unfragmented assemblages, including several age diagnostic taxa: *Actinocyclus maccollumii* (age range of 2.4-2.84 Ma), *Thalassiosira elliptipora* (0.64-2.06 Ma), *Thalassiosira vulnifica* (2.15-3.18 Ma), *Thalassiosira inura* (2.53-4.77 Ma), and a taxon tentatively identified as *Rouxia diploneides* (2.55-4.7 Ma). The deeper interval was identified for diatom sampling by on-ice geochemist G. Kuhn after initial examination of the on-ice XRF data, which showed a similar combination of geochemical peaks at 47.00 mbsf and 48.20-48.24 mbsf. The ability to recognize diatomaceous intervals from XRF data is a useful tool in searching for these intervals within thick diamictite units that often lack visual clues to the occurrence of siliceous microfossil-bearing intervals.

The age assignment for the diatomaceous interval between 47.00 and 48.24 mbsf is based on the total range of *A. maccollumii* (2.84 to 2.4 Ma), and further restricted by the occurrence of diatoms with useful last appearance datum ages (LAD) - *R. diploneides* (2.55 Ma), *T. vulnifica* (2.15 Ma), and *T. inura* (2.53 Ma). These constraints combined with consideration of the absence of older mid- and early Pliocene diatoms *F. praeinterfrigidaria, F. interfrigidaria, F. weaveri, F. praecurta and*

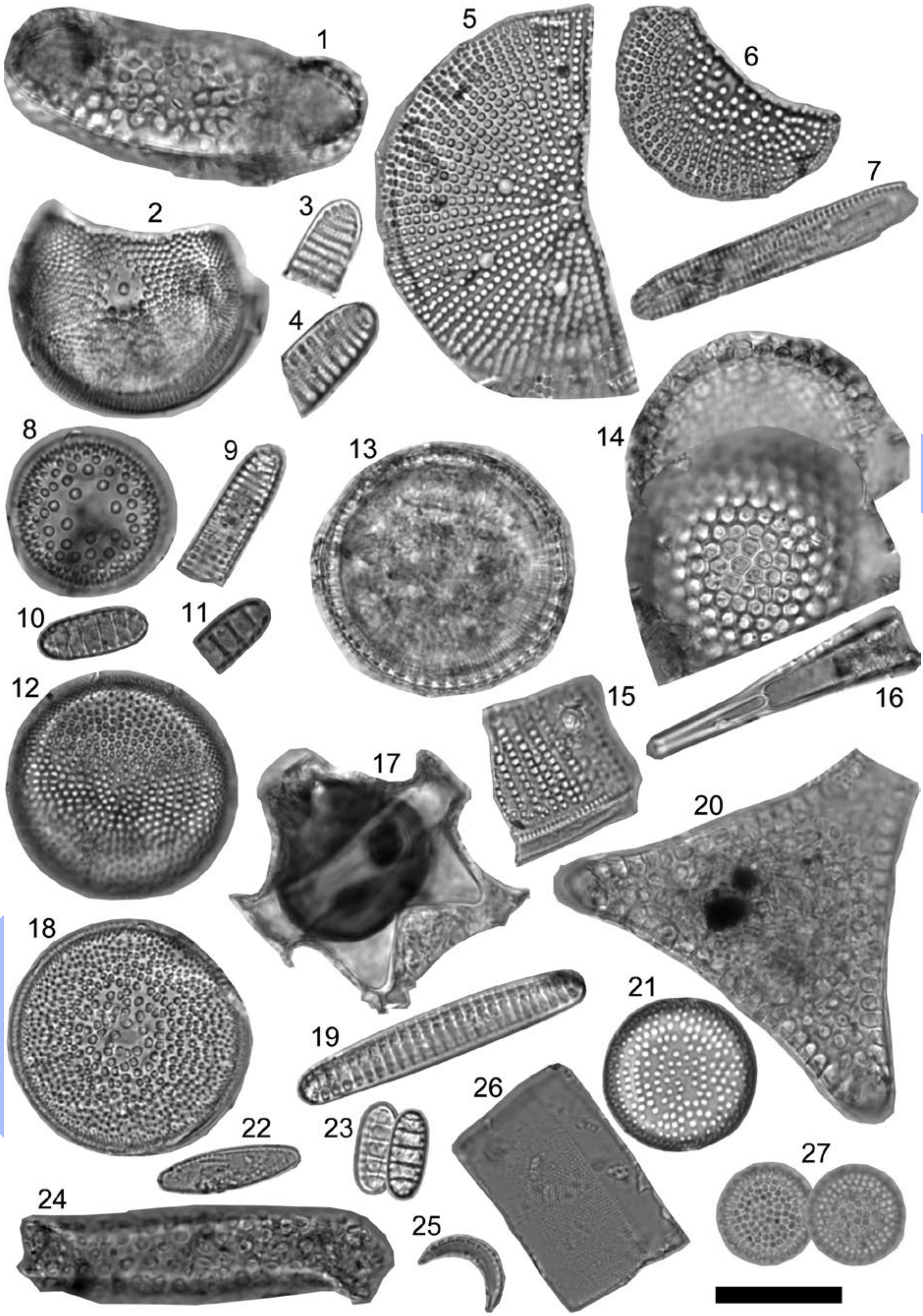


Fig. 5 - Light microscope images of representative diatoms from the AND 2-2A drillcore, scale bar = 10 μm. Photomicrographs 1-7 are from sample depth 47.00 mbsf; 8 is from 234.15 mbsf; 9 and 12 are from 236.32 mbsf; 10-11 are from 235.35 mbsf; 13-16 are from 294.58-59 mbsf; 17-21 are from 310.43-44 mbsf; 22-23 are from 311.43 mbsf; 24-26 are from 431.44 mbsf; and 27 is from 763.84 mbsf. 1: Eucampia Antarctica; 2: Thalassiosira inura; 3-4: Fragilariopsis sp. fragments; 5: Thalassiosira vulnifica fragment; 6: Actinocyclus sp. fragment; 7: Rouxia sp.; 8: Actinocyclus ingens; 9: Nitzschia sp. 17 Schrader fragment; 10-11: Denticulopsis lauta s.l.; 12: Actinocyclus sp.; 13: Paralia sulcata; 14: Eustephanius sp. at two focal levels; 15: Aulacodiscus browneii; 16: Rhizosolenia sp.; 17: Resting spore cf. Dicladia capreola; 18: Actinocyclus sp.; 19: Denticulopsis maccollumii; 20: Trinacria sp.; 21: Actinocyclus sp.; 22: Synedropsis cheethamii; 23: Denticulopsis dimorpha at two depths; 24: Eucampia antarctica var. twista; 25: Dactyliosolen antarcticus; 26: Endictya sp. fragment; 27: Thalassiosira praefraga at two focal levels.

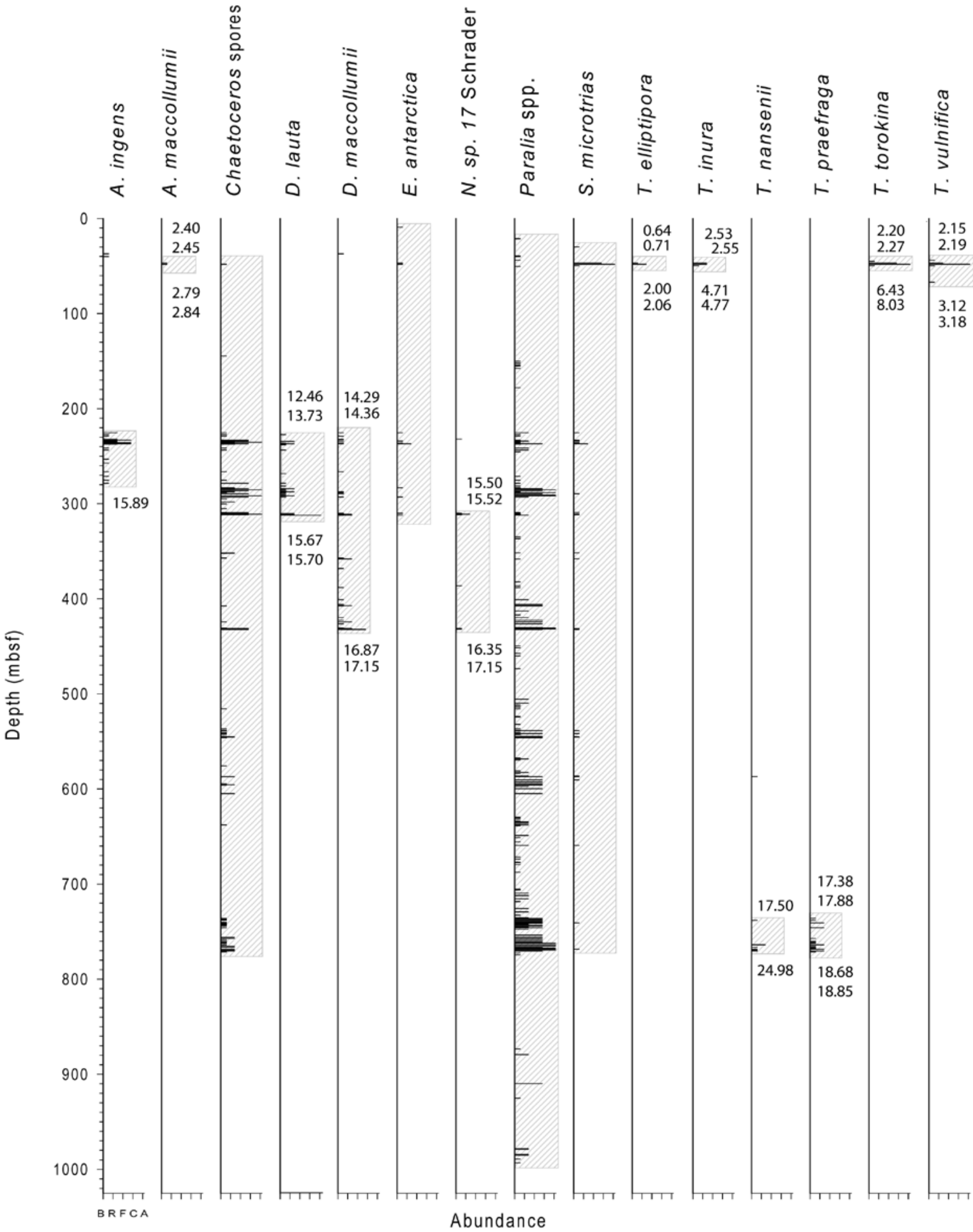


Fig. 6. Abundance of key diatom biostratigraphic marker taxa plotted against depth in the AND-2A drillcore. Shaded boxes show the range occurrences of these species in the entire core. First and last occurrences of some species are indicated above and below the boxes. Ages are from Cody et al. (2008).

T. complicata suggests that this interval of reversed polarity (Acton et al., this volume, a) is equivalent to Chron C2r.2r.

The diatom assemblage also includes *Stellarima microtrias, Eucampia antarctica* and several *Fragilariopsis* species, and is likely indicative of a sea-ice influenced palaeoenvironment during the late Pliocene.

UNIT III (224.82-50.50 mbsf): Late Miocene to Early Pliocene?

One-hundred-forty-three samples were examined in this interval. Lithology varies from diamictite with minor sandstone, conglomerate and clayey siltstone to planar bedded sandstone and conglomerate. No age-diagnostic taxa are recognizable and most samples are barren. Only extremely rare fragments of diatoms were observed. Identifiable taxa include *Paralia* spp. and stephanopyxids , along with occasional very small fragments of *Actinocyclus* spp. The presence of these taxa possibly indicates a source in shallow water-neritic environment, but the paucity of biosiliceous material makes any interpretation extremely tentative.

UNIT IV (278.55-224.82 mbsf): Middle Miocene to Late Miocene (15.89-14.29 Ma)

Thirty samples were examined from this unit, which is composed of diamictite with biogenic silica, sandstone and minor conglomerate, and siltstone.

The first appearance of *Actinocyclus ingens* (15.89 Ma) at 278.55 mbsf, and the last appearances of *Denticulopsis maccollumii* (14.29 Ma) at 225.38 mbsf and *D. lauta s.l.* (LAD 12.46 Ma) at 234.15 mbsf provide and age between 15.89–14.29 Ma for this interval.

A diverse assemblage also includes diatoms *A. octonarius, Chaetoceros* resting spores, *Coscinodiscus* spp., *Denticulopsis* spp., *Denticulopsis lauta s.l., Eucampia antarctica, Grammatophora* sp., *Paralia* spp., *Rhizosolenia* spp., *Stephanonycites variegatus*, *Stellarima microtrias*, *Thalassionema* spp., *Thalassiothrix* spp., *Trinacria* spp., ebridians and silicoflagellates. This mixture of open marine, possibly sea-ice indicative and nearshore taxa is difficult to interpret in terms of palaeoenvironment and may indicate reworking from a range of local sources.

UNIT V (432.34-278.55 mbsf): Middle Miocene (15.7 - 14.5 Ma)

One-hundred-thirty-two samples were examined from this interval, which comprises a mixture of lithologies, including diamictite with biogenic silica, sandstone and minor conglomerate, siltstone, claystone, diatomite, and volcanic-bearing diamictite. Between 278.55 and 310.02 mbsf a relatively diverse diatom assemblage occurs in clast-poor muddy and sandy diamictite. The interval from 310.02 – 312.12 mbsf is a diatomite to silt-bearing diatomite. From 312.12 to 430.26 mbsf diatoms are mostly absent from mainly volcanic-bearing, clast-rich diamictite and sandstone. From 430.26 – 432.34 mbsf diversity and abundance of diatoms increases in biosiliceous/volcanic bearing clast-poor diamictite.

The diatomite and silt-bearing diatomite between 310.02 and 312.12 mbsf contains an assemblage of age-diagnostic taxa. Overlapping ranges of first occurrence (FO) of *Denticulopsis lauta s.l.* at 312.03 mbsf (FAD 15.7 Ma) and last occurrence (LO) of *Nitzschia* sp. 17 *sensu* Schrader (1976) at 310.10 mbsf (LAD 15.5 Ma) suggest a tight age control of ~200,000 years for this diatomite interval, between 15.7 to 15.5 Ma).

The diatom-bearing clast-poor diamictite between 430.26 – 432.34 mbsf contains a mixed and probably locally reworked assemblage indicative of a number of palaeoenvironments including productive open marine (*Actinocyclus octonarius, Actinocyclus* spp., *Coscinodiscus marginatus, Coscinodiscus* spp., *Dactyliosolen antarcticus, Denticulopsis maccollumii*, *Denticulopsis* spp., *Nitzschia* sp. 17 of Schrader (1976); *Rhizosolenia* spp., and *Thalassionema* spp.), nearshore/benthic (*Chaetoceros* resting spores, *Paralia sulcata, Stephanonycites* spp., *Grammatophora* spp., and sponge spicules), and sea-ice (*Stellarima microtrias*). The first occurrences of diatoms *Denticulopsis maccollumi* at 432.34 mbsf and *Nitzschia* sp. 17 at 431.98 mbsf (both FAD 17.15 Ma) indicate an age younger than 17.15 Ma at ~432 mbsf.

Macro-fossiliferous sandstone intervals at 351, 357 and 377 mbsf containing *in situ* pectinid bivalves were examined, and the sediments infilling the bivalves contained a moderately diverse assemblage of diatoms including: *Cocconeis* spp., *Trinacria* spp., *Denticulopsis maccollumii*, and *Stellarima microtrias*. The observation of *Eucampia antarctica* and *Eucampia antarctica* var. *twista* within this interval may require the extension of the current FAD of this taxon from the late Miocene into the middle Miocene, as previously suggested by Harwood et al. (1989).

UNITS VI and VII (736.20 - 432.34 mbsf): Early Miocene (17.38 – 17.15 Ma)

Two-hundred-eleven samples were examined from these two intervals, which are dominated by volcanic bearing mudstone, diamictite, and sandstone with some conglomerate.

Age control is provided primarily by absence constraints rather than occurrences; it represents an interval between the LO of *Thalassiosira praefraga* at 736.20 mbsf (LAD 17.38 Ma) up to the first occurrences of *Denticulopsis maccollumii* and *Nitzschia* sp. 17 suggests an age between 17.38 to 17.15 Ma.

Between 432.34 and 460.20 mbsf diatom abundance is low. The few species present include benthic taxa (*Grammatophora* sp., *Rhabdonema* sp.), suggesting shallow water depths in which the photic zone extended to the sea floor (<100 m). The interval between 536.42 – 546.06 mbsf includes a diverse flora that may indicate a productive (*Chaetoceros* resting spores) shallow water-neritic environment (*Stephanopyxis* spp., *Paralia sulcata*). The lower 100 metres of this interval comprises volcanic bearing diamictite, sandstone and sandy mudstone, and volcanic bearing sandstone and siltstone, which are either barren or contain only fragmented specimens. Here, the assemblages are severely fragmented, hampering diatom identification to species level, thus no palaeoenvironmental interpretation is possible for this lower interval.

UNIT VIII (771.50-736.20 mbsf): Early Miocene (18.85-17.38 Ma)

Thirty-five samples were examined in this interval, which comprises volcanic-bearing diamictite to biosiliceous/volcanic-bearing diamictite. Diatom abundance is generally greater than one valve per 5 fields of view. This Unit is inclusive of the range of *Thalassiosira praefraga* from 771.50 up to 736.20 mbsf, which constrains the age of this unit between 18.85 Ma and 17.38 Ma. The occurrence at abundances of less than 1 valve per field of view of *Thalassiosira nansenii* between 763.84 - 770.50 mbsf supports an age older than 17.5 Ma below 763.84 mbsf, based on the observations of Harwood et al. (1999) from the CRP-1 drillhole.

This Unit contains a moderately diverse assemblage (26 species or species groups identified) including *T. praefraga*, *T. nansenii*, *Thalassionema* spp. and *Coscinodiscus* spp., which indicate open marine conditions. The occurrence of diverse and rare (greater than 1 valve per twenty fields of view) *Chaetoceros* resting spores may indicate relatively productive marine conditions.

The well-preserved diatom assemblage at this great depth in the core is surprising, it is well below the depth at which opal-A is commonly altered to opal C-T. The persistence of volcanic glass throughout the core may provide a buffer of dissolved silica in the pore water to enhance diatom preservation (Panter et al., this volume).

UNIT VII (1138.54 - 771.50 mbsf): Early Miocene (> 18.85 Ma)

One hundred seventy-five samples were examined in this interval, which comprises lithologies of volcanic-bearing diamictite, sandstone, and sandy mudstone, sandy siltstone, sandstone with and without dispersed clasts, fine siltstone and diamictite with sandstone. In general, diatoms are absent from this interval. The deepest interval containing recognizable diatom fragments and rare, complete valves of *Stephanopyxis* spp. and *Paralia* spp., is at a depth of 1 120.94 mbsf.

Diatom-based age control is inferred from the absences of *Thalassiosira praefraga* (FAD 18.85 Ma) and *Kisseleviella tricoronata*, *Hemiaulus angustobrachiatus* and *Stephanonycites* sp. A of Olney et al. (2007) with LADs at ~22.24 Ma based on strontium and argon derived dates in the CRP-2/2A drillcore. These observations indicate an age range between 18.85 Ma and 22.24 Ma, but the lack of age diagnostic taxa and probable environmental exclusion within this interval makes our assignment tentative.

SUMMARY

The AND-2A core contains a unique biosiliceous microfossil record of the early Miocene to late Pliocene. This preliminary investigation recognised diatom-bearing units that will provide key information for new stratigraphic intervals from locations proximal to the Antarctic continent. Overlapping stratigraphic intervals with other diatom-bearing drillcores such as CRP-1 (Harwood et al., 1999), CRP-2/2A (Scherer et al., 2001) and AND 1-1B (Scherer et al., 2007) will provide a means of further advancing our regional understanding of diatom biochronology and paleoecology, which will be the focus of future research. Diatom biostratigraphy provided significant input to the age m[illegible] for the AND-2A drillhole (Acton et al., this volume) and guided all initial on-ice age assignments, which were subsequently confirmed and refined by radiometric dating. Palaeoenvironmental interpretations have thus far been limited to broad generalizations. Future analysis (particularly taxonomic), utilizing more labor-intensive sample preparation techniques and additional sampling, will allow further refinement of the on-ice biostratigraphy and palaeoenvironmental interpretation.

CALCAREOUS NANNOFOSSILS

GENERAL

Samples from the AND-2A core for the study of calcareous nannofossils were taken approximately every two meters, and smear-slides were prepared and examined on-ice. Additional samples submitted for inspection to off-ice investigator A. Di Stefano proved to be unproductive. Off-ice examination of smear-slides consisted of scanning at 1250x in approximately 200 fields-of-view. On- and off-ice smear-slide analysis did not yield coccolithophores (with the exception of three intervals of reworked Cretaceous taxa), discoasters, or other calcareous nannofossils. However, calcareous dinoflagellates and other calcareous microfossils are found to occur with rare to common abundance.

THORACOSPHAERA AND CALCISPONGES

Calcareous dinocysts of the genus *Thoracosphaera* were recorded in 35 samples from the approximately 400 examined (Tab. 2). Several productive horizons were recognized within this stratigraphic sequence and appear to be related to lithology and $CaCO_3$ concentration (as estimated from sedimentology smear-slides).

DISTRIBUTION IN CORE

LSU I (44.06 - 0.0 mbsf)

Nine samples were examined from this Lithostratigraphic Unit (LSU). Calcareous dinoflagellate fragments, as well as calcareous spicules, were noted in four samples (<9.02, 9.35, 20.57, and 39.89 mbsf), all in rare abundance.

LSU V (432.34 - 278.55 mbsf)

From this interval, 42 samples were examined and 12 samples yielded calcareous microfossils. Productive samples were concentrated between 281 to 321 mbsf and consist of calcareous dinocyst fragments that probably belong to *Thoracosphaera saxea* and *Thoracosphaera heimi*.

LSU VII (736.20 - 604.84 mbsf)

Calcareous dinoflagellates were observed in seven of the 25 samples examined within this interval. *T.*

Tab. 2 – Distribution of calcareous dinoflagellates and reworked nannofossil material in the AND-2A drillcore. Symbols as follows: T = Thoracosphaerid material; REW = Reworked nannofossil material.

Sample Depth (mbsf)	*LSU*	*Micro-fossil*	*Comments*
<9.02	I	T	Fragments
9.35-9.36	I	T	Fragments
20.57-20.58	I	T	Fragments
39.89-39.90	I	T	Fragments
48.20-48.21	II	T	Fragments
48.24-48.25	II	T	Fragments
65.65-65.66	III	T	Fragments
66.80-66.81	III	T	Fragments
67.47-67.48	III	T	Fragments
112.36-112.37	III	T	Fragments
114.00-114.01	III	T	Fragments
155.72-155.73	III	T	Fragments
157.56-157.57	III	T	Fragments
274.18-274.19	IV	T	Fragments
276.54-276.55	IV	T	Fragments
281.34-281.35	V	T	Fragments
292.63-292.64	V	T	Fragments
296.46-296.47	V	T	Fragments
310.99-311.00	V	T	Fragments
315.08-315.09	V	T	Fragments
317.95-317.96	V	T	Fragments
319.95-319.96	V	T	Fragments
320.96-320.97	V	T	Fragments
372.24-372.25	V	T	Fragments
377.74-377.75	V	T	Fragments
501.22-501.23	VI	T	Fragments/Whole Specimens
501.83-501.84	VI	T	Fragments
613.82-613.83	VII	T	Fragments
626.16-626.17	VII	T	Fragments
660.70-660.71	VII	T	Fragments
667.66-667.67	VII	REW	Cretaceous material
671.17-671.18	VII	T	Fragments/Whole Specimens
681.45-681.46	VII	T	Fragments/Whole Specimens
688.51-688.52	VII	T	Fragments
791.42-791.43	IX	T	Fragments
906.42-906.43	IX	REW	Cretaceous material
923.34-923.35	IX	REW	Cretaceous material

saxea and *T. heimi* dinocyst fragments were noted. In addition, two complete specimens of potentially undescribed species were observed at 671.16 and 681.46 mbsf. Their affiliation is questionable as they lack the typical shape of modern calcareous dinocysts.

PALAEOENVIRONMENTAL IMPLICATIONS

Previous drilling projects within the Ross Sea noted that thoracosphaerid abundance and preservation often correlated with warm or abnormal surface water conditions (Villa & Wise 1998; Watkins & Villa 2000; Watkins et al., 2001). In the AND-2A drillcore, calcareous dinoflagellate remains are concentrated in intervals interpreted from other proxies (microfossil, macrofossil, and lithology) of warmer surface water conditions, supporting this interpretation and their use as an indicator of warm surface waters.

CALCAREOUS FORAMINIFERA

GENERAL

A total of 462 sediment samples from the AND-2A core were collected on-ice for S. Ishman and K. Johnson (on-ice foraminiferal core characterisation), A. Asioli (off-ice agglutinated foraminifera) and F. Lirer and M. Sprovieri (off-ice planktonic foraminifera and foraminiferal stable isotopic analysis). Supplementary table S1 providing foraminifera occurrence data is available on-line at the Terra Antartica website www.mna.it/english/Publications/TAP/terranta.html and the SMS Project science drive http://www.andrill.org. These and other SMS Project data will be available to the broader scientific community at the end of the SMS Project data moratorium period.

Samples of ~20 cc volume were collected for foraminiferal analyses. Additional samples of varying volume were provided by on-ice palaeontologist M. Taviani as residues from samples collected for macrofossil analysis and as 'fast-track' samples. Of these, 459 samples were committed for calcareous benthic and planktonic foraminiferal analyses with 261 samples examined on-ice and the balance of 198 samples shipped off-ice to F. Lirer and M. Sprovieri. On-ice processing was scheduled in phases, dependent on the depth and lithification of the sediments.

All on-ice samples were first weighed. Loosely consolidated samples in the upper ~ 120 mbsf of the core were manually disaggregated into pebble-size particles or smaller and soaked in a 5% calgon solution for 24 hours. Samples between 122 and ~140 mbsf were soaked for 24 hrs in 3% H_2O_2 and boiled for 5 minutes to disaggregate the sediment before sieving. Samples from approximately 140 mbsf and below were broken into small pebble-size fragments using a Carver Press, followed by gentle breaking with a mortar and pestle. The disaggregated samples from both processes were sieved over nested sieves of 63 µm and 38 µm mesh size. Residues from the two size fractions were collected and dried at <50°C. To achieve the goal of core characterisation, the on-ice ≥63 µm size fraction was split using a microsplitter to a 1/8th sample size, which was examined to determine the presence/absence of foraminifera. To date, 377 sample splits have been examined for foraminifera, with 219 samples producing foraminifera from at least 24 taxonomic groups. Foraminifera were recovered from all Lithostratigraphic units (LSU) except LSU 1, 10 and 13. Abundance and preservation vary; greatest abundance and diversity was noted in LSU 7. Estimates were made on their relative abundance per split using the following criteria: 1-2 very rare; 3-5 rare; 6-15 common; and >15 abundant.

Foraminifera were noted in thin-sections prepared for M. Taviani and K. Bassett from the following sample intervals: 48.95 - 48.97, 136.44 - 136.47, 251.48 - 251.51, 351.51 - 351.59, 355.22 - 355.24, 377.61 - 377.69, 377.71 - 377.73, 377.92 - 377.95, 413.35 - 413.38, 420.38 - 420.41, 423.94 - 423.96, 444.32 - 444.35, and 575.60 - 575.62 mbsf.

REMARKS

Foraminiferal occurrences in the AND-2A drillcore are described from the 165 sample splits examined for foraminifera. The remaining sample residues, from those splits already examined and the remaining samples, will be picked post-drilling for a more comprehensive foraminiferal evaluation of the core. The data reported below includes foraminiferal occurrences by LSU. It also includes state of preservation through visual estimation of the foraminifera as defined in Strong and Webb (2000):

Good – Test microstructure unaltered or little altered, pores clearly visible, chambers may be unfilled.

Fair – Test microstructure altered, minor to moderate recrystallization may be visible, some decortication and corrosion of test material, secondary infilling of chambers by calcite or clay commonly present.

Poor – Test microstructure strongly altered to unrecognizable, extensively recrystallized or decorticated, may be preserved as steinkern only, test broken or distorted.

DISTRIBUTION IN CORE

A total of 24 taxonomic groups of foraminifera were identified from 48 sample intervals within the AND-2A core. These include both planktonic and calcareous benthic foraminifera. Two agglutinated taxa were picked but not identified (at 232.40-232.43 and 430.41-430.48 mbsf). Diversity per sample ranged from 1 to 10 taxa. Preservation ranged from Good to Poor. The planktonic foraminiferal taxa include *Neogloboquadrina pachyderma*, *Antarcticella* sp. cf. *A. antarctica* and *Globorotalia* sp. Commonly calcareous benthic taxa include *Globocassidulina subglobosa, Nonionella* spp., *Cassidulinoides porrectus, Fursenkoina* sp. and *Ammoelphidiella* spp., among others.

LSU 1.1 - 1.3

1.1 Mixed volcanic and sedimentary rock

1.2 Volcanic: basaltic and monomictic lava breccia

1.3 Volcanic sedimentary rock

Two samples collected from 0 to 28.70 mbsf contained foraminifera: 10.14 - 10.16 and 28.13 - 28.15mbsf. Foraminifera in these samples were very rare but preservation was good.

LSU 2

Diamictite with interbedded sandstone, siltstone, and conglomerate

Foraminifera were present with good preservation in samples from the intervals 49.21 - 49.23, 49.89 - 49.91, 55.18 - 55.19, 61.87 - 61.89, 64.74 - 64.76, 66.98 - 67.00, 68.72 - 68.74, 73.09 - 77.11, 83.76 - 83.80, 84.56 - 84.58, and 98.09 - 98.11 mbsf. This LSU contained both planktonic and benthic foraminifera. The planktonic foraminifera are represented by *Neogloboquadrina pachyderma* and *Antarcticella* sp. and occur primarily in sample interval 49.89 - 49.91 mbsf, but also occur in interval 83.76 - 83.80 mbsf. These samples represent the first and last occurrences of *N. pachyderma* in core 2-2A indicating a maximum age for the base of LSU 2.1 at ~11.05 million years (m.y.). The benthic foraminiferal assemblage is comprised of 5 taxa, the most common being *Cassidulinoides porrectus.* Other distinguishing taxa within LSU 2 are *Ehrenbergina glabra* and *Cassidulinoides parkerianus*, which is restricted to this unit. *Ammoelphidiella* sp. also occurs in this unit. If this taxon is identified as *Ammoelphidiella onyxi* it would indicate a Pliocene age for LSU 2.

LSU 3

Planar-bedded sandstone and conglomerate

Five samples from LSU 3 were examined for foraminifera with 3 samples, 107.18 -1 07.20, 110.26 - 110.28, and 116.04 - 116.06 mbsf, bearing 2 taxa. Benthic foraminifera present are *C. porrectus* and *Quinqueloculina* sp. and are fair in their preservation.

LSU 4

Diamictite with conglomerate, sandstone and silt-stone

Eighteen sample intervals from LSU 4 contained foraminifera: 123.34-123.36, 137.09-137.11, 140.03-140.05, 144.18-144.20, 150.48-150.50, 156.09-156.11, 157.44-157.46, 158.75-158.77, 161.68-161.70, 167.60-167.62, 170.48-170.50, 178.19-178.21, 196.60-196.62, 201.35-201.37, 205.18-205.20, 209.61-209.63, 213.07-213.09, and 223.95-223.97 mbsf. Preservation is fair to poor. The number of benthic foraminiferal taxa occurring within LSU 4 is three, *Globocassidulina subglobosa,* Ellipsolagenidae, and *Alabaminella weddellensis,* with no planktonic foraminifera observed.

LSU 5

Diamictite with sandstone and minor siltstone

Thirty-seven samples from LSU 5 were examined for foraminifera with 19 intervals producing foraminifera: 226.85-226.87, 228.43-228.45, 229.40-229.43, 232.40-232.43, 234.80-234.83, 236.39-236.42, 240.75-240.78, 250.31-250.34, 258.08-258.11, 259.68-259.71, 264.22-264.26, 265.47-265.50, 272.04-272.07, 277.53-277.57, 285.64-285.66, 287.87-287.90, 290.22-290.25, 292.23-292.26, and 294.21-294.24 mbsf. Preservation is poor to fair. A total of 8 calcareous benthic foraminifera taxa occur in LSU 5 that include *Nonionella* spp., *G. subglobosa,* *Fursenkoina* sp., *Pullenia* sp., *C. porrectus* (oldest occurrence in AND-2A is within LSU 5), *Epistominella exigua* (restricted to this LSU) and *Pyrgo* sp.

LSU 6

Diamictite with conglomerate, sandstone, and siltstone

Two out of 17 sample intervals examined from the uppermost part of LSU 6.1 produced foraminifera with poor preservation: 298.92 - 298.95 and 305.14 - 305.17 mbsf. Four taxa of calcareous benthic foraminifera are represented by *Nonionella* spp., *Elphidium* spp., *Fursenkoina* sp. and *G. subglobosa*. This is the youngest occurrence of *Elphidium* spp. in AND-2A.

LSU 7

Volcanic-bearing diamictite with volcanic-bearing sandstone

Fourteen out of 33 sample intervals from LSU 7 produced foraminifera: 351.71-351.74, 353.76-353.79, 357.87-357.90, 365.51-365.53, 365.92-365.95, 370.94-370.97, 377.25-377.30, 377.49-377.52, 377.92-377.95, 384.98-385.01, 392.96-392.99, 429.16-429.20, 429.64-429.73, and 430.41-430.48 mbsf. This unit included the most productive intervals of the core, 377.25-377.30 and 377.49-377.52 mbsf with 63 and 34 specimens, respectively. This unit also had the greatest foraminiferal taxonomic diversity with 13 taxa present including planktonic *Globorotalia* sp. It also produced a single specimen of Ostracoda. Calcareous benthic taxa present include *Nonionella* spp., *Ammoelphidiella* spp., *Elphidium* spp. and *Cibicides lobatulus*, and the oldest occurrence of *Cibicides* sp., *Melonis* sp., *Fissurina* sp., *Anommalinoides* sp., *Fursenkoina* sp., *G. subglobosa*, *Pullenia* sp. and *Gyroidina* sp. Preservation in LSU 7 is poor to good with some specimens replaced and infilled with secondary calcite.

LSU 8.1

Volcanic-bearing mudstone with/without dispersed clasts, sandstone, conglomerate and diamictite

One out of 10 sample intervals from LSU 8.1 yielded a single poorly preserved foraminifer at 494.15-494.19 mbsf.

LSU 8.2

Volcanic-bearing diamictite, mudstone with/without dispersed clasts, and sandstone

No foraminifera were recovered from the 4 sample intervals examined.

LSU 8.3

Volcanic-bearing sandstone, conglomerate, mudstone with dispersed clasts, and diamictite

Three out of 5 sample intervals examined from LSU 8.3 yielded foraminifera: 569.21 - 569.23, 577.15 - 577.18, and 579.31 - 579.34 mbsf. Three calcareous benthic foraminiferal taxa are present that include *Nonionella* spp., *Ammoelphidiella* spp. and Buliminacea. Preservation is poor.

LSU 8.4

Volcanic-bearing diamictite, siltstone, sandstone, and conglomerate

Two out of 12 sample intervals examined from LSU 8.4 yielded foraminifera: 589.51 - 589.54 and 601.51 - 601.54 mbsf. Two calcareous benthic taxa occur in LSU 8.4, *Cibicides lobatulus* and *Pyrgo* sp. whose preservation is poor to fair.

LSU 9

Volcanic-bearing sandstone, siltstone, and minor diamictite

Ten out of 13 samples from LSU 9 were examined for foraminifera: 608.33-608.36, 611.21-611.23, 612.83-612.85, 615.19-615.22, 617.17-617.20, 619.55-619.58, 622.14-622.17, 626.14-626.17, 634.13-634.16, and 646.98-647.01 mbsf. A single planktonic foraminifer, *Globorotalia* sp. and 3 benthic taxa were identified, *Ammoelphidiella* spp., *Pyrgo* sp., *Nonionella* spp. (the oldest occurrence in the AND-2A core) and *Elphidium* spp. Preservation is poor to fair.

LSU 10

Volcanic-bearing diamictite, sandstone, and sandy mudstone

Of the 33 samples examined from LSU three contained foraminifera: 648.94 - 648.97, 693.21 - 693.24, and 698.29 - 698.32 mbsf.

LSU 11

Sandy siltstone with dispersed clasts, and sandstone with/without dispersed clasts

Five samples from the 32 samples examined from LSU 11 produced calcareous benthic foraminifera: 783.04 - 783.07, 789.77 - 789.80, 803.99 - 804.02, 811.96 - 811.99 and 848.41 - 848.44 mbsf. One specimen of *Pyrgo* sp. was observed from each of these intervals. Preservation is fair to poor.

LSU 12

Diamictite with subordinate siltstone and minor siltstone

One out of 23 sample intervals from LSU 12 yielded calcareous benthic foraminifera: 964.89 - 964.92 mbsf, where a single specimen of *Pyrgo* sp. was observed. Preservation is fair.

LSU 13

Fine siltstone, coarse siltstone, and very fine-grained sandstone with dispersed clasts and rare diamictite

Four sample intervals were examined for foraminifera from LSU 13 and all were barren.

LSU 14

Diamictite with sandstone

One out of nine sample intervals selected for foraminiferal analysis from LSU 14 contained a single *Pyrgo* sp. specimen that was visible on the split core surface between 1077.33-1077.38 mbsf. Preservation is poor.

BIOSTRATIGRAPHY

Age: Two planktonic foraminifera in the AND-2A core have some biostratigraphic utility. The first occurrence of *Neogloboquadrina pachyderma* in the Southern Ocean is known to occur near the top of Chron C5r (~11.5 Ma), ranging from late Miocene to Recent. *C. antarctica* (*Antarcticella*) is known from the late Oligocene through the middle Miocene of the Ross Sea (Leckie & Webb 1985). However, the *Antarcticella* sp. Recovered from the AND-2A core has yet to be identified.

MARINE AND TERRESTRIAL ORGANIC-WALLED FOSSILS

INTRODUCTION

Over 230 palynological samples spaced at approximately 5 m intervals were collected from the AND-2A core. Alternate samples to be prepared and examined by different labs were sent to New Zealand (M. Hannah, J.I. Raine), U.S.A. (S. Warny, R. Askin) and Germany (B. Mohr). A table listing the palynological samples and their respective laboratory is presented (Tab. 3). Some of the samples sent to New Zealand were processed and returned to the CSEC at McMurdo Station for analysis on-ice by M. Hannah, who was collecting the samples on behalf of the palynology group. Most of the remaining samples

Table 3 – Palynological samples taken from the AND-2A drillcore during the drilling season. Suffixes to the sample depths denote 'c' = clast, 'm' = macrofossil matrix. Palynologist initials identify sample recipients.

Core	Sample Top (m)	Palyn.	Core	Sample Top (m)	Palyn.	Core	Sample Top (m)	Palyn.
10	21.36	MH	139	368.27	MH	213	757.10	SW
17	28.28	SW	140	372.16	SW	214	762.15	BM
26	37.30	BM	141	377.48	BM	215	767.30	MH
31	44.12	MH	142	383.67	MH	216	772.24	SW
32	47.03	SW	142	384.87	SW	217	777.14	BM
35	49.99	BM	144	392.95	BM	218	781.63	MH
37	53.89	MH	144	395.15	MH	220	789.65	SW
40	58.07	SW	146	403.46	SW	221	792.51	BM
44	64.91	BM	147	409.68	BM	223	798.13	MH
47	68.79	MH	147	412.44	MH	224	802.90	SW
50	74.20	SW	148	418.17	SW	225	807.74	BM
52	78.00	BM	149	424.19	BM	227	812.44	MH
55	83.71	MH	150	427.37	MH	228	817.52	SW
58	89.84	SW	152	431.91	SW	229	822.45	BM
59	92.16	BM	152	432.23	BM	230	827.49	MH
59	92.20	MH	153	437.19	MH	231	832.56	SW
61	95.24 c	MH	155	442.37	SW	231	837.63	BM
61	95.65 c	MH	156	449.61	BM	232	842.57	MH
62	96.60	MH	156	452.30	MH	233	847.59	SW
64	102.14	SW	157	458.12	SW	234	852.38	BM
65	107.05	BM	158	460.73	BM	235	857.47	MH
65	107.35	MH	158	465.20	MH	236	862.18	SW
67	112.17	SW	159	470.22	SW	236	867.19	BM
68	114.27	BM	160	475.63	BM	237	872.30	MH
69	119.36	MH	162	481.00	MH	238	877.20	SW
71	122.43	SW	163	485.29	SW	239	882.22	BM
76	130.95	BM	165	490.24	BM	240	887.64	MH
76	135.14	MH	165	495.32	MH	241	892.23	SW
77	140.05	SW	166	501.60	SW	242	897.16	BM
78	142.62	BM	167	506.39	BM	243	902.64	MH
78	143.05	MH	168	512.14	MH	244	908.13	SW
81	149.78	SW	169	516.49	SW	244	912.70	BM
84	154.35	BM	170	522.44	BM	245	917.17	MH
85	157.33	MH	171	528.57	MH	246	922.61	SW
86	159.53	SW	172	532.44	SW	247	927.42	BM
89	164.52	BM	173	540.17	BM	248	933.27	SW
90	168.06	MH	173	543.69	MH	248	937.05	BM
92	172.96	SW	174	547.32	SW	249	941.88	MH
92	174.65	BM	176	553.37	BM	250	947.54	SW
93	176.21	MH	176	557.51	MH	251	951.30	BM

have now been processed and microscopic evaluation is on-going. This preliminary report is based upon quantitative data for marine palynomorphs from 73 samples, and terrestrial palynomorphs from 55 samples, as well as qualitative observations from other samples.

Care was taken to ensure that the processing stream was similar in all three laboratories. The processing method was conventional, involving successive treatment of *c.* 10-20 g of crushed sample with hydrochloric acid, hydrofluoric acid, hydrochloric acid, and some or all of the following: nitric acid, heavy liquid flotation, sieving to retain the 6 to 250 micron size fraction; finally strew mounting in glycerine jelly or polyvinyl alcohol (PVA). Some residues were stained with Safranin red. Post drilling samples are large enough to be processed in all three laboratories to ensure comparability of results.

As in studies of previous Ross Sea drillhole material, the principal palynological residue in most samples comprises coal fragments derived from the Beacon Supergroup and Ferrar Group of the Transantarctic Mountains. Accessory components are brown plant tissue and varying amounts of spores and pollen (collectively termed miospores), marine and freshwater algal cysts and acritarchs, foraminiferal chamber linings, scolecodonts, and a few modern laboratory contaminant miospores. The contaminant material can be recognised by taxonomy (*e.g. Pinus*), the excellent state of preservation, bright autofluorescence in blue-violet incident light excitation, and in some cases by the presence of remnant protoplasm.

Tab. 3 – Continued.

Core	*Sample Top (m)*	*Palyn.*	*Core*	*Sample Top (m)*	*Palyn.*	*Core*	*Sample Top (m)*	*Palyn.*
95	183.01	SW	178	563.50	SW	252	957.46	MH
97	187.78	BM	178	567.84	BM	253	962.28	SW
99	192.47	MH	179	573.41	MH	254	970.74 c	MH
100	194.97	SW	180	578.24	SW	254	972.40	BM
104	204.98	BM	181	583.65	BM	255	976.55	MH
107	212.24	MH	182	588.05	MH	256	982.29	SW
108	216.79	SW	183	593.29	SW	257	987.26	BM
109	219.73	BM	184	599.16	BM	258	992.83	MH
111	225.44	MH	184	603.73	MH	259	997.42	SW
112	229.16	SW	185	605.61 m	MH	260	1 002.41	BM
113	229.44	BM	185	609.47	SW	261	1 007.34	MH
114	235.45	MH	186	613.23	BM	262	1 012.50	SW
115	239.65	SW	187	618.49	MH	263	1 017.44	BM
116	244.71	BM	188	624.03	SW	263	1 022.41	MH
116	250.28	MH	188	627.36	BM	265	1 027.40	MH
117	254.56	SW	190	632.19	MH	266	1 032.62	BM
117	255.80	BM	193	640.01	BM,SW	267	1 037.44	MH
118	258.89	MH	194	646.35	MH	268	1 041.70	SW
118	263.04	SW	195	652.16	SW	269	1 048.14	MH
120	269.37	BM	196	657.42	BM	269	1 052.19	BM
120	274.59	MH	197	663.03	MH	270	1 056.76	SW
121	279.19	SW	198	667.37	SW	272	1 063.71 m	MH
122	284.22	BM	199	672.43	BM	272	1 065.52	BM
122	289.84	MH	200	680.89	MH	273	1 067.78	SW
124	294.50	SW	201	682.40	SW	274	1 072.62	SW
124	298.08	BM	201	687.19	BM	275	1 076.79	BM
126	304.97	MH	202	689.27	MH	276	1 082.65	MH
126	310.51	SW	203	697.32	SW	276	1 087.92	SW
127	312.91	BM	204	702.48	BM	278	1 094.47	BM
128	320.13	MH	205	707.46	MH	279	1 097.14	MH
129	328.40	SW	206	712.11	SW	280	1 102.06	BM
131	335.98	BM	207	719.30	BM	281	1 107.70	SW
131	337.73	MH	207	723.40	MH	282	1 112.59	MH
135	350.48	SW	208	727.37	SW	283	1 117.62	BM
135	351.39	BM	209	733.17	BM	284	1 121.48	MH
135	351.71 m	MH	210	738.16	MH	284	1 126.81	MH
137	355.94	MH	211	744.91	SW	286	1 138.47	BM
137	361.36	SW	211	747.27	BM			
138	366.26	BM	212	753.74	MH			

MARINE PALYNOMORPHS

All but two of the samples examined yielded marine palynomorphs, however both the absolute abundance and diversity of the marine palynomorph floras is extremely variable. Figure 7 presents a generalized range chart listing all the samples examined at the time of this report. The column labelled 'total abundance' is a simple count of all the palynomorphs identified in the samples, including terrestrial palynomorphs that are labelled in the body of the chart as undifferentiated terrestrial in the 'others' category. In most cases, a complete count of the palynoflora was conducted; however where this proved impossible, totals were adjusted to reflect the proportion of the slide counted. Plotted counts are not corrected for sample size.

TAXONOMY: The observed flora is grouped into five categories:

Acritarchs: The acritarch assemblage is dominated by individuals assignable to the genus *Leiosphaeridia*, particularly towards the base of the drillhole. Grey spheres are probably unidentified peridinioid fossil dinoflagellate cysts (dinocysts).

In-situ marine: This category is dominated by dinoflagellate cysts. Of particular importance are two taxa: *Pyxidinopsis* sp. a variable form previously recorded from the lower part of Cape Roberts Project drillhole CRP-2/2A and the upper part of CRP-3 (Hannah et al., 2000, 2001), and *Operculodinium centrocarpum*.

Eocene Dinocysts: Three species of dinocysts, considered to be elements of the Eocene – Oligocene Transantarctic flora (Wrenn & Hart, 1998) were identified as reworked into the core. The most common species is *Vozzhennikovia apertura* but *Deflandrea antarctica* and *Spinidinium macmurdoense* are also present.

Algae: This category is dominated by the prasinophyte alga *Cymatiosphaera* spp. Freshwater colonial algae are recorded sporadically between samples at 122.43 and 827.49 mbsf, especially colonial chlorococcales (*Pediastrum* and *Scenedesmus*-type) and Zygnemaceae.

Others: Linings of microforaminifers, scolecodonts (jaws of polychaete annelids), and undifferentiated terrestrial material comprise this category.

STRATIGRAPHIC DISTRIBUTION: The AND-2A core can be divided into three broad marine palynomorph intervals based on abundance and composition of the marine palynomorph flora present, these are labelled MP1, MP2 and MP3 on figure 7 and are presented below. All ages are from Acton et al. (this volume, b).

_MP1_ (225.44 - 0.00 mbsf): Recent to Late Miocene 7.5 Ma to the top of the section

This interval yielded sparse to moderate assemblages of presumed contemporaneous and reworked marine and terrestrial palynomorphs. Marine palynomorphs include leiospheres, various *Micrhystridium* species, annelid buccal parts, and single to rare occurrences of a number of dinoflagellate cyst species, which give no indication of being reworked. There are sporadic occurrences of reworked Eocene – Oligocene dinocysts.

_MP2_ (437.19 - 225.44 mbsf): Middle Miocene c. 16.5 - 15 Ma

Samples from MP2 yielded extremely variable marine palynomorph assemblages ranging from barren to very abundant. A few of the samples (e.g. 310.51 mbsf) contained abundant marine palynomorph assemblages comprised almost entirely of *Operculodinium* sp. and a species provisionally assigned to the genus *Pyxidiniopsis*. The palaeoenvironmental significance of these apparent blooms is uncertain. However, given that they appear to coincide with a portion of the Miocene climatic optimum, this interval is of high palynological interest and a target for further study. Freshwater algae are notably more common in middle Miocene samples, especially colonial chlorococcales (*Pediastrum* and *Scenedesmus*-type) and Zygnemaceae, consistent with increases in rainfall (or meltwater), standing water, and run-off.

_MP3_ (1126.81 - 437.19 mbsf): Early Miocene c. 19.5 - 16.5 Ma

The early Miocene – middle Miocene boundary is dated at about 16.4 Ma, resulting in this interval being largely early Miocene in age, coeval with Cape Roberts Project CRP-1 drillcore and the upper part of the CRP 2-2A drillcore (Hannah et al., 1998, 2000). Samples from interval MP3 yielded low to moderately diverse assemblages. There is a steady down-hole increase in palynomorph yield, chiefly a result of a substantial increase in the numbers of leiospheres. In most samples, individuals assignable to *Leiosphaeridia* dominate the flora. Similar leiosphere assemblages were a feature of the Cape Roberts Project CRP-2/2A drillcore where they were interpreted as representing cool to cold conditions, with some floating sea-ice and a substantial freshwater input (Hannah et al., 2000; Prebble et al., 2006a).

TERRESTRIAL PALYNOMORPHS

~~Abundance and diversity of terrestrial palynomorphs recovered from the drillhole is extremely variable (Fig. 8), but although they are generally less abundant than marine palynomorphs (Fig. 7).~~ They are absent in only three of the samples examined. Figure 8 presents a generalized range chart listing the taxa identified in samples examined at the time of writing. For most samples, the whole preparation was examined, but for some samples with abundant organic residues, counts were adjusted proportionally to the sample scanned. The first two columns in figure 8 show the abundance of miospores inferred to be derived from

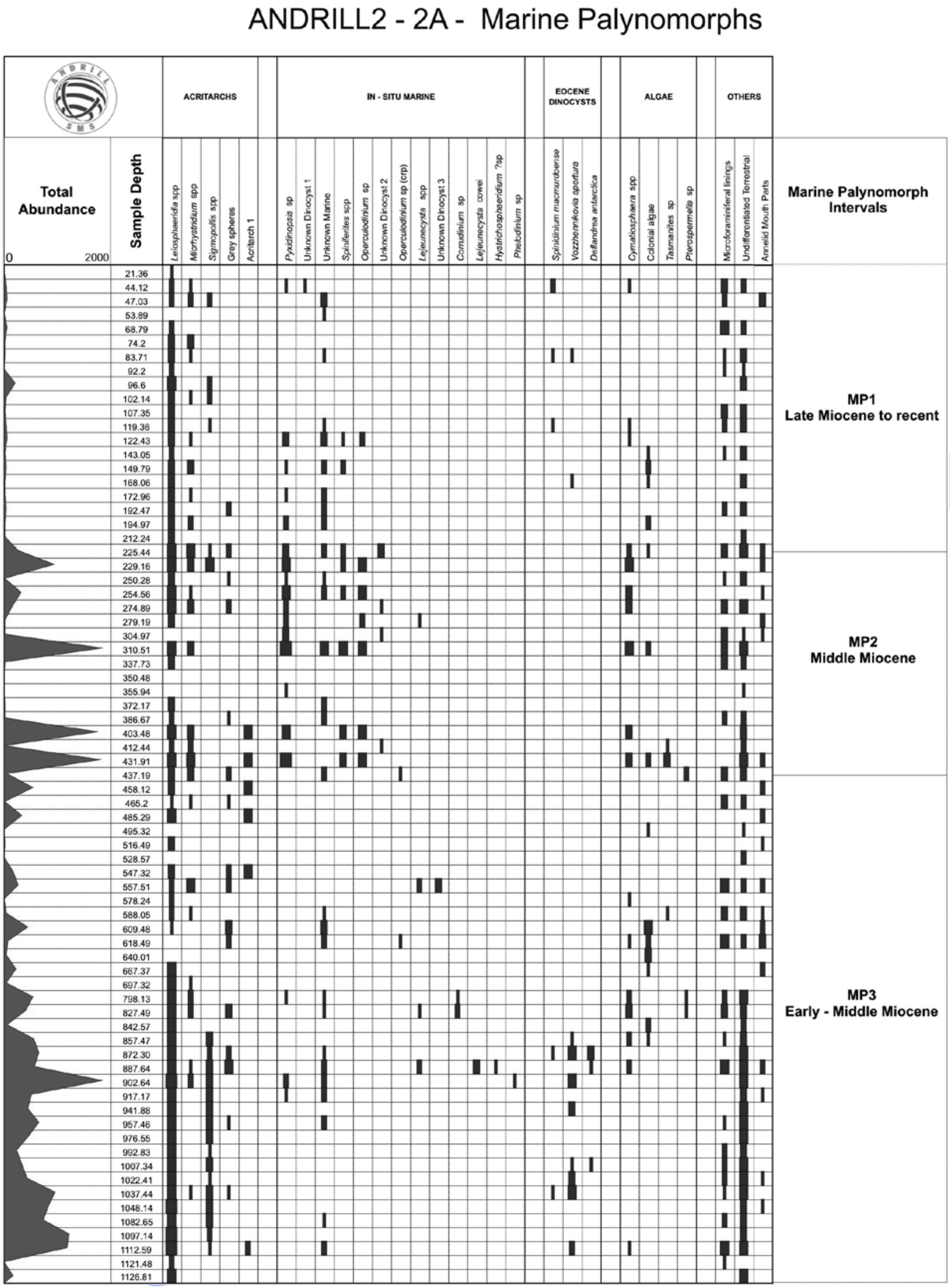


Fig. 7 – Stratigraphic distribution of acritarchs, dinoflagellates and other organic-walled fossils in the AND-2A drillcore. The total abundance column at left showing specimen counts has a linear scale from 0 to 2 000 individuals, but range bars for individual taxa have widths reflecting these count classes - rare, sparse, common, or abundant.

Cenozoic sediments, and from Permian and Mesozoic sediments, respectively.

TAXONOMY: Redeposited Permo-Triassic Beacon Supergroup and Jurassic Ferrar Group miospores are present in low numbers throughout the core and are distinguished from Cenozoic species by their taxonomy and generally darker colour. Preservation of these Beacon Supergroup elements is better than usually observed from outcrop samples from the adjacent Transantarctic Mountains, and a source further inland is postulated. Many identified taxa are long-ranging, but taxa with a Permian range include *Granulatisporites* spp., taeniate bisaccate pollen and monosaccate pollen. A few specimens of *Corollina* pollen derive most likely from Lower Jurassic Ferrar Group sediments, although the genus has a latest Triassic to Cretaceous range. *Retitriletes nodosus*, present at 543.69 mbsf, is positive evidence of Cretaceous provenance. For the current report, only the distribution of Cenozoic miospores is presented in detail in figure 8.

Taxonomic classification of Cenozoic miospores has been based on studies of palynomorphs recovered from McMurdo Sound glacial erratics (Askin, 2000), CIROS-1 (Mildenhall, 1989) and Cape Roberts Project drillcores (Raine, 1998; Askin & Raine, 2000; Raine & Askin, 2001; Prebble et al., 2006b), and the Meyer Desert Formation (Sirius Group) in the Beardmore Glacier region (Askin & Markgraf, 1986), and unpublished data. Most elements of the AND-2A palynoflora are known from these localities, but some less common taxa are new. On the basis of known stratigraphic ranges, some species are considered to be recycled from Eocene to Oligocene strata, but many common taxa are long-ranging and discrimination of recycled and penecontemporaneous specimens is not possible. Some less common or insufficiently taxonomically resolved taxa are combined in figure 8.

The Cenozoic taxa comprise:

Bryophyte spores: These include the form species *Belgisporis* sp., an apparently alete, perinate spore possibly with affinity to Marchantiales; several species of *Coptospora* with varied sculpture that are probably referable to the moss family Bartramiaceae (*e.g. Conostomum*); and *Stereisporites* species, mostly referable to *Sphagnum*.

Pteridophyte spores: A single species of *Retitriletes* with microreticulate sculpture, similar to spores of a Patagonian species of *Lycopodium* (clubmoss), occurs in a number of samples, especially in the middle Miocene interval. A leptosporangiate fern sporangium was found at 259 mbsf, indicating the coeval presence of ferns. Fern spore taxa include species of *Baculatisporites*, *Cibotiidites*, *Cyathidites*, *Gleicheniidites*, *Laevigatosporites*, and *Osmundacidites*, but fern spores are not abundant and many are inferred to be redeposited because they are more frequent in intervals where there is other evidence of redeposition.

Coniferophyte pollen: Bisaccate pollen of *Podocarpidites* species, referable to the Family Podocarpaceae, is most abundant in this category, with minor numbers of specimens of other podocarp taxa, many likely redeposited, including *Microalatidites*, *Microcachryidites antarcticus*, *Phyllocladidites mawsonii*, and *Trichotomosulcites subgranulatus*.

Angiosperm pollen: The core contains the first accepted records of fossil grass pollen (Poaceae) from the Ross Sea region. Other monocotyledonous pollen taxa include *Assamiapollenites* sp. (unknown affinity; 418.17 and 772.24 mbsf), *Liliacidites* sp. (Liliaceae *s.l.* in 4 early to middle Miocene samples), and possible Sparganiaceae/Typhaceae (bullrushes, burr[illegible]ds in 7 early to middle Miocene samples).

Nothofagidites is the most abundant angiosperm pollen, of which several form-taxa are present: *Nothofagidites asperus*, referable to *Nothofagus* subg. *Lophozonia*, is uncommon and present only in the lower Miocene interval; *Nothofagidites flemingii* and the smaller *N.* sp. *cf. N. flemingii*, referable to *Nothofagus* subg. *Nothofagus*, are common throughout; *Nothofagidites lachlaniae*, *N.* sp. A and *N.* (*Fuscospora* type), all referable to *Nothofagus* subg. *Fuscospora*, are the most abundant forms, the last undifferentiated type perhaps representing several species. Finally, *Nothofagidites* (*Brassospora* type), referable to *Nothofagus* subg. *Brassospora* is uncommon and probably redeposited throughout the section.

Chenopodipollis spp. may be partly referable to Chenopodiaceae, but also to *Colobanthus* (Caryophyllaceae), a genus of cushion plants characteristic of modern subantarctic and austral-alpine environments. Other taxa in this category include Stylidiaceae (trigger plants; 58.07 and 652.16 mbsf), Droseraceae (sundews; 922.61 mbsf), Campanulaceae (bellflowers; 947.54 mbsf), and Ericales (heaths; 284.22 and 418.17 mbsf).

Other angiosperm taxa present include *Peninsulapollis* spp. (possibly redeposited from Paleogene or Upper Cretaceous sediments); several species of Proteaceae, at least one of which is present and probably coeval in other Ross Sea Miocene and upper Oligocene deposits; the distinctive form "*Tricolpites* sp. a"; and miscellaneous undifferentiated dicotyledonous pollen of unknown affinities.

STRATIGRAPHIC DISTRIBUTION: Based on the samples analyzed, the section is divided into three terrestrial palynomorph intervals (TP1 to TP3 in Fig. 8).

TP1 *(225 – 0 mbsf): Late Miocene to Recent c. 7.5 Ma to the top of the section*

This interval is characterized by low miospore abundance in many samples. Most specimens are of long-ranging taxa, especially *Nothofagidites* spp., and species that characterize the underlying early to middle Miocene interval (notably *Belgisporis* sp., *Coptospora* spp., and *Retitriletes* sp.) are absent in most samples. *Nothofagidites* (*Brassospora* type) and *Phyllocladidites mawsonii* are almost certainly redeposited, and it is considered that the miospore assemblages of the interval are likely to be largely derived from erosio[illegible] Paleogene strata.

TP2 *(c. 590 – 225mbsf); late Early to Middle Miocene c. 17 – 15 Ma*

This interval is characterized by more abundant miospores, including common bryophyte spores (*Belgisporis* and *Coptospora* spp.), and the presence of *Retitriletes* sp. and "*Tricolpites* sp.a" in a number of samples. These species are known previously from

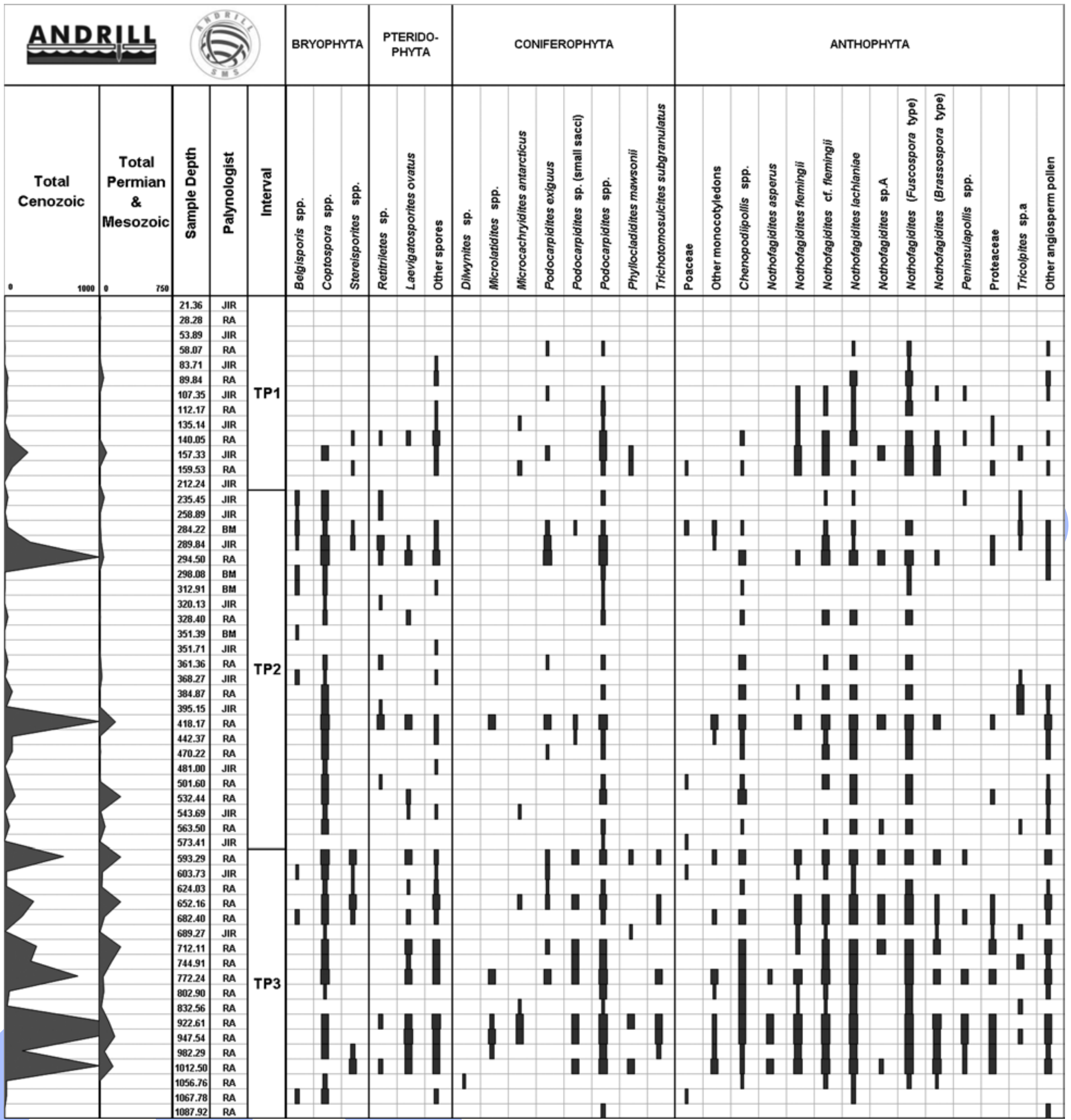


Fig. 8 - Stratigraphic distribution of miospores in the AND-2A drillcore. The two total abundance columns at left showing specimen counts have a linear scale, but range bars for individual taxa have widths reflecting these count classes - –rare, sparse, common, or abundant.

the uppermost Oligocene to lower Miocene section of the CIROS-1 and Cape Roberts Project (CRP) drillcores, and the Meyer Dessert Formation (Sirius Group) outcrop at the Beardmore Glacier, and from Dry Valley Miocene deposits. Samples from 284 - 294 mbsf have notably high counts of *Nothofagidites* and *Podocarpidites* pollen.

TP3 *(1126 – c. 590 mbsf); Early Miocene c. 19.5 –17 Ma*

Miospore assemblages from this interval are similar to those of the overlying middle Miocene interval, but are characterized by a greater abundance of common recycled Eocene (and older?) specimens, *e.g. Nothofagidites* (*Brassospora* type).

PALEOCLIMATIC INFERENCE: Pollen and spores from the middle Miocene section of AND-2A core provide the first stratigraphically-constrained record of terrestrial vegetation in Victoria Land during this time interval. The spore-pollen assemblages below 225 mbsf are similar to those reported in the uppermost Oligocene to lower Miocene sections of CIROS-1 and CRP cores. They probably represent a mossy tundra vegetation with proportions of shrub podocarps and *Nothofagus*, and other plants varying according to topographic aspect and microclimate. For most of the lower and middle Miocene interval, a general climate cooler than the modern austral polar-alpine tree limit is suggested, although at times this limit (10°C January mean) may have been reached.

TERRESTRIAL LIGNIN-RICH ORGANIC MATTER

GENERAL

The study of organic matter dispersed in sediments includes the optical analysis in reflected light of lignin-rich fragments of the huminite-vitrinite and inertinite macerals' groups (Stach et al., 1982) that may help in palaeoenvironmental, palaeothermal and palaeoburial reconstructions even at high latitudes, as testified in James Ross Island and in the Weddell Sea (*e.g.* Whitman et al., 1988; Thompson & Dow, 1990).

Vitrinite thermal maturity analysis consists of measurements in reflected monochromatic light of telinite, telocollinite and collinite macerals reflectance (Fig. 9) that gather in one or more than one cluster allowing the identification of different populations of vitrinite fragments (either coeval or reworked from older rocks). Regular (*e.g.* gaussian) distribution of reflectance data permits mean vitrinite reflectance (%Ro) calculation. Only indigenous populations -- generally testified by the lowest mean value in the sample -- can provide reliable data on the thermal state of the hosting sediments, whereas reworked populations with higher reflectance values give useful information on materials, modes and time of reworking from the surrounding areas. Furthermore, the distribution in a sedimentary succession of vitrinite reflectance is often used to detect amounts of sediments that are missing in correspondence of unconformities, even at very low temperatures (Dow, 1977).

The other mainly lignin-rich macerals that may be present belong to the inertinite group, but generally their reflectance is not measured as they do not provide useful pieces of information on the thermal state of the sedimentary succession. Their description and abundance evaluation contribute to the characterisation of the organic facies of the AND-2A core.

The preliminary study performed entirely off-ice had two aims:

1. To define the vertical distribution and abundance of lignin-rich particles of different origin and composition.
2. To describe the state of conservation and the thermal maturity of organic particles, mainly through vitrinite reflectance measurements.

MATERIALS AND METHODS

A total of 113 samples for organic matter analysis were collected on-ice by M. Hannah from the AND-2A core from the intervals 26.22 to 1132.73 mbsf along the whole Miocene-Quaternary succession (Tab. 4). Samples were first described macroscopically, weighed and photographed. Forty-six samples - mainly derived from the clayey, siltitic and arenaceous drilled intervals belonging to all LSUs (in grey in Tab. 4) - were selected and prepared according to the European Standard procedures for reflected light analyses of dispersed organic matter in order to avoid the elimination of the non-stabilized kerogene (manual picking on whole-rock samples). Ten samples, from LSUs 4, 5, 7, 10, 12, 13, 14, described as clast-rich to clast-poor sandy and muddy diamictite, were prepared according to the American standard procedures, mainly based on HCl and HF attack and sieving to concentrate the stabilised kerogene fraction. Then samples were incorporated in non-fluorescent epoxy resin and lapped. Preparation of the other samples is still ongoing.

Reflected light analyses were performed using the MSP200 equipment on Zeiss Axioskop 40 with an oil immersion objective x50, monochromatic light and three standards of known reflectance (0.426%; 0.595%; 0.905%) c/o the "Lab of Preparation and Analysis of Organic matter dispersed in sediments" of the Department of Geological Science of "Roma Tre" University.

RESULTS

Main results on vitrinite reflectance distribution are summarised in table 4, occurrence of both vitrinite and inertinite fragments in the entire succession is given in figure 10, whereas a summary of the main response given by each LSU with representative %Ro histograms is reported in figure 11.

ABUNDANCE OF VITRINITE AND INERTINITE MACERALS

Excluding those devoid of kerogen (15 samples), analysed samples generally show a scarce content in organic matter dispersed in sediments (mainly less than 25 fragments) ascribed to both vitrinite and inertinite groups' macerals (Fig. 9 a-e, g-i). Only LSUs 10 to 14 contain significant amount of fragments with a maximum in LSU 11, never exceeding 100 fragments. An isolated peak - not exceeding 50 fragments - is recorded in LSU 2. Where the total amount of lignin-rich fragments sensibly increases, the main contribution is given by inertinite macerals (Fig. 10) either unstructured (Fig. 9a) or highly structured (*e.g.*, fusinite, Fig. 9i). This component does not provide any information on both the thermal state of sediments and the degree of reworking from older rocks or from oxidised coeval lignin-rich material. Pyrite either finely dispersed or in discrete aggregates is often present (Fig. 9f). For each sample, a maximum of 25 measurable points of macerals of the vitrinite group were detected.

Vitrinite when present, never exceeds 25, and more frequently less than 20 either unstructured (*e.g.* collinite) or structured (*e.g.* telinite) fragments. Different vitrinite populations were recognised (Tab. 4) with organic thermal maturity ranging from the immature (%Ro<0.5%) to the mature stage (0.5<%Ro<1.35%) and up to the late mature interval (up to 1.5%) when compared to the stages of hydrocarbon generation - most of them reworked.

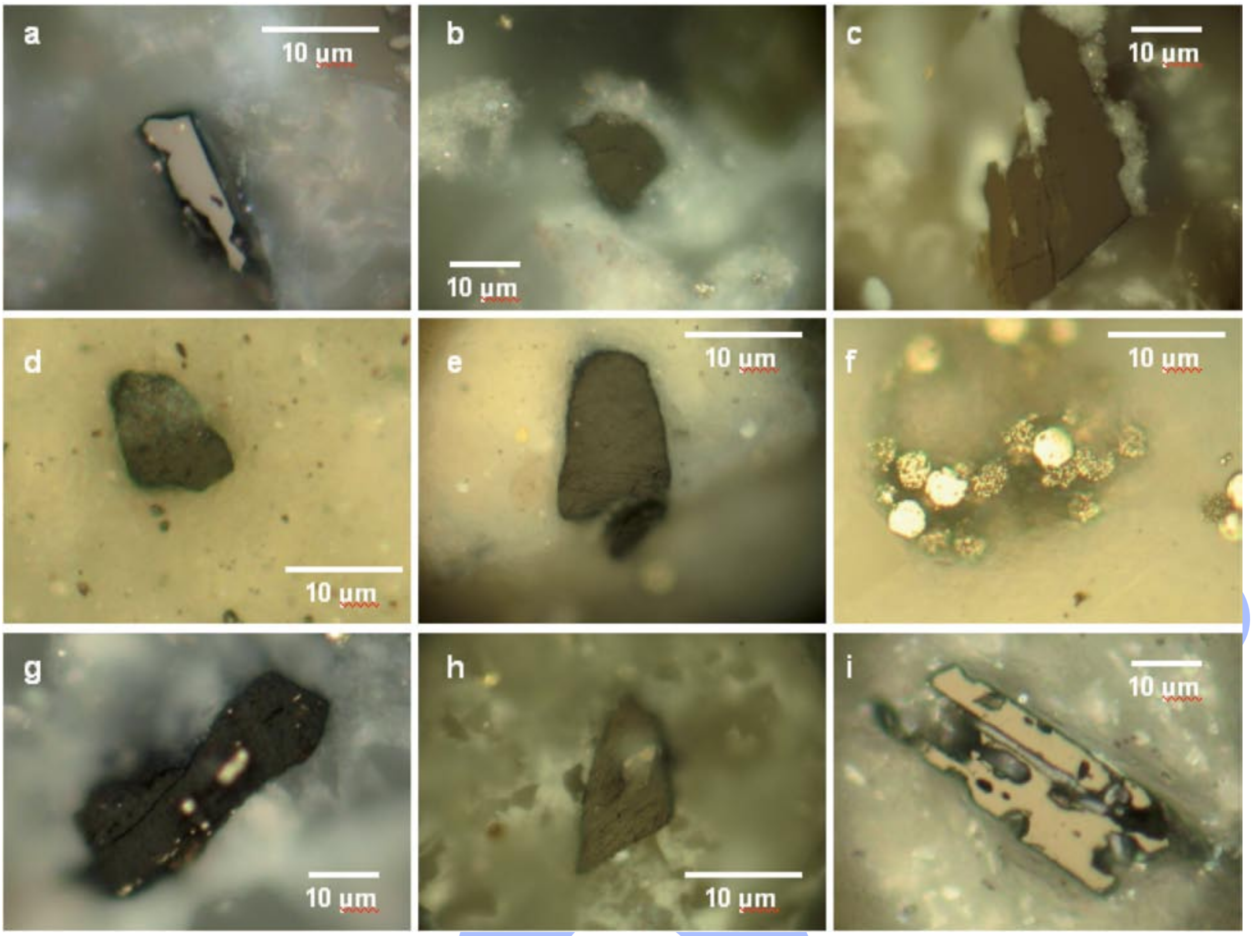


Fig. 9 – Micrographs of vitrinite and inertinite fragments from the AND-2A drillcore; (a) Inertinite (Ro=0.778%), sample 26.22 mbsf; (b) Vitrinite (Ro=0.466%), sample 37.20 mbsf; (c) Vitrinite (Ro=0.169%), sample 44.14 mbsf; (d) Vitrinite (Ro=0.348%), sample 434.85 mbsf; (e) Vitrinite (Ro=0.440%), sample 968.15 mbsf; (f)Pyrite, sample 997.44 mbsf; (g) Vitrinite (Ro=0.586%), sample 1012.456 mbsf; (h) Vitrinite (Ro=0.681 %), sample 1022.36 mbsf; (i) Inertinite (Ro=1.451%), sample 1132.69 mbsf.

DISTRIBUTION IN CORE

Vitrinite reflectance data is presented below by lithostratigraphic unit (Fielding et al., this volume).

LSU 1: 37.07 mbsf - the top of the core section

The unit consist of 37.07 m of volcanic siltstone and medium sandstone with dispersed clasts. In detail, LSU 1.3 is barren in organic matter.

LSU 2: 98.47 - 37.07 mbsf

Preliminary results suggest that organic matter belonging to both groups is almost absent. When vitrinite fragments are present they are quite scattered with the less reflecting ones, indicating highly immature stages of hydrocarbon generation (Ro=0.118%).

LSUs 3 to 4: 224.8 - 98.47 mbsf

In LSUs 3 and 4, vitrinite and/or inertinite fragments are slightly more abundant and indigenous vitrinite fragments are in the immature stage of hydrocarbon generation (Ro<0.5%). The number of analysed samples from these units is still low to validate the presence of a jump in thermal maturity data that may be hypothesized on the base the recorded hiatus between LSUs 3 and 4.

LSU 5: 296.34 - 224.82 mbsf

In LSU 5, vitrinite and inertinite fragments are quite scarce and reflectance data are scattered without a defined mode in the range comprised between the immature to the mid-mature stages of hydrocarbon generation, indicating the presence of reworked organic matter.

LSU 6: 339.92 - 296.34 mbsf

Vitrinite reflectance distribution concentrates at the boundary between the immature and the mature stage.

LSUs 7 to 8: 607.35 - 339.92 mbsf

In LSU 7 and LSU 8, vitrinite fragments are present and are quite scattered with the less reflecting ones, indicating immature stages of hydrocarbon generation (Ro<0.4%). In general more than one population is present with vitrinite values ranging from the immature and early mature stages.

LSUs 9 to 10: 607.35 - 778.34 mbsf

Units 9 and 10 are mainly characterised by reworked populations. Only one sample contained coeval vitrinite at the mature stage (Ro= 0.512%).

Tab. 4 - Vitrinite reflectance distribution in the AND-2A drillcore by lithostratigraphic units (LSU) and tentative populations. In dark grey: whole-rock samples; in light grey: concentrated samples; and in white: samples not yet analysed.

Core ID	*From (mbsf)*	*To (mbsf)*	*Pop. 1 ± sd*	*Total nr. vitr. frag*	*Pop. 2*	*Pop. 3*	*Pop. 4*
LSU 1.3 (20.57-37.07 mbsf)							
15	26.22	26.24	-	-	-	-	-
LSU 2 (37.07-98.47 mbsf)							
26	37.20	37.22	-	-	-	-	-
31	44.14	44.16	0.161 ±0.034	7		0.445	-
37	53.92	53.93	-	10	0.350	z-	-
44	63.12	63.14	-	5	0.290	0.560	-
50	74.14	74.16	-	10	0.287	0.630	-
55	83.26	83.28	0.118 ±0.042	16	0.286	0.390	-
58	90.01	90.03	-	15		0.476	-
LSU 3 (98.47-122.86 mbsf)							
64	102.22	102.24	0.166 ±0.050	20	0.318	0.445	-
67	112.49	112.51	0.141 ±0.078	14	0.274	z-	-
71	122.37	122.39	-	14	0.388	0.588	-
LSU 4 (122.86-224.82mbsf)							
75	132.54	132.56					
78	142.41	142.43					
82	152.67	152.69					
87	162.75	162.77	-	-	-	-	-
92	173.96	173.98					
96	183.82	183.84					
100	194.39	194.41	-	22	0.304	0.604	0.750
104	205.11	205.13					
105	208.31	208.33	-	-	-	-	-
108	215.45	215.47		16	0.477	0.700	0.900
LSU 5 (224.82-296.34mbsf)							
111	225.18	225.20					
113	229.31	229.34	-	-	-	-	-
114	235.20	235.23					
116	245.53	245.56					
119	265.26	265.29	-	-	-	-	-
121	275.39	275.42	-	-	-	-	-
122	285.14	285.17	0.291 ±0.028	10	0.458	0.650	
LSU 6 (296.34-339.92mbsf)							
124	295.25	295.28	0,302 ±0,067	12	0.560		
126	304.91	304.94					
127	315.11	315.14					
129	324.87	324.90	-	16	0.469	0.647	-
131	334.98	335.01	0.356 ±0.044	11	0.420	-	-
LSU 7 (339.92-436.18mbsf)							
134	350.37	350.40					
136	354.25	354.28	0.347 ±0,058	25	0.519	0.866	-
138	364.11	364.14					
141	375.00	375.03	-	24	0.448	0.727	-
142	384.19	385.22					
144	395.19	395.22					
148	415.55	415.58					
150	425.85	425.88					
152	434.85	434.88	-	-	-	-	-
LSU 8.1 (436.18-502.69mbsf)							
155	445.07	445.10	-	8	-	-	-
157	455.27	455.30	0.287 ±0.041	15	0.566	0.800	-
159	466.30	466.33					
160	476.16	476.19					
163	486.18	486.21					
166	496.76	496.79	-	-	-	-	-
LSU 8.2 (502.69-544.47mbsf)							
167	506.27	506.30					
169	516.30	516.33					
171	526.28	526.31	-	-	-	-	-
172	536.51	536.54					
LSU 8.3 (544.47-579.33mbsf)							
174	546.49	546.52	0.371 ±0.054	19	0.625	0.783	-
176	556.17	556.20					
180	577.38	577.41					

Tab. 4 - Continued.

Core ID	*From*	*To*	*Pop 1 ± sd*	*Abundance pop.1*	*Pop 2*	*Pop 3*	*Pop 4*
LSU 8.4 (579.33-607.35mbsf)							
182	587.11	587.14					
183	597.04	597.06					
185	607.35	607.38					
LSU 9 (607.35-648.74mbsf)							
187	617.55	617.58					
188	627.31	627.34	z-	-	-	-	-
193	637.18	637.21	z-	18	0.599	0.770	-
194	646.37	646.40	z-	-	-	-	-
187	617.55	617.58					
188	627.31	627.34	-	-	-	-	-
193	637.18	637.21	-	18	0.599	0.770	-
194	646.37	646.40	-	-	-	-	-
LSU 10 (648.74-778.34mbsf)							
196	657.31	657.34					
198	667.42	667.45	-	-	-	-	-
200	677.52	677.55					
201	687.26	687.29	-	19	0.578	0.825	-
202	692.24	692.27	0.472 ±0.038	13	0.641	0.825	-
203	697.52	697.55	0.512 ±0.058	12	-	-	-
205	707.30	707.33					
207	719.22	719.25					
208	727.68	727.71	-	-	-	-	-
210	738.22	738.25					
211	747.29	747.32					
213	757.12	757.15					
215	767.37	767.40					
217	777.19	777.22					
LSU 11 (778.34-904.66mbsf)							
220	789.62	789.65	0.400 ±0.078	15	0.716	-	-
223	798.15	798.18	-	9	0.680	-	-
225	807.76	807.79	0.458 ±0.072	20	0.685	-	-
228	817.54	817.57	0.401 ±0.063	24	0.633	0.853	-
230	827.51	827.54	-	16	0.619	0.768	0.963
213	837.75	837.78					
233	847.52	847.55	-	13	0.736	0.931	-
235	857.56	857.59					
236	867.27	867.30					
238	877.25	877.28					
240	887.61	887.64	-	-	-	-	-
242	897.18	897.21					
LSU 12 (904.66-996.69mbsf)							
244	907.56	907.59					
245	917.25	917.28					
247	927.47	927.50	-	28	1.033	1.228	1.542
248	936.91	936.94					
250	947.51	947.54					
252	957.43	957.46					
253	968.15	968.18	-	-	0.889	-	-
255	976.52	976.55	-	17	1.021	-	-
257	987.33	987.36	-	-	-	-	-
LSU 13 (996.69-1 040.28mbsf)							
259	997.44	997.47	-	15	1.135	-	-
261	1 007.36	1 007.39					
262	1 012.45	1 012.50	0.666 ±0.040	17	0.850	1.000	1.300
263	1 022.36	1 022.41	0.597 ±0.067	25	0.850	1.000	1.225
266	1 032.39	1 032.45					
LSU 14 (1 040.28-1 138.54mbsf)							
268	1 041.65	1 041.70					
269	1 052.14	1 052.19					
272	1 062.77	1 062.82					
274	1 072.43	1 072.48	-	10	-	-	1.400
276	1 082.67	1 082.72					
278	1 094.50	1 094.55					
279	1 097.22	1 097.27	0.658 ±0.035	8	0.850	1.000	-
281	1 107.65	1 107.70	-	-	-	-	-
283	1 117.52	1 117.57					
284	1 126.77	1 126.81					
285	1 132.69	1 132.73	-	-	-	-	1.474

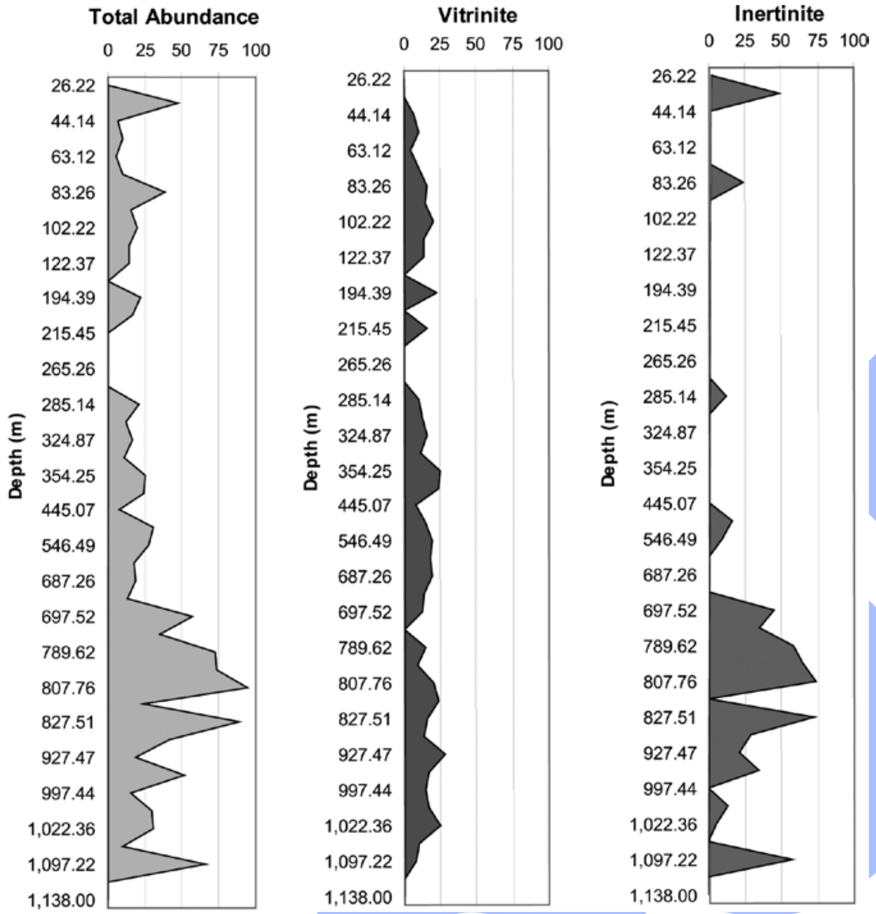


Fig. 10 - Range chart of organic matter dispersed in sediments in the AND-2A drillcore. The graphs are based on the raw counts.

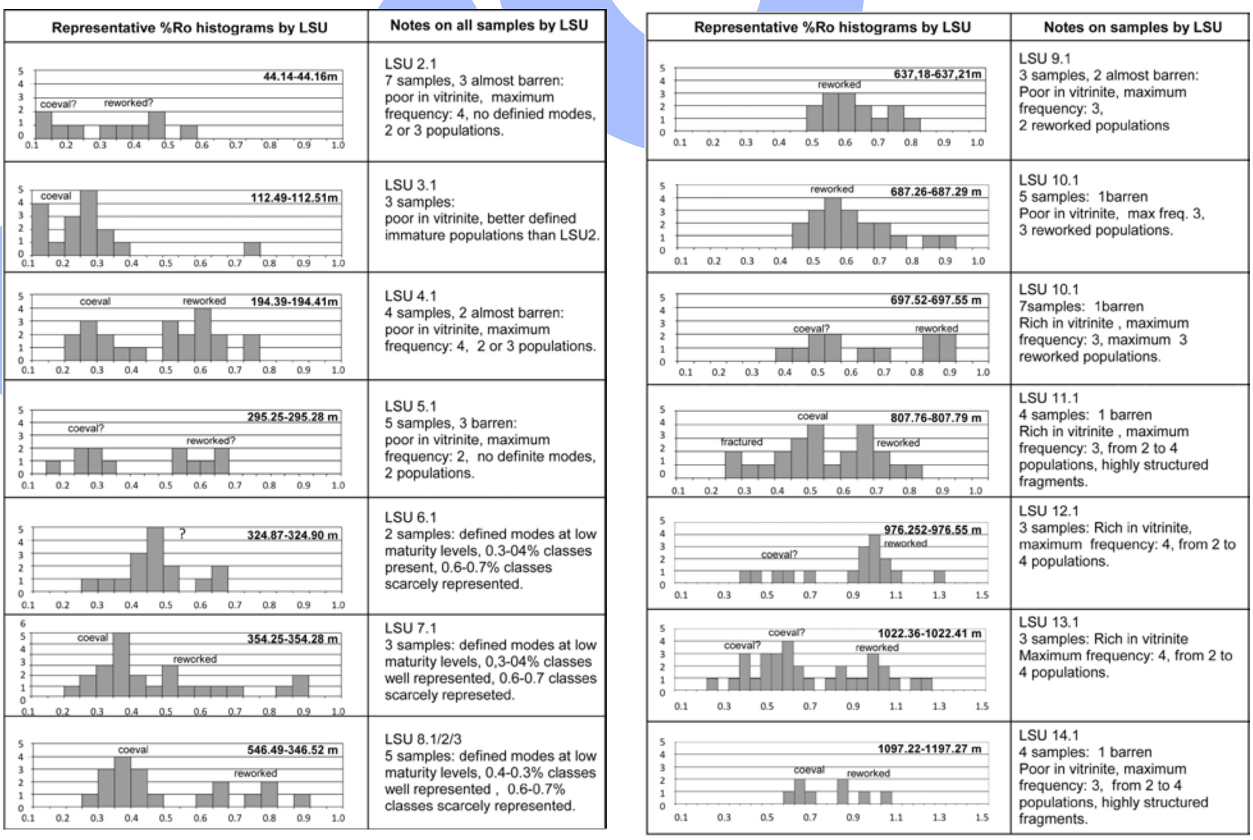


Fig. 11 - Summary of the main results of organic matter in the AND-2A drillcore reported for each LSU.

LSU 11: 904.66 - 778.34 mbsf

Vitrinite and/or inertinite fragments are slightly more abundant and indigenous vitrinite fragments are in the immature stage of hydrocarbon generation (Ro<0.5%).

LSUs 12 to 14: 1138.54 - 904.66 mbsf

Excluding the barren sample, this interval is dominated by reworked fragments of inertinite with values at 1.542%.

SUMMARY OF LIGNIN-RICH ORGANIC MATTER DISPERSED IN THE AND-2A CORE

This preliminary study demonstrated the presence of significant assemblages of lignin-rich organic matter fragments belonging to both huminite-vitrinite and inertinite groups with a net predominance in the LSUs marking the mid- Miocene climatic optimum. Most of the vitrinite content appears to be reworked with %Ro values ranging from immature to late mature stages of hydrocarbon generation, but we cannot exclude a trend of increasing thermal maturity with depth derived from fragments coeval with sediments that range from thermally immature values - down to 900 mbsf - to early mature down to the bottom of the hole. In case the coeval nature of these fragments is confirmed from the integration with future analyses and interpretation of a more complete record of thermal maturity throughout the entire succession, this result may directly provide constraints for burial and thermal modelling and may indirectly contribute to palaeoclimate reconstructions.

MACROFOSSILS

GENERAL

More than 600 horizons were inspected for their potential macrofossil content from the AND-2A core (Tab. 5; for details see supplementary table S2 available on-line at the Terra Antartica website www.mna.it/english/Publications/TAP/terranta.html and the SMS Project science drive http://www.andrill.org), as plainly visible in the working half of the split core sections (in a few occasions also in the archive half sections), or in fast track samples, smear slides and thin sections. The majority of samples yielded results. The macropalaeontological yield of AND-2A therefore is the highest for drilling in Antarctica, surpassing all CRP drillcores combined (*cf.* Taviani & Beu, 2003).

The preservation state of many macrofossils is, however, extremely poor due to diagenetic processes (see Panter et al., this volume). Most of the macrofossil yield is represented by minute, often highly decalcified fossils, for which a taxonomic assessment is impossible. In some cases, deposition of secondary calcite was observed, often as infillings of polychaete tubes. These diagenetically altered fossils are likely unsuitable for palaeoenvironmental oriented geochemistry and Sr-dating, although we collected some samples to assess their potential to yield ages (Acton et al., this volume).

More rarely, shell carbonate was completely dissolved leaving vugs reminiscent of the original shell. Pyritisation was identified as infillings of polychaete tubes and as bivalve moulds. To these calcareous macrofossils, we must add fish scales identified in smear slides (B. Field), and macrofossils seen in thin sections (including slides prepared for K. Bassett (Fig. 2a, b), and in micro-palaeontological residues (S. Ishman, K. Johnson)).

This macropalaeontological analysis refers to metazoan and plant remains independently from the actual size of the fossil remain. Connected aggregates of spicules (bundles) are considered fossil sponges. Individual sponge spicules were accounted as siliceous microfossils (see subsection "Marine diatoms and other siliceous microfossils") and are not considered here. Ichnogenera linked to the life activity of metazoans (trace fossils) are not treated here (see Fielding et al., this volume).

METHODS

The on-ice preparation of macrofossils required various techniques to isolate and consolidate them. When not possible otherwise (*i.e.*, hand removal or washing), fossil isolation was often performed by applying a gentle pressure with a vice to facilitate the splitting of host sediment through weakness planes produced by the fossil. Washing in water over a mesh (63 micrometers for potential micropalaeontological studies) was only rarely performed due to the high risk of breaking friable carbonate parts. Further cleaning was achieved by using a scalpel and dental tools. On many occasions, especially when fossils were contained within poorly cemented or loose sand, consolidation was obtained by impregnation with epoxy and/or application of silica-based hardeners. Samples surveyed for the presence of bryozoans were processed off-ice using a freeze-thaw process to break down the matrix, then washed through a >63 µm sieve. After overnight drying in an oven at 40°C, macrofossil fragments were picked out of the disaggregated samples.

RESULTS

In order of relative abundance, the following taxonomic macropalaeontological groups were positively identified in the AND-2A core:
- Mollusca (Bivalvia: > 7 species; Gastropoda: > 4 species)
- Annelida (Polychaeta tubes > 4 species)
- Bryozoa (> 5 species)
- Echinodermata (1 species)
- Crustacea-Cirripedia (1 species)
- Porifera (1 species)
- Brachiopoda (1 species)

- Chordata (Pisces, only as scales)
- Incertae sedis
- Macroplants.

Mollusca

Molluscs are quite common in Cenozoic marine sediments of Antarctica (Dell & Fleming, 1975; Gaždzicki & Pugaczewska, 1984; Pugaczewska, 1984; Beu & Dell, 1989; Jonkers & Taviani, 1998; Taviani, et al. 2000; Taviani & Beu, 2001, 2003; Jonkers, 2003; Whitehead et al., 2006; Scherer et al., 2007). Molluscs are also present at various levels in the AND-2A core and contribute substantially to a shell-rich bed between c. 430.54 - 430.68 mbsf (the pectinid bed, Fig. 12). While gastropods (at least 4 species: Figs. 12, 13a) appear strongly affected by diagenesis, this is not always the case with bivalves (at least 7-8 species: Figs. 12, 13b, c).

The palaeontological record of phylum Mollusca of the AND-2A core is remarkable in terms of palaeoenvironmental and palaeoclimatic implications to reconstruct the history of the Antarctic biota. In fact, the ecological meaning of costate pectinids (*Austrochlamys* spp.) and veneracean clams is consistent with milder-then-present seawater temperatures in the nearshore of the Miocene Ross Sea. A further value of the very few unrecrystallized bivalve shells (mainly pectinids) lies with their potential use as palaeoceanographic proxies based upon geochemical techniques to decipher signals encoded in their skeletons (*cf.* Taviani & Zahn, 1998).

Annelida

Annelida, especially as polychaete tubes, are consistently recorded from outcrop and drillcore records in the Cenozoic of Antarctica where they represent one of the most diffuse macrofossil legacies (Dell & Fleming, 1975; Gaždzicki & Pugaczewska, 1984; Jonkers & Taviani, 1998; Taviani et al., 2000; Taviani & Beu, 2001; Scherer et al., 2007). In the AND-2A core, polychaete calcareous tubes (mostly attributable to Family Serpulidae) are almost ubiquitous (Fig. 14 a-d). Besides the calcitic tubes, the occurrence of Annelida in marine sediments of the AND-2A core is also documented by scolecodonts (see subsection Marine and terrestrial organic-walled fossils). Tubes are common throughout the AND-2A core, although with variable diversity and abundance. The calcitic tubes are often highly decalcified and/or infilled and/or replaced by secondary minerals (see Panter et al., this volume). At least 4-5 different taxa are recognized, ranging from the commonly observed tubes with annular rings (Cape Roberts Science Team, 1998; Scherer et al., 2007: Fig. 14a), to other forms possibly representing undescribed species. *In situ* tubes seem to be consistently associated with fine-grained lithologies, and often form almost monospecific assemblages (Fig. 14b); they are interpreted as representing highly silted shelfal settings. Such tubes also occur in various coarse-grained lithologies, but may represent reworked/displaced fossils. On one occasion (pectinid bed at 430.54 - 430.68 mbsf) polychaete tubes were found as encrusters on the external valve of a large pectinid (Fig. 14b).

Bryozoa

Bryozoa are consistently recorded from outcrop and drillcore records in the Cenozoic of Antarctica (Dell & Fleming, 1975; Gaždzicki & Pugaczewska, 1984; Jonkers & Taviani, 1998; Taviani et al., 2000; Scherer et al., 2007). In the AND-2A core bryozoans seem largely restricted to LSU 7 and, mostly LSU 9, and consists solely of cheilostome Bryozoa.

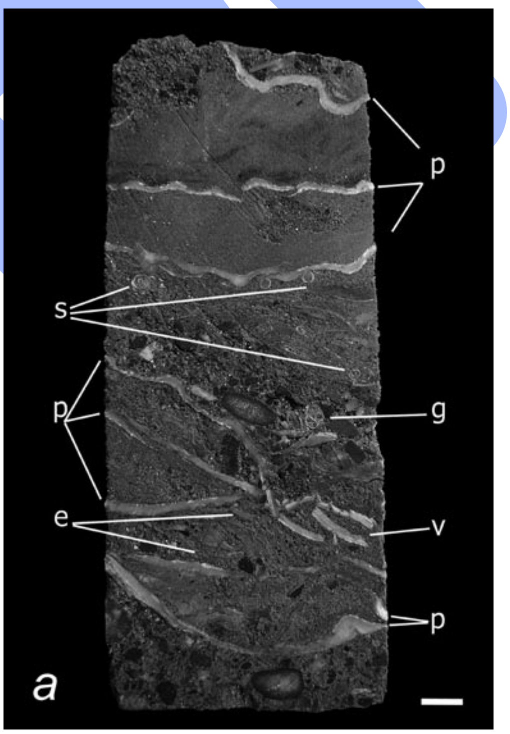
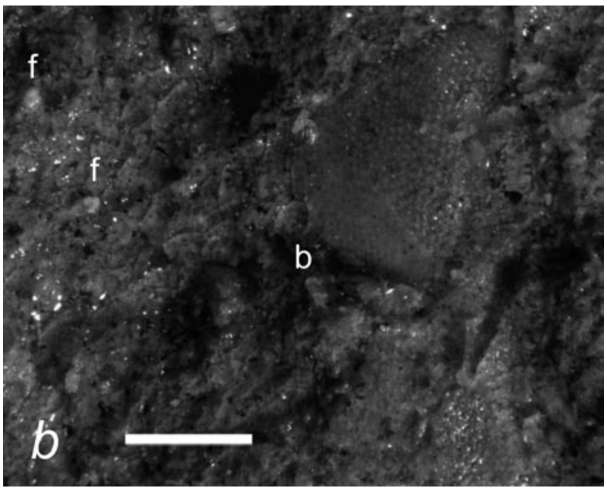


Fig. 12 – (a) Shell concentration, the 'pectinid bed' at 430.54-430.68 mbsf (archive half of the drillcore); 'p' = costate pectinid bivalve, mostly articulated, the lowermost specimen is the source of the polychaete, bryozoan and the echinoid shown in Fig. 13b, 14a, and 15a, respectively; 'e' = echinoids, 'g' = gastropod, 's' = polychaete serpulid tubes, 'v' = articulated veneroid bivalve [scale bar = 10 mm]; (b) carbonate-rich interval at 616.27 mbsf within LSU 9 hosting well-preserved calcitic fossils, including benthic foraminifers 'f' and brachiopods 'b [scale bar = 1 mm].



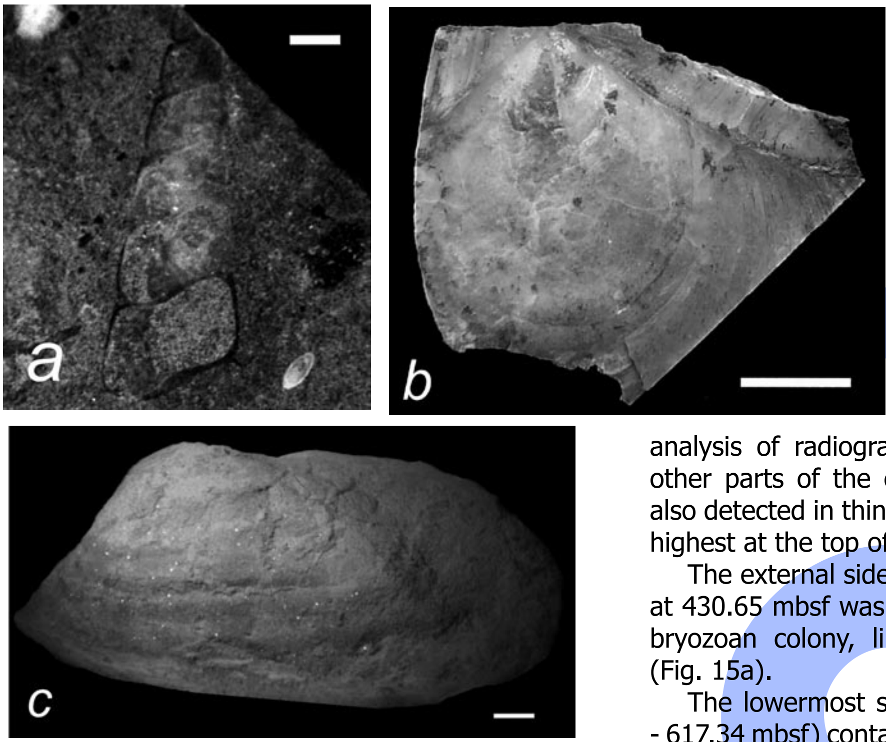


Fig. 13 – Mollusca: (a) turritellid gastropod mould infilled by secondary calcite (377.61 mbsf) [scale bar = 1 mm]; (b) articulated and pristine shell of the pectinid Adamussium alanbeui (1063.71 mbsf) [scale bar = 5 mm; (c) mould of a hiatellid bivalve (543.06 mbsf) [scale bar = 2 mm].

Preservation of bryozoans is generally poor, with extensive abrasion and recrystallization smoothing out distinguishing features. Cavities in fossils often contained a geoidal infill of coarser calcite crystals. Samples not containing bryozoans contained mainly polychaete and bivalve shell fragments. Suggested possible cyclostome bryozoans were identified as colony-formed polychaete tubes. More detailed analysis of radiographs may reveal bryozoans in other parts of the core. Possible bryozoans were also detected in thin sections. Bryozoan diversity is highest at the top of LSU 9.

The external side of a large, thick pectinid valve at 430.65 mbsf was encrusted by a well-preserved bryozoan colony, likely attributable to *Exochella* (Fig. 15a).

The lowermost sample with bryozoans (617.33 - 617.34 mbsf) contains poorly preserved fragments of rigid, cylindrical, branching colonies similar to the modern genera *Swanomia* or *Melicerita*. In addition, the sample contains unilamellar sheets with no distinguishing features preserved. Encrusting, unilamellar *Smittina* colonies occur at 617.03 mbsf (Fig. 15c). Interval 616.79 - 616.81 mbsf contains relatively well-preserved fragments of sheet-forming colonies similar to the modern genera *Exochella*. The dorsal sides of the fragment have bulging imprints as

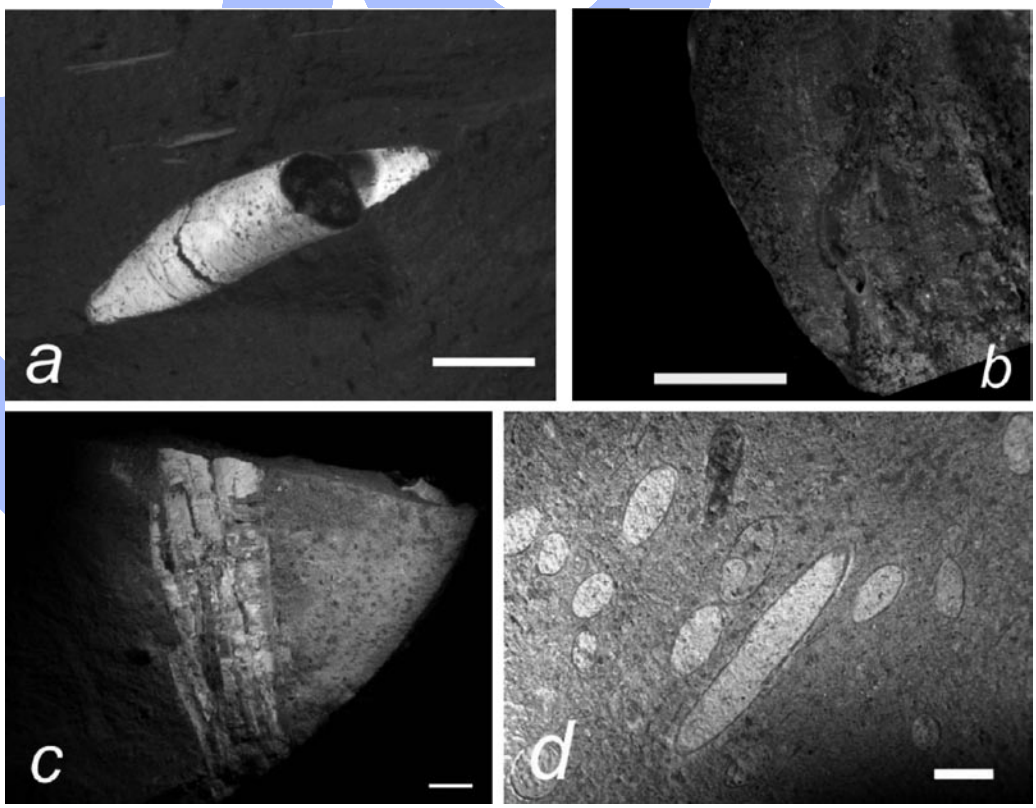


Fig. 14 – Annelida (Polychaeta): (a) chalky tube still retaining faint traces of annular ornamentation (533.01 mbsf) [scale bar = 2 mm]; (b) encrusting tube on the external valve of a pectinid shell (430.66 mbsf) [scale bar = 5mm]; (c) flute-like aggregate (144.77 mbsf) [bar = 2 mm]; (d) dense aggregate of polychaete tubes completely dissolved at infilled (613.13 mbsf) [bar = 2 mm].

if the colonies encrusted a porous substrate, such as sponges. In the next upcore sample, the same types of fragments are less well preserved. Free colonies are not uncommon, as for example at 616.59 mbsf (Fig. 15b).

The top two bryozoan-containing samples contain poorly preserved (recrystallised and abraded) fragments of a somewhat diverse assemblage of sheet-forming colonies.

Genera of similar modern forms are the sheet-forming *Lageneschara*, *Acanthophragma* and *Exochella*, while the cylindrical branch-fragments of erect bryozoans are similar to modern *Polirhabdotos*, *Swanomia*, *Melicerita* and *Cellarinella*.

Echinodermata

Echinoid spines and minute shell fragments are recurrent in Tertiary marine sediments of Antarctica (Gaždzicki & Pugaczewska, 1984; Jonkers & Taviani, 1998; Taviani et al., 2000; Scherer et al., 2007; Quaglio et al., 2008) and were also identified in the AND-2 core. Platy fragments belonging to a crushed shell of an undetermined regular echinoid occur in the pectinid bed at 430.65 mbsf (Fig. 16a).

Crustacea (Cirripedia)

A few loose plates belonging to a large acorn cirriped similar to the extant *Bathylasma* were recovered; barnacle plates are remarkably resilient fossils and often occur in the Cenozoic of Antarctica (Gaždzicki & Pugaczewska, 1984; Scherer et al., 2007). However, the occasional material represented in AND-2A is mostly highly decalcified (see Panter et al., this volume), with only one exception at 986.01 mbsf (Fig. 16b).

Porifera

A bundle of connected spicules, intepreted as the remains of an undetermined sponge mat, was found at 377.25 mbsf in close association with a (decalcified) large pectinid (Fig. 17). Similar findings are quite scarce in the Tertiary drillcore record of Antarctica (Taviani et al., 2000), whereas loose spicules are abundant.

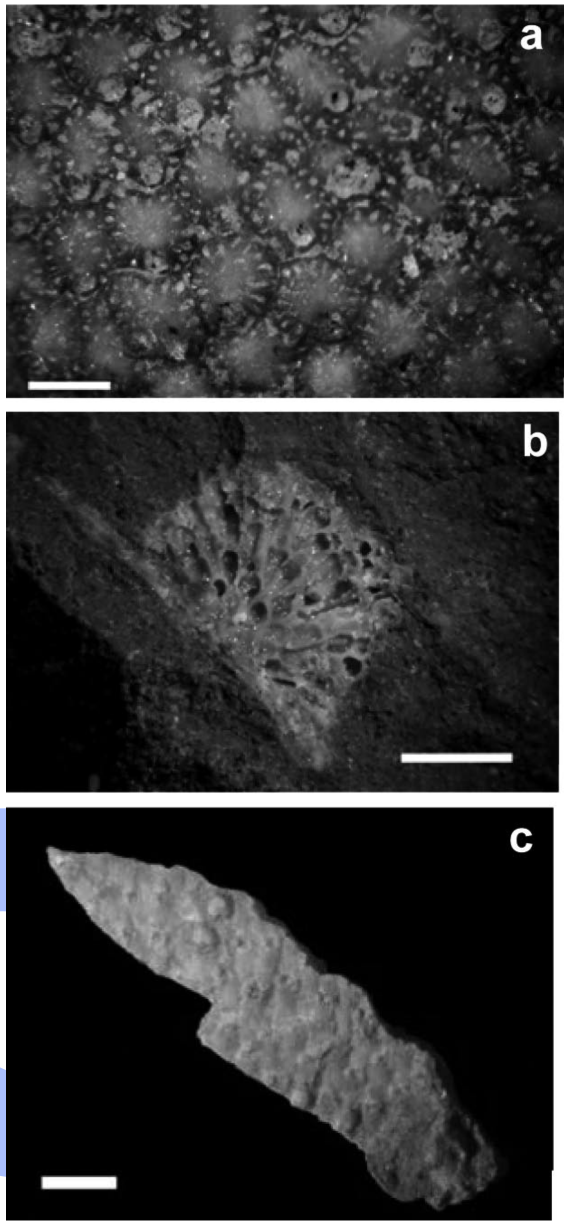


Fig. 15 – Bryozoa: (a) colony (cf. Exochella) encrusting a pectinid valve (430.65 mbsf) [scale bar = 0.5 mm]; (b) recrystallised bulbous colony of possible bryozoan (616.59 mbsf) [bar = 0.5 mm]; (c) basal view of unilamellar colony fragment, genus aff. Smittina, (617.03 mbsf) [scale bar = 0.5mm].

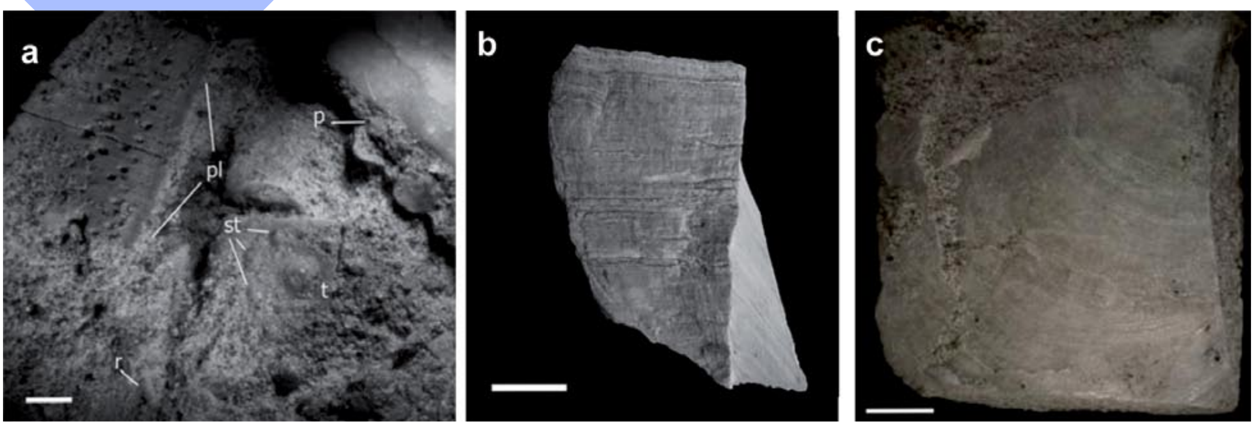


Fig. 16 – Other invertebrate fossils: (a) regular echinoid shell (430.65 mbsf) with plate fragments 'p', tubercle 't', scrobicular tubercles 'st' and spines 'r' [scale bar = 2 mm]; (b) large barnacle plate (986.01 mbsf) [scale bar = 5 mm]; (c) articulated terebratulid brachiopod (617.40 mbsf) [scale bar = 2 mm].

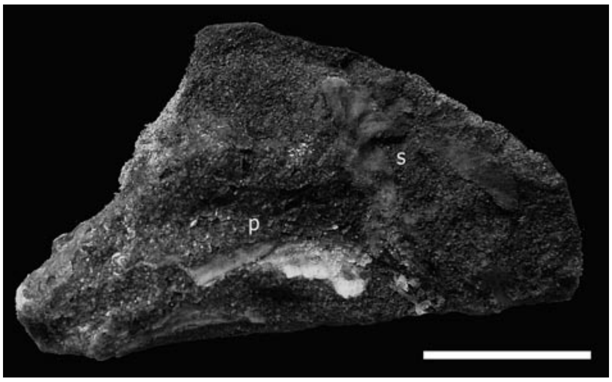


Fig. 17– Porifera: Sponge mat 's' (377.25 mbsf) in close association with a large pectinid 'p' bivalve, decalcified [scale bar = 1 cm].

Brachiopoda

Brachiopods are rarely recorded from Tertiary outcrop and drillcore records of Antarctica (Gaždzicki & Pugaczewsk, 1984; Taviani et al., 2000; Taviani & Beu, 2001; Scherer et al., 2007; Quaglio et al., 2008). In the AND-2A core they only occur in LSU9 at 616.27 and 617.40 mbsf where an almost complete articulated terebratulid brachiopod was identified (Fig. 16c).

Chordata (Pisces)

The record in AND-2 is limited to a few scales belonging to undetermined fishes mainly seen in smear slides.

Incertae sedis

Some macrofossil remains were too poorly preserved to assess their taxonomic position. The occurrence of cnidarians tentatively recorded by sedimentological logging could not be confirmed. A mould of a possible arthropod with a carbonaceus cuticle was observed at 136.04 mbsf. A 'chitinous' cross-shaped fossil at 857.30 mbsf is tentatively identified as a fish vertebra.

Macroplants

Carbonized plant macroscopic remains were observed rarely in the core (*e.g.* 517.86 mbsf), but are not considered further at this preliminary stage of investigation. The only relatively large fragment of coal will eventually be analysed for its potential taxonomic assessment by the off-ice palaeobotanist E. Kennedy. Individual and dispersed coal remains were sent to off-ice scientist S. Corrado to investigate vitrinite reflectance and related results are reported in the previous subsection of this report - Terrestrial lignin-rich organic matter.

DISTRIBUTION IN THE CORE

LSU 1*: 37.07 mbsf to the top of the section*

This interval is barren of macrofossils, with the exception of a fish scale seen in smear slide at 22.13 mbsf; no palaeoenvironmental or chronological information is available from macropalaeontology.

LSU 2*: 98.47 - 37.07 mbsf*

This interval contains indeterminable macrofossil fragments, tentatively ascribed in some cases to cirripeds and/or bivalves, possible polychaete tubes, and rare fish scales. The only recognisable macrofossils are polychaete tubes included in an intraclast at 95.65 mbsf. Macrofossils are all marine, but the impossibility of establishing their taxonomic position impedes any further environmental consideration. Their advanced dissolution, however, calls for their consideration as a likely source of carbonate re-precipitation as cement within the core.

No macrofossil of established ecobiostratigraphic significance has been identified in this interval. Polychaete tubes contained in the sedimentary intraclast at 95.65 mbsf are consistent with a Miocene age based upon similar records in CRP drillholes.

Some macrofossil fragments were extracted for Sr-dating, although very likely the original carbonate is altered.

LSU 3*: 122.86 - 98.47 mbsf*

This interval contains prevalent polychaete tubes and undeterminable macrofossil fragments, tentatively ascribed in some cases to barnacle cirripeds and/or bivalves. No further palaeo-environmental or chronological information can be proposed based upon macropalaeontology.

LSU 4*: 224.82 - 122.86 mbsf*

This unit is rich in macrofossils. The interval between c. 140-145 mbsf is particularly rich in calcareous benthic macrofossils, although rarely well-preserved and intact, suggestive of some transport and/or reworking. The most common fossils in this interval are polychaetes, followed by bryozoans (mainly detectable in thin sections) and bivalves.

The macrofossil content is dominated by polychaetes belonging to two dominant forms: individual tubes up to c. 1 cm in length, with annular growth rings reminiscent of *Serpula* s.l., and small gregarious sheet-like tube aggregates. Highly decalcified but recognizable large cirriped plates >3 cm, reminiscent of the extant *Bathylasma* acorn barnacle, were identified at 158.79 and 159.02 mbsf. Bivalves are also present, including pectinids at 208.96 mbsf.

Although transport cannot be ruled out within this diamictite-dominated sedimentary unit, the macrofossils are all open marine and interpreted as indicative of a shelfal setting. Some macrofossil fragments were selected for Sr-dating.

LSU 5*: 224.82 - 296.34 mbsf*

The macrofossil content is dominated by polychaete tubes (mostly recrystallized) showing a remarkable variety of shapes.

Although transport cannot be ruled out within this diamictite-dominated sedimentary unit, the macrofossils are all open marine and interpreted as indicative of a shelfal setting, perhaps under the episodic influx of turbid waters. Some macrofossil fragments were sampled for Sr-dating.

LSU 6*: 339.92 - 296.34 mbsf*

The macrofossil content is dominated by polychaete tubes, mostly recrystallised, showing a remarkable variety of shapes.

Although transport cannot be ruled out within this diamictite-dominated sedimentary unit, the macrofossils are all open marine and interpreted as indicative of a shelfal setting perhaps under the episodic influx of turbid waters.

LSU 7*: 436.18 - 339.92 mbsf*

This unit provided the most spectacular macropalaeontological documentation of the AND-2A core in terms of quality, quantity and significance of fossils.

Some lithologies of this unit bear remarkable mollusk content, at places even organised as discrete multi-cm-thick shell layers. Most productive lithologies are poorly cemented to loose sandy layers. Most noteworthy shell layers occur at 366.80 and 430.54 mbsf and consist of articulated pectinids. At least two species of pectinids occur in this unit, *i.e.* pectinid sp. (well-preserved shell at 366.80 mbsf) and costate pectinid at 430.54 mbsf. Remarkable is the occurrence of other mostly articulated bivalves (veneracean clam and hiatellid sp.), and gastropods, either as moulds (turritellid sp. at 377.61 mbsf) or chalky to well-preserved shells (buccinid, naticid, etc.). Polychaete tubes are present but not particularly common, together with sporadic occurrences of echinoids, bryozoans, sponges and possible barnacles. The palaeontological content of this unit is highly diagnostic of shallow-water subtidal environments at least episodically under-supplied by fine particles, as testified by a diverse benthic assemblage dominated by suspension feeders. An obvious corollary is the postulated presence of a substantial primary production (most likely diatoms) to support the bivalve populations. The biogeographical affinity of pectinids and veneraceans suggest non-extreme polar conditions when this LSU was deposited.

No age indications are evident from the fossils. The shells of pectinind sp. at 366.80 mbsf, indet. thick pectinid at 416.78 mbsf, veneracean at 428.44, 429.28, 429.30 and 430.49 mbsf, barnacle at 430.41 mbsf, are interpreted as pristine, and fragments were selected for Sr-dating.

LSU 8*: 607.35 - 436.18 mbsf*

Macrofossil content is dominated by polychaete tubes (size >2 cm), elongated and often in high numbers, with tubes parallel to bedding. Rare articulated semi-infaunal bivalves such as protobranchs (cf. Sareptidae sp., 543.15 mbsf), hiatellid sp. (546.06 mbsf), and pectinids (indet. at 568.72 mbsf, and costate pectinid, 605.61 mbsf), and bryozoans (at 568.00 mbsf) occur in this unit.

Macrofossils in this unit are all open marine and interpreted as indicative of a shelfal setting perhaps under the episodic influx of turbid waters. Local high organic content in the sediment may account for pyritisation of shells (*e.g.* cf. Sareptidae sp. at 543.15 mbsf: see figure x in Panter et al., this volume). The presence of pectinids might indicate times of reduced sediment supply (*e.g.* costate pectinid, 605.61 mbsf).

No age indications. The shell of a costate pectinid at 605.61 mbsf is interpreted as pristine and a fragment was selected for Sr-dating.

LSU 9*: 648.74 - 607.35 mbsf*

Macrofossil content is dominated by polychaete tubes, sheet-like bryozoans, undetermined bivalves and brachiopods.

Macrofossils from this unit are all open marine and interpreted as indicative of a shelfal setting perhaps under the episodic influx of turbid waters. Pectinids might indicate times of reduced sediment supply.

LSU 10*: 778.34 - 648.74 mbsf*

Macrofossil content is dominated by polychaete tubes, mostly recrystallised. Pectinids (cf. *Austrochlamys* sp. at 740.84 mbsf) and undetermined bivalves, often completely recrystallised.

The macrofossils are all open marine and interpreted as indicative of a shelfal setting perhaps under the episodic influx of turbid waters. Pectinids might indicate times of reduced sediment supply.

LSU 11*: 904.66 - 778.34 mbsf*

Macrofossil content is dominated by polychaete tubes, mostly recrystallized. Pectinids (costate pectinid at 783.96 and 800.93 mbsf, and possibly at 783.96 mbsf) and indeterminable bivalves, often completely recrystallised.

Macrofossils from this unit are all open marine and interpreted as indicative of a shelfal setting perhaps under the episodic influx of turbid waters. Pectinids might indicate times of reduced sediment supply.

LSU 12*: 996.69 - 904.66 mbsf*

Macrofossil content is dominated by polychaete tubes, mostly recrystallised. Uncommon pectinids (large, strongly costate *Austrochlamys* sp. at 917.39 mbsf, and a probable pectinid at 970.74 mbsf) and undetermined bivalves, often chalky.

Macrofossils in this unit are all open marine and interpreted as indicative of a shelfal setting perhaps under the episodic influx of turbid waters. Local high-organic content in the sediment may account for pyritisation of shells (*e.g.* pyritised bivalve and polychaete moulds at 960.48 mbsf). Pectinids might indicate times of reduced sediment supply (*e.g.* *Austrochlamys* sp. at 917.39 mbsf, and a probable pectinid at 970.74 mbsf) although reworking cannot be ruled out.

No age indications although *Austrochlamys* is compatible with a Miocene age.

***LSU 13**: 1040.28 - 996.69 mbsf*

Diffuse occurrence of bioturbation in this unit is a clear indication of marine habitats suitable to diverse benthic metazoan life. In spite of that, this unit held only a modest macropalaeontological content in the form of sporadic polychaete tubes and undetermined bivalve fragments.

Fossils are all marine but no detailed palaeoenvironmental or chronological information can be provided by macropalaeontology.

***LSU 14**: 1138.54 - 1040.28 mbsf*

Macrofossils here are all open marine and interpreted as indicative of a shelfal setting perhaps under the episodic influx of turbid waters. Pectinids might indicate times of reduced sediment supply.

No age indication possible, although *Adamussium* sp. cf. *A. alanbeui is* compatible with a Miocene age (Taviani & Beu, 2003). The shell of *Adamussium* sp. cf. *A. alanbeui* at 1063.71 mbsf is interpreted as pristine and a fragment was therefore selected for Sr-dating.

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Supplementary Information

The following supplementary information in tables and figures for this contribution are available on-line at the Terra Antartica website www.mna.it/english/Publications/TAP/terranta.html and at the ANDRILL data site www.andrill.org/data.

Supplementary table S1 - Sample intervals collected for foraminiferal analyses, the relative abundance of Foraninifera in the samples (Very Rare = 1-2; Rare = 3-5; Common = 6-15; Abundant = >15 specimens per split), and the state of preservation.

Supplementary table S2 - Distribution of macrofossils in AND-2A core with remarks on depth (mbsf), taxonomy, sample type, communal distribution.