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Chronostratigraphy of the CRP-3 Drillhole, Victoria Land Basin, Antarctica

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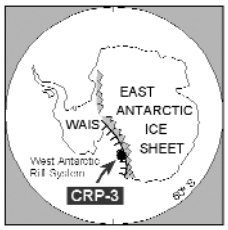

Abstract - An 823 m thick glaciomarine Cenozoic section sitting unconformably on the Lower Devonian Beacon Supergroup was recovered in CRP –3. This paper reviews the chronostratigraphical constraints for the Cenozoic section. Between 3 and 480.27 mbsf 23 unconformity bounded cycles of sediment were recorded. Each unconformity is thought to represent a hiatus of uncertain duration. Four magnetozones have been recognised from the Cenozoic section. The record is complex with several "tiny wiggles" recorded throughout. Biostratigraphical or Sr ages, which could be used to link these magnetozones to the magnetic polarity time scale are restricted to the upper 190 m of sediment. Two diatom datums (*Cavitatus jouseanus* at 48.9 mbsf and *Rhizosolenica antarctica* at 68.60 mbsf), together with five Sr-isotope dates derived from molluscan fragments taken from between 10.88 and 190.29 mbsf indicate an early Oligocene (*c*. 31 Ma) age for this interval. The appearance of a new species of the bivalve ?*Adamussium* at about 325 mbsf, suggests that the Oligocene age can be extended down to this level. This confirms that the dominantly reversed magnetozone (R1), recorded down to about 340 mbsf, is Chron C12r. The ages imply high sedimentation rates and only minimal time gaps at the sequence boundaries. Below 340 mbsf there are no independent datums to guide the correlation of the magnetozones to the magnetic polarity time scale. However, the absence of *in situ* dinocysts attributable to Transantarctic Flora, if not a result of environmental control, limits the age of the base of the hole to between *c*. 33.5 and 35 Ma.

INTRODUCTION

This paper summarises the current state of the chronostratigraphy for the CRP -3 hole, drilled to a depth of 939 meters below the sea floor (mbsf) in the Victoria Land Basin, western Ross Sea with a core recovery of 97% (all basic well data from Cape Roberts Science Team, 2000). One of the aims of the Cape Roberts Project was to core and sample the oldest Cenozoic sediments in the basin in order to document the onset of Antarctic glaciation. The coring of the oldest Cenozoic strata was achieved when the Beacon Sandstone, of Early Devonian age, was encountered at 823.11 mbsf. The overlying Cenozoic strata consist of mostly shallow marine sandstone and minor conglomerate, with increasingly well-developed mudstone-bearing sequences above 330 mbsf. The strata show some degree of glacial influence throughout the core.

A preliminary assessment of the chronostratigraphy of CRP-3 above 350 mbsf is provided in the initial report (Cape Roberts Science Team, 2000). This preliminary age assessment was based largely on biostratigraphical data collected during the core characterisation phase, extended by palaeomagnetic data to 350 mbsf. All biostratigraphical data used were recorded from above *c*. 195 mbsf.

Diatom analysis suggested that the sediments above 68.6 mbsf are early Oligocene in age with a maximum numerical age of 33 Ma. Analysis of the diagenetically altered siliceous microfossil assemblages recovered from between *c*. 70 and 195 mbsf suggested that the interval was younger than Chron C13n (all numerical ages and linkages refer to the magnetic polarity time scale from Berggren et al., 1995). The identification of the last appearance datum (LAD) of the nannofossil species *Transversopontis pulcheroides* at 114.3 mbsf suggested a minimum age of 32.4±0.5 Ma for this horizon.

An initial characterisation of the magnetostratigraphy of the upper 340.8 m of core showed that the magnetic polarity record is dominated by reversed polarity. Several thin (<20 m) intervals of normal polarity were recorded within this interval. It is possible that these short-period polarity intervals

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represent "tiny wiggles" which are increasingly recorded in Eocene and Oligocene marine magnetic anomaly profiles (Cande & Kent, 1992). Using the rather sparse biostratigraphical control for the upper 195 m the entire period of dominantly reverse polarity was thought to represent part of Chron C12, of early Oligocene age.

Sequence stratigraphical analysis delineated 23 unconformity-bounded sequences between the top of the hole and 480.27 mbsf. Although sediments from below 480.27 mbsf do show clear evidence of repetitions of distinct lithologies, no cycles could be confidently identified. The sequence boundaries documented above 480.27 mbsf are thought to be the distal equivalents of the "glacial surfaces of erosion" recorded in CRP 2/2A (Cape Roberts Science Team, 1999; Fielding et al., 2000) and as such represent hiatuses of unknown length.

The present assessment of the chronostratigraphy of CRP-3 is based on the subsequent post-drilling research. Key additional chronostratigraphical data include 5 Sr age determinations (Lavelle, this volume), additional palaeontological evidence – in particular macrofossils (Taviani & Beu, this volume), and palynology (Hannah et al., this volume; Raine & Askin, this volume), and magnetostratigraphical data down to 790 mbsf, the top of the basal Cenozoic conglomerate (Florindo et al., this volume). Unfortunately most additional chronostratigraphical datums are recorded from the upper 350 m of core. All relevant data are discussed below and tabulated in table 1. Figure 1 plots the position of chronostratigraphical data against the core log and a portion of the magnetic polarity time scale (MPTS) of Cande & Kent (1995).

BIOSTRATIGRAPHY

DIATOMS AND NANNOFOSSILS

The first appearance datum (FAD) of *Cavitatus jouseanus* is recorded at 48.44 mbsf (Harwood & Bohaty, this volume). This datum occurs at or near the boundary between Chrons C12n and C12r (Harwood & Maruyama, 1992; Baldauf & Barron, 1991; Barron et al., 1991). Harwood & Bohaty (this volume) suggest a numerical age for the datum of 30.9 Ma. The FAD of *Rhizosolenia antarctica* at 68.60 mbsf is coincident with a significant and permanent down-hole deterioration in the preservation of diatom assemblages. The position of this FAD in the core may reflect the evolutionary appearance of *Rhizosolenica antarctica* or it may be due to a preservational change. Harwood & Bohaty (this volume) suggest a numerical age of 33.1 Ma for this datum, but, because of the likely influence of preservation on the position of the datum, it should be regarded as providing maximum age only.

The calcareous nannofossil *Transversopontis pulcheroides* has its LAD at 114.3 mbsf coincident with a peak in nannofossil abundance. Wise (1983) places this datum in the middle of the *Blackites spinosus* zone on the Falkland Plateau, suggesting a numerical age of 32.4 ± 0.5 Ma.

MACROFOSSILS

A new species of a scallop assignable to the genus *Adamussium* has been recorded from between *c*. 20 and *c*. 325 mbsf (?*Adamussium* n. sp., Taviani & Beu, this volume). All known species of *Adamussium* have

Tab. 1 - Chronostratigraphical data from the CRP-3 drill hole. It was considered that specimens of the Transantarctic Flora were not *in situ* because of their low numbers, sporadic distribution and often fragmentary preservation.

Biostratigraphy

Group	Datum Type	Species	Depth in hole (mbsf)	Age (Ma)
Diatoms	FAD	*Cavitatus jouseanus*	48.44	30.9
	FAD	*Rhizosolenia antarctica*	68.60	<33.1
Nannofossils	LAD	*Transversopontis pulcheroides*	114.3	32.4 ± 0.5
Macrofossils	Single Appearance	*Flabellum rariseptatum*	140.69	Oligocene
	FAD	? *Adamussium* n.sp.	*c*. 325	Oligocene

Strontium

Datum	Sample	Depth in hole (mbsf)	Age (Ma)	Error (+)	Error (-)
Sr1	Modioilid bivalve (*in situ*)	10.88	30.9	0.8	0.8
Sr2	Pectinid bivalve (uncertain)	29.94	31.0	0.7	0.8
Sr3	Pectinid bivalve (uncertain)	47.55	30.9	0.8	0.8
Sr4	Pectinid bivalve (uncertain)	190.29	31.0	0.7	0.8
Sr5	Pectinid bivalve (uncertain)	190.29	31.3	0.8	0.8

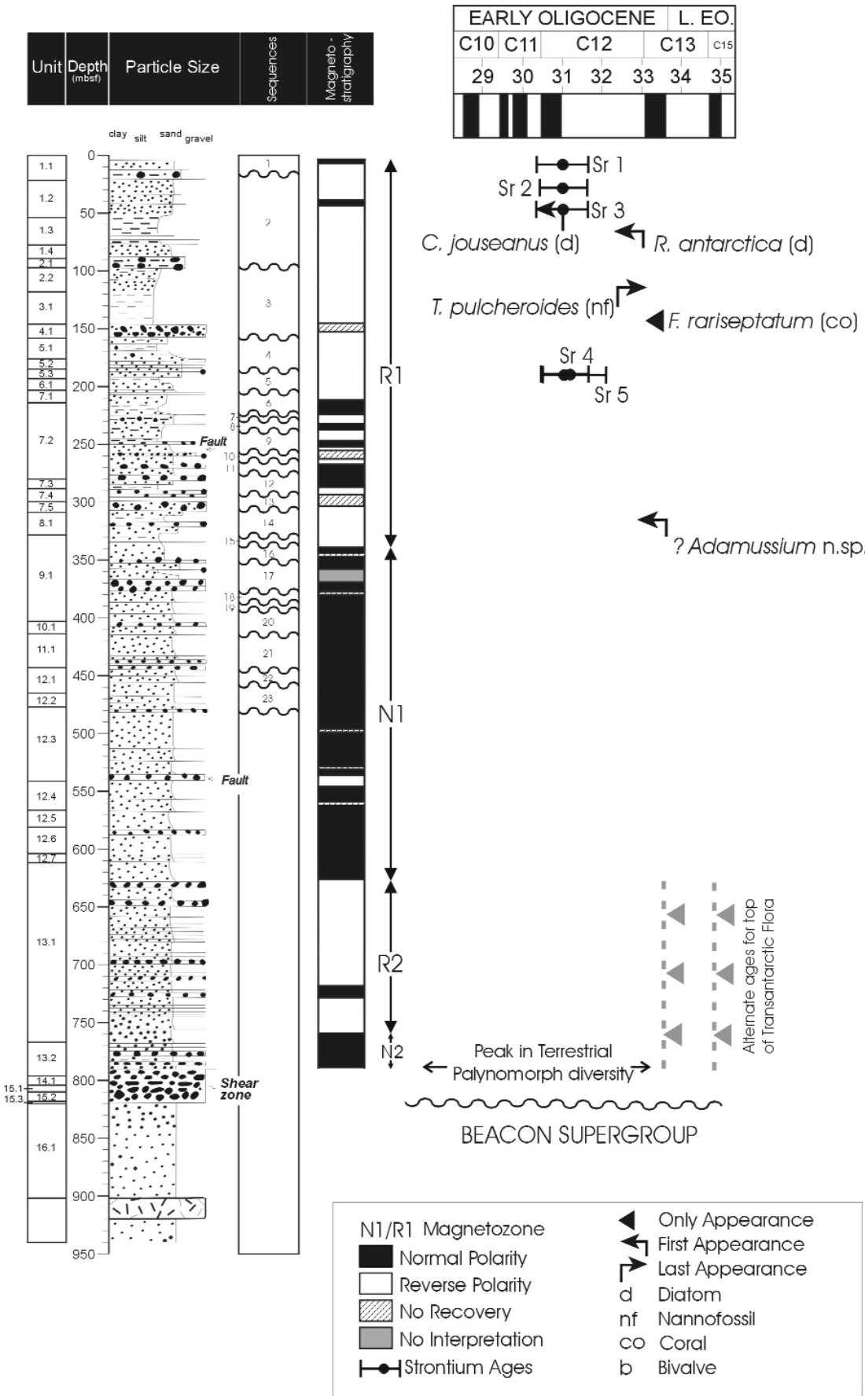

Fig. 1 - Chronostratigraphical constraints for CRP-3. The stratigraphical column with lithostratigraphical units and sequence boundaries from Cape Roberts Science Team (2000). See text for sources of all chronostratigraphical data. Because of the scarcity of these data no unique age/depth model can be drawn. The horizontal bar on the biostratigraphical datums is placed at the sample containing the event.

a circum-Antarctic distribution and are restricted to Oligocene and younger sediments. The solitary coral, *Flabellum rariseptatum*, has been recorded from Oligocene sediments on the Antarctic Peninsula and the Lower Miocene of King George Island (Stolarski & Taviani, this volume). In CRP-3 this coral is found in a single sample from 140.69 mbsf suggesting that this horizon can be no older than Oligocene.

MARINE PALYNOLOGY

Good to moderately well-preserved marine palynomorph assemblages, including dinoflagellate cysts (dinocysts) were recovered down to *c*. 330 mbsf, with an additional well-preserved assemblage at 781.36 mbsf (Cape Roberts Science Team 2000, Hannah et al., this volume). Most dinocyst species are new and until fully documented, they offer little to the chronostratigraphy of the drill hole. However, it is significant that no *in situ* specimens of species assignable to the Transantarctic Flora (Wrenn & Hart, 1988) were identified in any of the 82 samples from CRP -3. This well documented assemblage is widely known from the Antarctic region (Wilson, 1967, 1989; Goodman & Ford, 1983; Truswell 1986; Wrenn & Hart, 1988; Hannah, 1997). The assemblage has long been considered as mid Eocene to early Oligocene in age (Wilson, 1967; Wrenn & Hart, 1988; Raine et al, 1997). An LAD for an *in situ* dinocyst assemblage dominated by constituents of the Transantarctic Flora, was recognised in CIROS–1 at 455 mbsf, and dated as earliest Oligocene-Chron C13r, (Hannah et al., 1997). Wilson et al. (1998), on the other hand, dated the same horizon as latest Eocene-Chron C15n. Nevertheless, the absence of any *in situ* members of the Transantarctic Flora in CRP–3 suggests that the base of the Cenozoic sequence in CRP-3 is latest Eocene or younger in age.

It could be argued that in CRP-3 there are very few marine palynomorphs at all below *c*. 330 mbsf and the absence of the Transantarctic Flora may be a result of palaeoenvironmental factors. Palaeo-environmental control of the appearance of the Transantarctic Flora is not considered likely for the following reasons.

1. There are *in situ* dinocysts present in the lower part of the hole. Samples at 781.36 mbsf in a mudstone and at 788.69 mbsf in a sandstone contain significant numbers of a previously undescribed species of dinocyst (Dinocyst E, Hannah et al., this volume), indicating that the environment was suitable for both the growth and preservation of dinoflagellates.
2. Species representing the Transantarctic Flora have been found in sediments representing a wide variety of environments, including sandy beds on Seymour Island, which were thought to represent very shallow marine conditions (Wrenn & Hart 1988).

TERRESTRIAL PALYNOLOGY

The abundance of Cenozoic miospores is variable down to *c*. 370 mbsf. Below this level most samples are barren, with a few samples yielding only sparse assemblages (Raine & Askin, this volume). Although most of these assemblages do not represent the "warm–Eocene" floras expected in preglacial conditions, one sample at *c*. 781 mbsf yielded a surprisingly diverse assemblage of terrestrial palynomorphs including *Casuarina*-type pollen. This could reflect the development of a significant terrestrial flora on the continent, expected during warmer Eocene time. However, the low numbers of individuals recovered (12) and a peak in recycled Mesozoic palynomorphs in the same sample suggests that reworking of Eocene forms from older strata is a more likely explanation for the apparent increase in diversity.

STRONTIUM DATES

Sr-isotope ratios from five molluscan shell fragments from four stratigraphical levels were recorded (Lavelle, this volume). Single shell fragments were taken from 10.88 (S1), 29.94 (S2), and 47.55 (S3) mbsf. Two shell fragments were taken from 190.20 mbsf (S4 and S5). Careful examination indicates that all analysed shell material is not diagenetically altered. As the samples are mostly fragments, only S1 can be confidently identified as *in situ*. However, the consistency of the age determination over about 190 m of core suggest that sediment accumulation was extremely rapid and that very little time is unrecorded at the sequence boundaries. Comparison with the marine Sr isotope curve of Howarth and McArthur (1997) suggests that the best fit age for *all* shell fragments is 31.0 (+0.7, -0.8) Ma.

MAGNETOSTRATIGRAPHY

RESULTS

Post-drilling analysis of the palaeomagnetic properties of the core has established a complete magnetostratigraphy for the Cenozoic sequence down to *c*. 790 mbsf (Florindo et al, this volume). Two periods of dominantly reversed polarity R1 (3-340.8 mbsf) and R2 (627.3-760.0 mbsf) and two of normal polarity N1 (340.8-672.3 mbsf) and N2 (760.2-788.8 mbsf) were recognised. The record is complex and magnetozones R1, N1 and R2 contain thin intervals with opposite polarity (cryptochrons) which are interpreted to represent "tiny wiggles" previously identified in marine magnetic anomaly profiles (Cande & Kent, 1992).

CORRELATION TO THE MAGNETIC POLARITY TIME SCALE (MPTS)

As noted in the CRP-3 Initial Report (Cape Roberts Science Team, 2000), biostratigraphic data clearly correlate magnetozone R1, the long dominantly reverse polarity interval at the top of CRP-3 drill hole, with Chron C12r. This is also consistent with the Sr isotopic age of 31.0 Ma. Below *c*. 310 mbsf there are no unambiguous independent data to guide the correlation of the magnetozones to the MPTS. Florindo et al. (this volume) suggest that magnetozone N1, which underlies magnetozone R1, represents Chron C13n. Magnetozone R2 is then assumed to represent at least part of Chron 13r. Because the base of magnetozone N2 is also the base of the sampled section, its true thickness is unknown. Florindo et al. (this volume) follow the most conservative course and treat it as a transient period of normal polarity thus extending Chron C13r down almost to the base of the Cenozoic sequence, and implying an age no older than 34.8 Ma. Palaeomagnetic analysis on its own thus suggests that the base of the drill hole is late Eocene in age. A maximum numerical age of about 35 Ma is possible, if magnetozone N2 represents part of Chron C15n.

TOWARDS AN AGE MODEL FOR CRP-3

Figure 1 sets out the chronostratigraphical parameters for an age model of CRP-3. Most of the well-documented datums occur within the upper 190 meters of the hole. Because the core below *c*. 190 mbsf contains no reliable positive chronostratigraphical age constraints no age-depth curve can be drawn.

The Sr dates indicate that the interval from 10 to 190 mbsf is about 31Ma in age. This is consistent with most biostratigraphical datums. An exception is the LAD of the nannofossil *T. pulcheroides* which is considerably older than the dates implied by the Sr analysis, suggesting that this species is reworked in CRP–3. The 31 Ma age suggested by the Sr data implies that the upper half of R1 represents only the very youngest part of Chron C12r. The presence of ? *Adamussium* n. sp down to *c*. 325 mbsf confirms the Chron C12r assignment to the base of magnetozone R1. The sparse chronostratigraphical datums from the top of the hole suggest that sediment must have accumulated very rapidly, consistent with an early rift setting.

No other well dated chronostratigrapical datums are available to constrain the rest of the Cenozoic section. If, as seems likely, the lack of the Transantarctic Flora does have time significance, then some estimates of the maximum age for the base of the Cenozoic sequence can be made. Wilson et al. (1998) suggested a late Eocene (Chron C15n) age for the top of the Transantarctic Flora in CIROS –1. This implies a maximum age of Late Eocene-35 Ma for the Cenozoic sequence in CRP-3. This is consistent with the palaeomagnetic interpretation of Florindo et al., (this volume). The younger, Chron C13n, age for the same biostratigraphic datum in CIROS-1, interpreted by Hannah et al. (1997) puts a maximum age of earliest Oligocene-33.5 Ma on the base of the Cenozoic sequence. This is at odds with the correlation of magnetozones R2 and N2 with Chron C13r of the MPTS (Florindo et al., this volume) suggesting instead that Chron C13n extends to the base of the Cenozoic sequence in CRP-3. Thus the age of the base of the Cenozoic sequence in CRP-3 probably lies somewhere between *c*. 33.5 and 35 Ma, but require further data to narrow the range.

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