Terra Antartica
2000, 7(4), 461-472

TERRA ANTARTICA

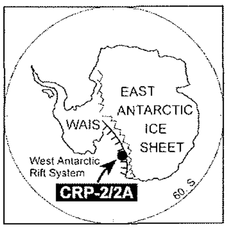
Oligocene and Miocene Foraminifera from CRP-2/2A, Victoria Land Basin, Antarctica

C.P. STRONG[1*] & P.N. WEBB[2]

[1]Institute of Geological & Nuclear Sciences, P.O. Box 30 368, Lower Hutt - New Zealand
[2]Department of Geological Sciences, The Ohio State University, Columbus, OH 43210 - USA

**Corresponding author* (p.strong@gns.cri.nz)

Received 31 August 1999; *accepted in revised version* 31 May 2000



Abstract - Sparse to moderately abundant foraminiferal assemblages from Oligocene and Lower Miocene sediments in the CRP-2/2A drillhole contain *C.*27 genera and 42 species of calcareous benthic foraminifera. No planktic or agglutinated taxa were observed. On the basis of their faunal characteristics, four Foraminiferal Units are defined in drillhole succession: Foraminiferal Unit I (26.91-193.95 mbsf), mostly sparse assemblages with *Elphidium magellanicum* and *Cribroelphidium* sp.; Foraminiferal Unit II (193.95-342.42 mbsf), mostly moderately abundant assemblages with *Cassidulinoides aequilatera* and *Eponides bradyi*; Foraminiferal Unit III (342.42-486.19 mbsf), moderately abundant to sparse assemblages characterised by *Cassidulinoides chapmani* and *Stainforthia* sp.; and Foraminiferal Unit IV, Impoverished (486.19-624.15, total depth, mbsf), with mostly barren residues, but with large Milioliidae recorded *in situ* at various horizons in the drill core.

Foraminiferal Units I-IV lack taxa allowing correlation to standard zonal schemes. Inspection of faunal records from CIROS-1 and DSDP 270 indicates that, although the faunas show an overall similarity, CRP-2/2A Foraminiferal Units I-IV are not identifiable at these sites. The units are therefore most likely to reflect local environmental changes, and probably will prove useful for local correlation, but their lateral extent is undetermined.

All four assemblages apparently represent various glacially-influenced shelf environments, and appear to reflect a long term deepening trend from Units IV to II, from perhaps inner to mid or outer-shelf depths, followed by a return to shallower, inner shelf, conditios for Unit I.

INTRODUCTION

Oligocene and Lower Miocene sediments of the CRP-2/2A drillhole at Cape Roberts, West Victoria Land Basin, yielded a fauna of *c.* 27 genera and 42 species of foraminifers (Tab. 1). The fauna comprises sparse to moderately abundant foraminiferal assemblages of low to very low diversity, consisting solely of calcareous benthic taxa, and apparently reflecting less than optimal marine conditions. These species are employed to subdivide the drillhole sequence into four distinctive Foraminiferal Units (Fig. 1). The taxa are briefly described, their stratigraphic occurrences are recorded, and selected, characteristic forms are illustrated with SEM photomicrographs.

The CRP-2 and -2A wells were drilled during October and November, 1998, with both being drilled at the same point on the sea-floor. CRP-2 was drilled to a total depth of *c.* 57 mbsf (metres below sea floor), at which point the sea-riser was reset to correct mud loss problems. The hole was then re-drilled and completed as CRP-2A. [See CRP Science Team, 1999, for more details of the drilling history.] There is about 6 m of overlap at between CRP-2 and CRP-2A samples in upper lithostratigraphical Unit 5.1, but since all samples contain similar faunas they are simply intercalated for this report.

The Oligocene and Miocene section in CRP-2/2A occupies the interval from 26.79 mbsf (metres below sea-floor) to 624.15 mbsf, the maximum penetration of the drillhole (Fig. 1). It comprises mainly muddy sandstones, sandy mudstones and diamictites, which were deposited in glacially-influenced marine environments. In the lithostratigraphic classification adopted for the drillhole (CRP Science Team 1999), the top of the Miocene is placed at the unconformable contact between Unit 2.2, yellow-brown Pliocene sandstone, and Unit 3.1, dark grey, Lower Miocene muddy sandstone (26.79 mbsf in CRP-2; 27.14 mbsf in CRP-2A).

MATERIALS AND METHODS

Foraminiferal samples, covering the interval from 34.28 to 623.77 mbsf, were selected from CRP-2/2A cores and were processed and initially examined at Crary Science and Engineering Center (CSEC), McMurdo Station. They were further studied after the drilling season at the Institute of Geological & Nuclear Sciences (GNS), Lower Hutt, New Zealand. The foraminiferal sample suite comprises 135 samples, of which 73 proved fossiliferous. The samples include: a) 32 "Fast-track" samples, taken by the site geologist at Cape Roberts for immediate analysis; b) 93 samples selected by CPS or PNW during core examination at CSEC; c) 4 macrofossil matrix samples provided by M. Taviani.; and d) 6 *in situ* observations of large miliolid foraminifers.

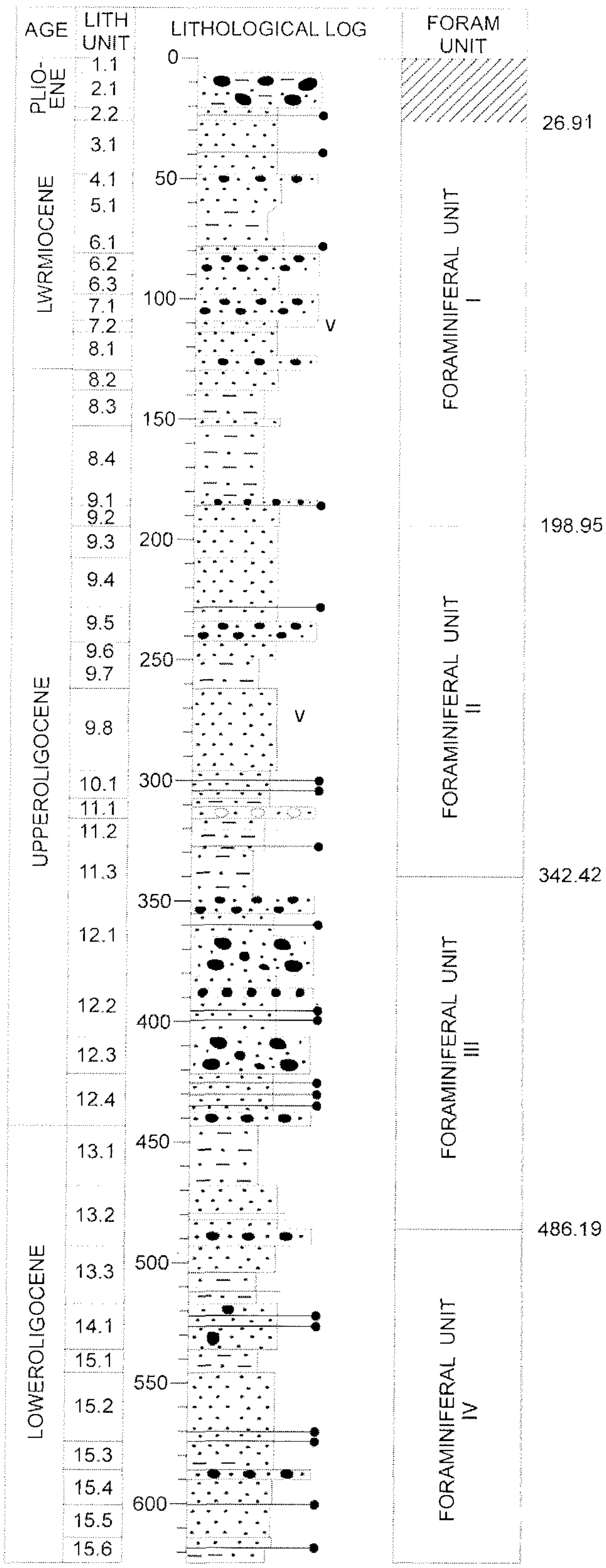


Fig. 1 - CRP-2/2A stratigraphy and biostratigraphy, showing adopted ages and relations of foraminiferal and lithological units.

Core sampling at CSEC was selective, since fine-grained sediments were considered the most likely to contain foraminifers; there was no attempt to sample all the lithotypes present. Diamictites, for example, were avoided, as earlier experience had shown them to be almost universally unfossiliferous. During core inspection, most samples were chosen from finely sandy to silty mudstones, which typically were the finest-grained lithology available. Samples, most weighing 50-100 g (undried) and representing *c.* 5 cm of core, were processed using standard techniques, and the resulting residues wet-sieved into >500 mm, >125 mm , >63 mm and <63 mm fractions. After drying, the first 3 fractions were examined for microfossils, and the last reserved for other studies. All fossil material, including sponge spicules, diatoms, shell fragments, etc., observed during picking was recorded (see Tab. 1), but samples lacking foraminifers are considered here to be "non-fossiliferous".

Most foraminifers were found to occur in the 125 - 500 mm residue, and systematic searches therefore focussed on this fraction. In addition, all >500mm residue was scanned for large specimens, and a portion of 63-125 mm material was examined for *c.* 5 minutes to determine if tiny foraminifers or other microfossils (e.g., diatoms) were present, and searched more extensively if specimens were encountered. When there was a large amount of >125 mm residue, the sample was subdivided, using a microsplitter, to yield at least 2 well covered (9 x 5 cm) picking trays (usually 1/4 to 1/8 of total residue) for examination. Absence of foraminifers upon completing this search routine defines the minimum criterion for determining a sample to be non-fossiliferous. The number of specimens shown in table 1, in most cases, represents individuals recovered from two to four trays of residue.

Preservation was visually estimated using the following criteria:

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

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

Poor—Test microstructure strongly altered to unrecognisable, extensively recrystallised or decorticated, may be preserved as steinkern only, test broken or distorted.

BIOSTRATIGRAPHY

Oligocene and Lower Miocene strata in CRP-2/2A contain four characteristic foraminiferal assemblages, distinguished by their taxonomic composition and overall character. They were described briefly in the Initial Report, and are discussed further below. The assemblages occupy successive parts of the CRP-2/2A sequence, and are designated as Foraminiferal Units I-IV (Cape Roberts Science Team 1999). Figure 1 shows their relationship to the lithostratigraphical units adopted for the drillhole (Cape Roberts Science Team, 1999). All assemblages comprise only calcareous benthic taxa; neither planktic nor agglutinated species were recorded in the Oligocene-Miocene section of CRP-2/2A. All foraminiferal taxa identified from CRP-2/2A are listed in table 1.

It is noted that some foraminiferal names used provisionally in the Initial Report for CRP-2/2A have been revised in the light of further work. These changes are noted below where appropriate.

Tab. 1 - Occurrence of foraminifera and other microfossils in CRP-2/2A Lithological units, degree of preservation, number of specimens recovered, and number of species per sample are also shown. In most cases, the number of specimens indicated were recovered from 2-4 trays of >125 mm residue. All CRP-2 samples are listed first, followed by CRP-2A samples, beginning with 52.88 mbsf. See text for preservation criteria.

	FORAMINIFERAL UNIT I																					
UNIT	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	4.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
BASE	26.93	28.06	29.00	31.03	33.37	36.09	36.28	36.38	37.54	40.12	41.15	47.54	51.73	52.69	54.36	57.42	52.96	55.76	56.68	61.46	63.83	64.75
TOP	26.91	28.00	28.95	30.95	33.29	36.05	36.24	36.30	37.49	40.04	41.07	47.41	51.72	52.63	54.28	57.32	52.88	55.68	56.61	61.38	63.80	64.67
Preservation				F	G	F						F	F		F	G	P		P	P	G	G
No. of species	0	0	0	2	2	1	0	0	0	0	0	1	1	0	6	1	0	0	1	9	5	5
SPECIES No. specimens:	NF	NF	NF	2	3	2	NF	NF	NF	NF	NF	1	1	NF	13	1	NF	NF	1	20	30	17
Ammoelphidiella pustulosa																				cf.		
Ammoelphidiella uniforamina																						
Ammoelphidiella sp.															X							X
Anomalinoides sp.																					X	
Bulimina sp.																						
Cassidulinoides aequilatera																						
Cassidulinoides braziliensis																						
Cassidulinoides chapmani																						
Cibicides lobatulus																						cf.
Cibicides refulgens																						
Cibicides spp.																						
Cribroelphidium sp.				X	X	X						X								X	X	
Elphidium excavatum gr.				X																		
Elphidium magellanicum															X					X	X	X
Epistominella exigua																						
Eponides bradyi																						
Fissurina bisulcata																						
Fissurina sp.					X																	
Fursenkoina schreibersiana																				X		
Lenticulina sp.																						
Marginulina tumida																						
Marginulina sp.																						
Marginulinopsis sp.																						
Melonis affinis																						
Melonis barleeanum																						
Miliolidae, large (*Pyrgo* spp)													X		X							
Nodosaria spp.																						
Nonionella bradii															X					X		
Nonionella iridea																			?	X	X	X
Nonionella magnalingua																						
Oolina apiculata															X					X	X	
Oolina globosa																						
Parafissurina lateralis																						
Pseudonodosaria symmetrica																						
Pullenia subcarinata															X	X				X		
Pullenia spp.																						
Pyrulinoides sp.																						
Quinqueloculina seminula																						cf.
Quinqueloculina tringularis																						
Rosalina globularis																						
Stainforthia sp.																						
Vaginulinopsis sp.																						
Diatoms				X								X			X				X	X		X
Echinoderm debris				X		X				X								X				X
Ostracods																						X
Shell fragments						X	X								X	X			X	X		X
Sponge spicules			X	X	X	X	X			X		X						X	X	X		

UNIT	5.1	5.1	5.1	6.1	6.1	6.1	6.1	6.1	6.3	6.3	6.3	6.3	7.1	7.2	7.2	7.2	7.2	8.1	8.1	8.1	8.1	8.1
BASE	68.20	71.22	71.47	75.67	76.12	80.04	80.58	80.68	91.59	94.84	96.76	96.84	107.77	109.24	110.64	111.09	113.63	114.80	118.61	118.92	122.65	122.92
TOP	68.12	71.13	71.42	75.60	76.04	79.96	80.55	80.65	91.51	94.76	96.71	96.79	107.69	109.17	110.56	111.03	113.55	114.72	118.53	118.84	122.57	122.84
Preservation	G	F	F	P	F				P	P	G	G						F			P	
No. of species	1	10	1	1	2	0	0	0	5	1	4	6	0	0	0	0	0	4	0	0	1	0
SPECIES No. specimens:	7	60	1	1	5	NF	NF	NF	8	1	6	18	NF	NF	NF	NF	NF	7	NF	NF	1	NF
Ammoelphidiella pustulosa																						
Ammoelphidiella uniforamina		X									X	X										
Ammoelphidiella sp.																						
Anomalinoides sp.																						
Bulimina sp.																						
Cassidulinoides aequilatera																						
Cassidulinoides braziliensis																						
Cassidulinoides chapmani																						
Cibicides lobatulus																						
Cibicides refulgens																						
Cibicides spp.									X													
Cribroelphidium sp.		X							X			X										
Elphidium excavatum gr.																		X			?	
Elphidium magellanicum		X	X		X				X		X							X				
Epistominella exigua											X	X						X				
Eponides bradyi																						
Fissurina bisulcata																						
Fissurina sp.																						
Fursenkoina schreibersiana		cf.																				
Lenticulina sp.																						
Marginulina tumida																						
Marginulina sp.																						
Marginulinopsis sp.																						
Melonis affinis																						
Melonis barleeanum																						
Miliolidae, large (*Pyrgo* spp)										X												
Nodosaria spp.				X																		
Nonionella bradii		X																				
Nonionella iridea	X	X			X																	
Nonionella magnalingua		X																				
Oolina apiculata		X																				
Oolina globosa		X							X													
Parafissurina lateralis												X										
Pseudonodosaria symmetrica		X																				
Pullenia subcarinata		X							X		X	X						X				
Pullenia spp.																						
Pyrulinoides sp.		X																				
Quinqueloculina seminula												X										
Quinqueloculina tringularis																						
Rosalina globularis																						
Stainforthia sp.																						
Vaginulinopsis sp.																						
Diatoms			X								X					X	X		X			X
Echinoderm debris																						
Ostracods	X	X																				
Shell fragments		X	X	X				X			X	X										
Sponge spicules						X		X	X	X	X	X		X	X	X	X	X	X	X	X	X

UNIT	8.1	8.2	8.2	8.2	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
BASE	123.52	130.78	131.90	136.92	139.52	144.55	145.66	147.93	149.36	149.52	150.77	155.12	158.48	159.93	161.06	163.06	164.50	166.98	169.04	171.12	178.04
TOP	123.44	130.73	131.82	136.84	139.44	144.47	145.58	147.85	149.29	149.48	150.71	155.04	158.38	159.85	160.98	162.98	164.42	166.90	168.96	171.04	177.89
Preservation	F	F	F	F	P		G								F	F	F	F	G	P	P
No. of species	4	2	4	5	4	0	4	0	0	0	0	0	0	0	4	2	1	1	7	1	2
SPECIES No. specimens:	4	4	9	16	7	NF	17	NF	NF	NF	NF	NF	NF	NF	6	2	1	1	9	2	2
Ammoelphidiella pustulosa																					
Ammoelphidiella uniforamina																					
Ammoelphidiella sp.							X												X		
Anomalinoides sp.																					
Bulimina sp.																					
Cassidulinoides aequilatera																					
Cassidulinoides braziliensis																					
Cassidulinoides chapmani																					
Cibicides lobatulus	X																				
Cibicides refulgens																					
Cibicides spp.															?						
Cribroelphidium sp.			X	X	?														X		?
Elphidium excavatum gr.																					
Elphidium magellanicum		X	X	X			cf.									X			X		
Epistominella exigua	X		X		X		X								X				X		
Eponides bradyi																					
Fissurina bisulcata																					
Fissurina sp.																					
Fursenkoina schreibersiana															X						
Lenticulina sp.																	X				
Marginulina tumida																			X		
Marginulina sp.																					
Marginulinopsis sp.																					
Melonis affinis				cf.																	
Melonis barleeanum																					
Miliolidae, large (*Pyrgo* spp)																					
Nodosaria spp.																					
Nonionella bradii	X																				
Nonionella iridea	X				X										?	?			?	?	
Nonionella magnalingua																					
Oolina apiculata																					
Oolina globosa																					
Parafissurina lateralis																					
Pseudonodosaria symmetrica																					
Pullenia subcarinata		X	X	X	X													?	X		?
Pullenia spp.																					
Pyrulinoides sp.																					
Quinqueloculina seminula							X														
Quinqueloculina tringularis																					
Rosalina globularis																					
Stainforthia sp.																					
Vaginulinopsis sp.																					
Diatoms	X			X	X											X	X	X	X		X
Echinoderm debris																					
Ostracods																				X	
Shell fragments		X														X		X		X	
Sponge spicules	X	X	X	X																	X

Tab. 1 - Continued.

UNIT I cont'd						FORAMINIFERAL UNIT II																																				FORAMINIFERAL UNIT III																					FORAMINIFERAL UNIT IV								
8.4	8.4	8.4	8.4	9.1	9.1	9.3	9.3	9.3	9.3	9.4	9.4	9.4	9.4	9.4	9.4	9.5	9.5	9.5	9.5	9.6	9.7	9.7	9.8	9.8	9.8	9.8	9.8	9.8	10.1	10.1	10.1	11.1	11.1	11.2	11.2	11.2	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3	12.1	12.1	12.2	12.2	12.2	12.2	12.3	12.4	13.1	13.1	13.1	13.1	13.1	13.1	13.2	13.2	13.2	13.3	14.1	15.1	15.2	15.3	15.4	15.5	15.6	15.6
178.04	179.48	181.41	183.24	184.03	185.72	194.03	195.72	200.88	204.67	209.80	214.60	215.68	221.46	225.50	227.12	229.39	231.80	236.33	241.56	249.65	251.80	260.18	263.92	271.80	278.88	282.66	287.86	292.21	296.88	302.32	306.24	306.75	310.08	316.52	319.26	322.32	330.85	334.91	335.33	338.92	342.50	345.33	345.39	345.58	347.61	358.35	382.07	390.37	396.73	400.45	412.37	429.44	444.86	449.61	459.79	461.43	465.18	466.46	473.63	482.58	486.28	507.86	524.48	543.97	564.68	584.59		604.60		623.77
177.89	179.40	181.33	183.16	183.95	185.64	193.95	195.57	200.80	204.59	209.72	214.52	215.60	221.38	225.42	227.04	229.37	231.72	236.25	241.48	249.57	251.72	260.04	263.84	271.72	278.80	282.58	287.76	292.09	296.80	302.24	306.15	306.67	310.00	316.44	319.18	322.24	330.77	334.88	335.25	338.82	342.42	345.30	345.36	345.50	347.53	358.24	382.03	390.25	396.65	400.37	412.29	429.36	444.78	449.56	459.71	460.88	465.06	466.44	473.55	482.50	486.19	507.77	524.41	543.87	564.58	584.48	599.04	604.50	619.98	623.67
P	P	P	G		G	G	G	G	F	F	F	G	F	G	G	F	G	G		F	G	G	F	F				G								F		F	G	F	P	F	F	F						G			G	F	F	F	G	F		F					G		F		F	
2	1	2	6	0	1	5	1	3	4	12	5	4	2	8	5	1	7	4	0	1	4	4	3	2	0	0	0	7	0	0	0	0	0	0	0	3	0	1	1	2	1	1	1	6	0	0	0	0	0	1	0	0	5	2	3	1	4	1	0	4	0	0	0	0	1	0	1	0	1	0
2	1	3	13	NF	1	10	1	6	11	20	11	7	2	16	37	-	50	11	NF	1	5	40	3	5	NF	NF	NF	15	NF	NF	NF	NF	NF	NF	NF	3	NF	-	2	2	3	-	-	22	NF	NF	NF	NF	NF	1	NF	NF	11	10	3	-	8	-	NF	18	NF	NF	NF	NF	1	NF	-	NF	-	NF
			X																																																																				
													X																																										X			X											
										X							X					X					X																									X																	
																							X																																																
																																				X																																			
						X				X	X	X		X	X		X	X		X	X		X				X							X				?				X									cf.		?														
																																									X																X			X											
																																									X			X						?			X	X	X		X			X											
									X	X			X																																								X							?											
																												X																																											
																				X																								X																									
?													X									X	X	X					X																																									
	?		X		X					X							X																																																			
			X			X		X	X					X	X		?					X	X																					X													X													
						?	X	X	X	X	X				X		X				X			X																																							X													
						X																																																																
										X				X	X		X	X																																																			
								X	X	X																		X																																									
																																																						X																	
														cf.														X																																									
			X									X			X	X		X	X				X						X										X																														
														X		X																							X			X	X												X		X										X		X	
		?								X																																																												
										X			?	X																																X																										
										X	X																																																												
										X																																																													
?						X					X	X						?																				X																						?															
			X																																																			X																	
												X																																																											
			X																																																																				
																																								cf.																															
										X																																																													
																																													X													X			X					X						
		X																																																																				
X	X	X	X						X	X	X		X		X		X																										X																													
							X			X					X			X																																																		
										X		X					X						X																																													
			X	X	X		X						X	X	X			X	X	X																						X	X											X				X				X										
X		X	X			X		X	X	X		X		X			X					X	X		X				X																										X	X	X		X													

The convention used herein is to place foraminiferal unit boundaries at the top of the sample interval containing the first downhole occurrence of the defining foraminifers. Only the upper depth is given for samples cited below; most cover a nominal stratigraphic interval of 5 cm. The full depth range for each sample is given in table 1.

Foraminiferal Unit I *(26.91 - 193.95 mbsf)* - Foraminiferal Unit I commences at the unconformable contact between Miocene and Pliocene sandstones. It includes lithostratigraphical Units 3.1 through 9.2, its lower boundary essentially coinciding with the base of the latter (193.65 mbsf). Thirty-eight of 70 samples from Unit I were fossiliferous, typically yielding sparse, low diversity foraminiferal faunas. Twenty genera and 28 species, 7 of them having only a single occurrence within the Unit, were recorded. Typical assemblages contain 5 or fewer individuals, representing 3 or fewer species, although somewhat richer faunas occur at a few levels. *Elphidium magellanicum* and *Cribroelphidium* sp. are the most typical and persistent taxa, appearing in most assemblages through the interval. *Nonionella iridea* has a short interval of persistent occurrence between *c.* 56 and 76 mbsf; while *Epistominella exigua* has scattered occurrences downhole from *c.* 95 m. Other taxa appear only sporadically. No planktics or agglutinated taxa were observed.

Preservation was classified as fair to good in *c.* 65% of the assemblages and the remaining ones were considered poor. Poorly preserved specimens generally were coarsely recrystallised and/or decorticated. Preservation shows no obvious stratigraphic trend, except for consistent, relatively strong, recrystallisation of specimens from Unit 6.1.

Maximum observed abundance and diversity occurs in the mudstones and fine sandstones of lower Unit 5.1. The most abundant and diverse assemblage occurs at 71.13 mbsf, with 10 species represented by 60 specimens, while lesser abundance peaks occur in the overlying 10 m of section, at 61.38, 63.80 and 64.67 mbsf. Common taxa include *Cribroelphidium* sp., *Elphidium magellanicum, Nonionella iridea*, and *Oolina apiculata.*

Isolated specimens of a large miliolid, probably *Pyrgo fornasinii*, or a related species, are recorded at 51.72, 54.28 and 94.76 mbsf.

There are persistently non-fossiliferous intervals from *c.* 36 to 41 mbsf (Unit 3.1, medium to fine sandstone), and from *c.* 107 to 123 mbsf (Units 7.1, 7.2 and 8.1; sandstone, diamictite and lapillistone).

Geochronologically significant features (Cape Roberts Science Team, 1999) within the interval include:

1 - The pumice bed of Unit 7.2 at *c.* 111 m to *c.* 114 mbsf, ^{40}Ar-^{39}Ar dated as Early Miocene, 21.44 +/- 0.05 Ma. Unfortunately, no foraminifera were recovered from dark grey siltstone interbeds associated with the pumiceous interval.

2 - The Upper Oligocene – Lower Miocene boundary, placed at *c.* 130 mbsf, based mainly on diatom and nannofossil evidence. No significant change in foraminiferal assemblages was noted near this level.

Foraminiferal Unit II *(193.95 - 342.42 mbsf)* - As noted above, the boundary between Foraminiferal Units I and II essentially coincides with the boundary between lithostratigraphical Units 5.2 and 5.3. The base of Unit II lies about 5 m above the base of lithostratigraphical Unit 11.3. The top of Unit II is marked by the first downhole occurrences of *Cassidulinoides aequilatera* (*C. bradyi* of Initial Report) and *Eponides bradyi*, both of which occur in most samples throughout the Unit. Twenty-five species and 20 genera, of which 7 species are single occurrences, are recorded in all. Samples are more consistently fossiliferous (23 of 35 samples, including three *in situ* records) and also display higher diversity and abundance than those of Unit I. While the total number of taxa is very similar to that of Unit I, more species tend to be present within each assemblage in Unit II. In addition to *C. aequilatera* and *E. bradyi,* typical species within this interval include *Epistominella exigua, Fursenkoina schreibersiana, Melonis barleeanum, Ammoelphidiella* spp. and *Cribroelphidium* sp. No planktic or agglutinated benthic forms were observed.

Preservation was judged to be good in about half of the samples, and in the remainder, which were slightly recrystallised, to be fair (see Tab. 1).

Foraminiferal Unit II can be subdivided into upper and lower portions. Samples from the upper part, from 193.95 mbsf down through 260.04 mbsf, yield common foraminifers, typically 10-50 specimens, representing 4-9 species. The most abundant faunas occur from *c.* 225 to 231 mbsf, and there are minor abundance peaks at *c.* 210 and 260 mbsf. Large miliolids were recorded at 225.42 and 229.37 mbsf.

The lower portion of Unit II, from 260.04 mbsf to 342.42 mbsf, yields sparser faunas, often with only 1 or 2 species, and there are substantial barren intervals from *c.* 275 mbsf to *c.* 290 mbsf, and from *c.* 295 mbsf to *c.* 320 mbsf. A large miliolid specimen was observed *in situ* at 334.88 mbsf.

A pumice-rich interval at 280 m gave a Late Oligocene ^{40}Ar-^{39}Ar age of 24.22 Ma. Diatom and calcareous nannofossil data further indicate that Foraminiferal Unit II is entirely Late Oligocene (Cape Roberts Science Team, 1999).

Foraminiferal Unit III *(342.42 - 486.19 mbsf)* - The Unit extends from *c.* 5 m above the base of lithostratigraphical Unit 11.3 to about the middle of Unit 13.2. *Cassidulinoides chapmani* (*C. braziliensis* of Initial Report) and an unnamed *Stainforthia* sp. (*Fursenkoina* sp. of Initial Report) are the most common taxa within this interval, and occur in most assemblages. *Epistominella exigua, Cassidulinoides braziliensis* and *Eponides bradyi* occur occasionally. Abundance is low to moderate, with 11 of 20 samples (including 4 *in situ* records) yielding faunas. Most assemblages contain from 3 to 6 species, and a total of 15 species and 11 genera were recorded, with 5 single occurrences. Large (up to 6 mm in diameter) miliolid specimens occur *in situ* at 345.30, 345.36, 460.88 and 466.44 mbsf. Preservation is assessed as predominantly fair, with most specimens displaying very minor to moderate recrystallisation.

Unit III assemblages are poorly developed above about 440 mbsf, and the most diverse faunas occur in the lower third of the Unit. There is a pronounced increase in abundance and diversity below *c.* 444 mbsf, the stratigraphic level interpreted to represent the Upper Oligocene-Lower Oligocene boundary (Cape Roberts Science Team, 1999). A major barren interval occurs from *c.* 347 to *c.* 435 mbsf, and includes all of lithostratigraphical Units 12.1 and 12.2, which consist of diamictite and sandstone.

As noted above, the unconformable contact between Upper and Lower Oligocene lies within foraminiferal Unit III. It is placed at 443.18 mbsf, the boundary between lithostratigraphical Units 12.2 and 13.1, and based on four diatom species and three species of calcareous nannoplankton (Cape Roberts Science Team, 1999).

Foraminiferal Unit IV, Impoverished *(486.19 – 624.15 mbsf)* - Samples from this unit, which begins near the middle of lithostratigraphic Unit 13.1 and continues through Unit 15.6 (bottom of hole), were well indurated and difficult to disaggregate. Only one sample (564.58 mbsf) of the 8 examined proved fossiliferous, yielding a single, moderately preserved, specimen of the same *Stainforthia* sp. found in Unit 3. The seven remaining samples were apparently barren of foraminifers, with no specimens being observed under the microscope either as free specimens or in chips of partly disaggregated residue. Despite the apparent absence of smaller foraminifers, isolated specimens of large, moderately well preserved biloculine miliolids (probably *Pyrgo* spp.) were observed *in situ* in the core at 599.04 and 619.98 mbsf. Two genera and probably 2 species therefore represent the known fauna of the Unit. The presence of the miliolids may indicate a specialised, perhaps hypersaline, environment unsuitable for other species (Murray 1973).

The age at the base of Unit IV, is poorly constrained by both palaeomagnetic and fossil data, but it is considered more likely to be earliest Oligocene, rather than late Eocene, in age (Cape Roberts Science Team, 1999).

PALAEOENVIRONMENT

It is likely that the entire CRP-2/2A section accumulated in relatively nearshore marine environments. Foraminiferal Units I-IV, as described above, contain calcareous benthic foraminiferal faunas of moderate to very low abundance and diversity, which lack both planktics and agglutinated benthic foraminifera. Diversity indices (· = <2) are consistent with those for nearshore shelf seas (Murray 1973). These factors suggest that all four assemblages reflect a variety of glacially influenced inshore situations, which were isolated from oceanic circulation. A similar environmental setting is suggested by diatom assemblages, with the absence or low abundance of benthic diatoms suggesting turbid conditions and minimum water depths of the order of 50 m. (Cape Roberts Science Team, 1999).

Palaeodepth is especially difficult to interpret, as water temperature, rather than depth, *per se,* is a major controlling factor in foraminiferal distribution. *Epistominella exigua,* for example, is considered to have an upper depth limit of *c.* 2000 m in mid to low latitudes during the Neogene (van Morkhoven and others, 1986), but the species lives today in the Ross Sea at depths of only a few metres (Bernhard, 1987).

Diversity and abundance changes in faunas from Foraminiferal Units IV, III and II suggest a long-term deepening trend, from inner shelf to perhaps outer shelf or upper bathyal depths of up to a few 100 metres, followed by a return, indicated by the Unit I fauna, to more inshore environments, where water depths may have been measured in 10's of metres. The sparse fauna of Unit IV, with scattered large miliolids, is consistent with a shallow water (possibly hypersaline at times, due to brine formation) environment, above wave base (c.50 m?), as suggested by the presence of possible hummocky cross-bedding (Cape Roberts Science Team, 1999). Unit III faunas probably reflect increased water depths, especially from *c.* 440 – 485 mbsf, with further deepening indicated by the more consistently occurring and diverse faunas of Unit II. Unit I marks an abrupt return to low diversity, sparse faunas characterised by the shallow water taxa, *Elphidium* and *Cribroelphidium.*

AGE AND CORRELATION

All foraminifera from CRP-2/2A have either long or poorly known ranges, and no age-diagnostic species were encountered to permit external correlation to high latitude zonation schemes, *e.g.*, Stott & Kennett (1990). Although the CRP-2/2A faunas are less diverse than those described from DSDP Site 270 (Leckie & Webb, 1985), they bear a general resemblance to Oligocene and Miocene faunas from lithostratigraphic Unit 2 (especially 2B to 2I) from that drillhole. Foraminiferal Units II and III share some features of the *Globocassidulina-Cassidulinoides-Trochoelphidiella* Assemblage Zone from the lower sequence in DSDP 270, while Foraminiferal Unit I is comparable to the overlying *Epistominella-Elphidium-Nonionella* Assemblage Zone. CRP-2/2A faunas also are similar to those present in Units 5, 7, 8, 9 and 15 in CIROS-1. Significantly, no fauna equivalent to the lowermost CIROS-1 fauna (Unit 21; Webb, 1989, p. 105) was encountered in CRP-2/2A, which is consistent with nannofossil and diatom evidence that basal CRP-2/2A strata are younger than those in CIROS-1.

Based on its indicated age, and some mutual, Antarctica-New Zealand nannofossil occurrences, the CRP-2/2A sequence is apparently correlative with the Whaingaroan, Duntroonian, Waitakian and Otaian Stages of New Zealand (Morgans & others 1996), but there is no foraminiferal data to support this correlation.

Examination of range charts for CIROS-1 and DSDP 270 shows that equivalents of Foraminiferal Units I-IV are not recognisable in either drillhole, strongly implying that the Foraminiferal Units defined in CRP-2/2A are of relatively local significance, although their actual extent is undetermined.

It is interesting to note that *Cassidulinoides chapmani* and *C. aequilatera,* found, respectively in Unit II and Unit III, occur in the same stratigraphic order as in lower Miocene rocks of the Gippsland Basin, Australia (Carter, 1964).

DISCUSSION

The most striking feature of CRP-2/2A foraminiferal assemblages is their low diversity and low specimen abundance, as compared with equivalent faunas from Oligocene-Miocene sections in CIROS-1 (Webb, 1989) and DSDP Site 270 (Leckie & Webb, 1985). Inspection of species lists for the two sites indicates that they compare more closely with DSDP 270 faunas, suggesting that, in general, they represent more offshore conditions than in CIROS-1. Low diversity is manifested not only by the lack of planktic and agglutinated taxa, but also by the low number of species per assemblage, and appears to be only about half that expected in a normal marine setting (Murray, 1973). Webb (1989) demonstrated in CIROS-1 that maximum diversity and the occurrence of planktics were associated with the tops of sea-level cycles in diamictite/mudstone couplets. Detailed sampling through several such couplets in CRP-2/2A, however, failed to recover higher diversity faunas or planktic specimens, suggesting either that cycle tops had been consistently removed by subsequent erosion or that the site may have been fully isolated from oceanic circulation during the Oligocene and Miocene.

It is possible that the low abundance and low diversity are partly linked, and result from selective solution in a few cases, but it is more likely that, in the main, they reflect high sedimentation rates and somewhat inhospitable environments. Although specimens show obvious evidence of dissolution/recrystallisation in some samples, many other samples contain well preserved foraminifers spanning a wide size range from juveniles to adults, while other samples have yielded single, small, well preserved individuals.

Overall, there appears to be no consistent link between preservation and abundance or diversity. Most assemblages were obtained from 2-5 trays of residue, and maximum abundances were of the order of 15-20 specimens/tray. More extensive picking of a few selected samples tended to increase diversity only slightly, and also showed that the amount of material routinely picked provided a good representation of most taxa present.

All factors considered, low abundance and diversity seem to be a primary feature in most cases, and not an artefact of selective dissolution. These features seem most likely to be due to high sedimentation rates and associated effects, which may have also reduced benthic productivity.

PALAEONTOLOGICAL NOTES

Species identified from CRP-2/2A are listed alphabetically below, and are briefly described and discussed as appropriate. Specimens determined only to generic level, and listed in table 1 as undifferentiated "spp." are not described. Foraminiferal specimens, assemblage slides and residues are held at the Institute of Geological & Nuclear Sciences, Lower Hutt, New Zealand. Fossil Record Locality Number for CRP-2/2A is RS/f693, and foraminiferal curation number for residues and assemblage slides is F33047. Figured specimen curation numbers have the prefix "FP".

Ammoelphidiella pustulosa (Leckie & Webb)
Plate 1, fig. 1

Trochoelphidiella pustulosa Leckie & Webb, 1985, Pl. 8, Figs 1-12, 14-15; Pl. 21 Fig. 14-19, p1113.)

This species is distinguished by its low trochospiral form, its relatively rapid increase in chamber size in the last whorl, and the development of pustules, which are largely confined to the umbilical area on the ventral side.

Ammoelphidiella uniforamina (D'Agostino)
Plate 1, fig. 2

Trochoelphidiella uniforamina D'Agostino 1980, p. 76, Pl. 9, Figs. 1-12, Pl. 10, Figs. 11-13, Pl. 21, Figs 8-13; Leckie & Webb, 1985, Pl. 9, Figs. 10-12, Pl. 10, Figs. 11-13, Pl. 21, Figs 8-13.)

In comparison with *A. pustulosa*, the species displays a less rapid increase in chamber size, and has pustules extending from the umbilicus along the sutures on the ventral side.

***Ammoelphidiella* sp.**
Plate 1, fig.3

One or more species may be represented by small forms not referrable to the existing taxa cited above. Typical specimens are relatively smoothly finished, with incised, moderately curved sutures.

***Anomalinoides* sp.**

This small species (dia. 0.21 mm) has a smoothly rounded periphery, and about 6 chambers in the outer whorl. Sutures are oblique and gently curved on the spiral side, straight and nearly radiate ventrally. It occurs only rarely.

***Bulimina* sp.**

This small species (length 0.27 mm) is represented by a single specimen with a sharply tapering, smooth, test. Chambers are only slightly inflated, and tend to increase in height as added.

Cassidulinoides aequilatera Carter
Plate 1, fig. 4, 5

Cassidulinoides aequilatera Carter, 1964, p. 70, Pl. 2, Figs. 40-42.

Cassidulinoides bradyi Cape Roberts Science Team, 1999

This species was cited as *C. bradyi* in the Initial Report for CRP-2/2A (CRP Science Team 1999).

Specimens at hand compare well with Carter's figured specimens from Lower Miocene of Gippsland Basin. They are characterised by elongate, nearly cylindrical test, with little inflation of chambers. Chambers are considerably less inflated than in *C. parkerianus*, which is recorded from Pliocene strata in CRP2/2A (Webb & Strong, this volume).

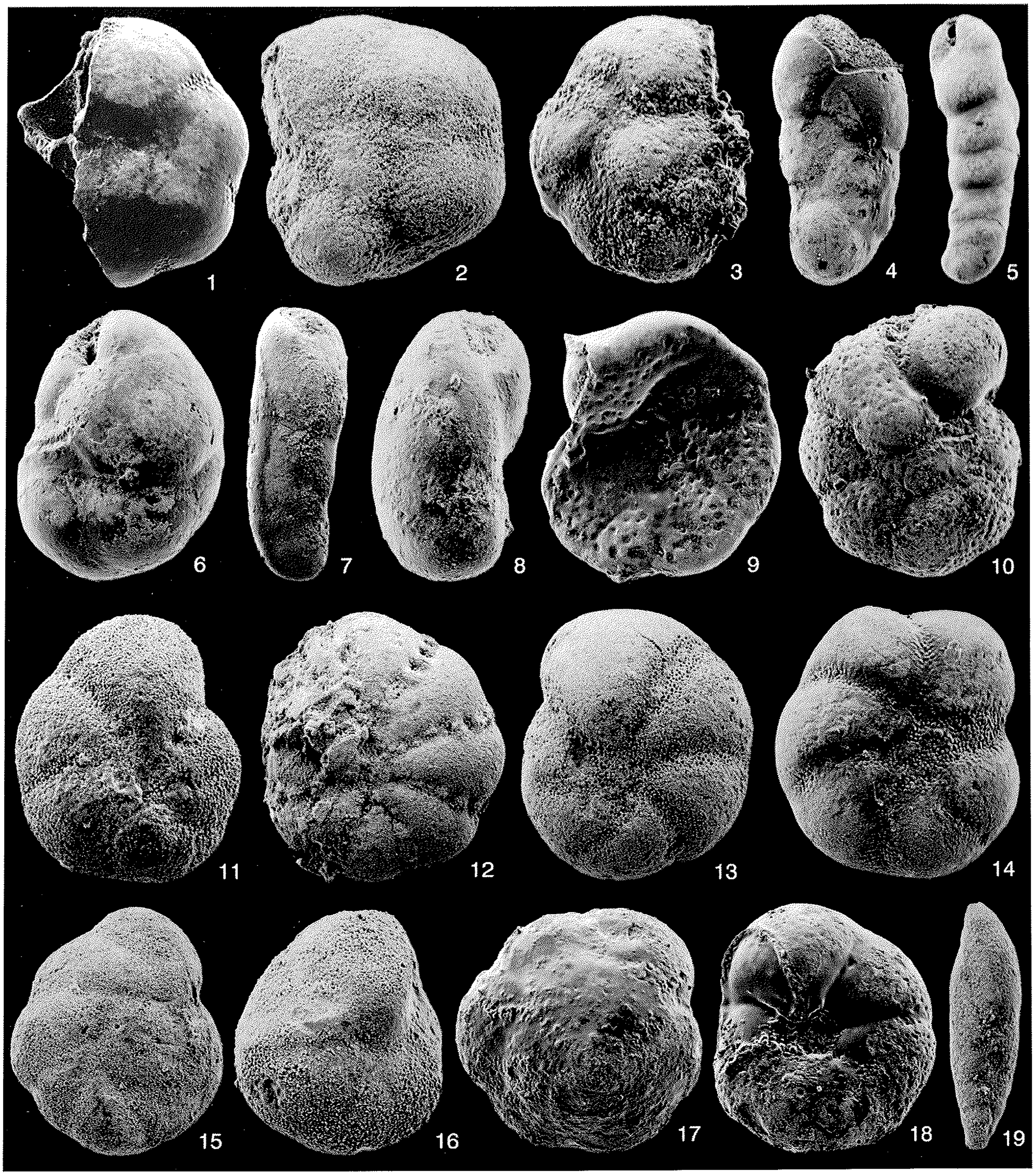


Plate 1

Figure (All specimens from CRP-2A unless noted)

1. *Ammoelphidiella pustulosa.* FP4792, dorsal view, diameter 0.390 mm, 183.16 mbsf.
2. *Ammoelphidiella uniforamina.* FP4793, dorsal view, diameter 0.265 mm, 96.79 mbsf.
3. *Ammoelphidiella* sp. FP4794, dorsal view, diameter 0.475 mm, 209.72 mbsf.

4, 5. *Cassidulinoides aequilatera.* 4, FP4795, front view, length 0.590 mm, 235.42 mbsf; 5, FP4796, side view, length 1.02 mm, 236.25 mbsf.

6. *Cassidulinoides braziliensis.* FP4797, side view, length. 0.340 mm, 444.78 mbsf.

7, 8. *Cassidulinoides chapmani.* 7, FP4798 side view, length 0.685 mm, 465.06 mbsf; 8, FP4799, side view, length 0.290 mm, 482.5 mbsf.

9, 10. *Cibicides lobatulus.* 9, FP4800, spiral view, diameter 0.345 mm, 204.59 mbsf; 10, FP4801, ventral view, diameter 0.690 mm, 209.72 mbsf.

11. *Cribroelphidium* sp. FP4802, side view, diameter 0.380 mm, 30.95 mbsf (CRP-2).
12. *Elphidium* ex gr. *excavatum.* FP4803, side view, diameter 0.580 mm, 114.72 mbsf.

13, 14. *Elphidium magellanicum.* 13, FP4804, side view, diameter 0.320 mm,71.13 mbsf; 14, FP4805, side view, diameter 0.435 mm, 63.80 mbsf.

15, 16. *Epistominella exigua.* 15, FP4806, spiral view, diameter 0.185 mm, 96.79 mbsf; 16. FP4807, ventral view, diameter 0.195 mm, 145.58 mbsf..

17,18. *Eponides bradyi.* 16, FP4808, spiral view, diameter 0.420 mm, 204.59 mbsf; 17, FP4809, ventral view, diameter 0.485 mm, 209.72 mbsf.

19. *Fursenkoina schreibersiana.* FP4810, side view, length 0.390 mm, 71.13 mbsf; 19, FP4811, side view, length 0.475 mm, 227.04 mbsf.

The species is characteristic of Foraminiferal Unit II, where it is common in most samples.

Cassidulinoides braziliensis (Cushman)
Plate 1, fig.6

Cassidulina braziliensis Cushman, 1932. *Fide* Ellis & Messina

Cassidulinoides braziliensis (Cushman). Leckie & Webb, 1985, p. 1112, Pl. 5, Fig. 13-14.

C. braziliensis is planispiral and moderately compressed in the early stages, later tending to uncoil. The aperture is oriented normal to the plane of coiling.

Leckie & Webb (1985) recorded the species in DSDP 270 from the lower half of Unit 2 (Late Oligocene to Early Miocene). It is a characteristic form in Foraminiferal Unit III.

Cassidulinoides chapmani Parr
Plate 1, fig. 7, 8

Cassidulinoides chapmani Parr, 1931, p. 99, 100, figs. a-c; Carter, 1964, p. 70, Pl. 2, Figs. 37-39.

This species is distinguished from *C. aequilatera* by its smaller size, thinner test wall and slightly compressed form. Carter (1964) notes that *C. chapmani* stratigraphically precedes *C. aequilatera;* this relationship is also observed in the CRP-2/2A drillhole. The species is characteristic of Foraminiferal Unit III.

Cibicides lobatulus (Walker & Jacob)
Plate 1, figs. 9, 10

Cibicides lobatulus (Walker & Jacob). Leckie & Webb, 1985, p. 1115, Pl. 11, Figs 10-12; Ward & Webb, 1986, p. 194, Pl. 6, Figs. 6, 7; Violanti, 1996, p.37, Pl. 10, Fig. 6.

C. lobatulus occurs sporadically throughout most of the CRP-2/2A sequence, and is relatively common in some samples. The species is a persistent component of Antarctic foraminiferal faunas, and ranges at least from early Oligocene to the Recent.

Cibicides refulgens Montfort

Cibicides refulgens Montfort. Leckie & Webb 1985, p. 1115, Pl. 11, Figs. 13-15.

The species is characterised by its moderately deep, plano-convex test, with about 7 chambers in the outer whorl. It is rare in the CRP-2/2A drillhole.

Cribroelphidium sp. - Plate 1, fig. 11

Cribroelphidium sp. Strong & Webb, 1998, p. 518, Pl. 1, Fig. 5-7.

This small species usually has about 5-7 chambers in the outer whorl, a lobulate outline, and a broadly rounded periphery. It is one of the most typical forms in Foraminiferal Unit I, and also occurs in Foraminiferal Unit II. It was also common through most of the section in CRP-1 (CRP Science Team 1998).

Elphidium ex gr. _excavatum_ (Terquem)
Plate 1, fig. 12

This robust form is characterised by its relatively large size (*c*. 0.6 mm), lobulate outline, broadly rounded periphery, and prominent retral processes. It appears to be related to *E. excavatum*, as described by Hayward and others (1997).

Elphidium magellanicum Heron-Allen & Earland
Plate 1, figs. 13, 14

Elphidium magellanicum Heron-Allen & Earland. D'Agostino, 1980, p. 75, Pl. 4, Fig. 5, 6, 9; Leckie & Webb, 1985, p. 1113, Pl. 7, Fig. 1-9.

The species occurs in many assemblages in Foraminiferal Units I and II. Its main characteristics are incised, gently curved sutures, and the extension of pustular shell material from the umbilicus along the sutures, which are marked by numerous pores.

Epistominella exigua (Brady)
Plate 1, figs. 15, 16

Epistominella exigua (Brady). D'Agostino, 1980, p. 74, Pl. 4, Fig. 7, 8; Violanti 1996, Pl. 10, Fig. 5.; Mead, 1985, p. 230, Pl. 2, Fig. 1-4.

Epistominella vitrea Parker. Leckie & Webb, 1985, p. 1113, Pl. 6, Figs. 1-5; Ward & Webb 1986, p. 190, Pl. 4, Figs. 15-16.

Mead (1985) discusses the relationships of *E. exigua* and *E. vitrea*. The CRP-2/2A specimens are identical to reference specimens of *E. exigua* from DSDP Site 206, held in the GNS foraminiferal collections. The species occurs sporadically throughout much of the drillhole sequence, and is common in some assemblages. It is also recorded in CIROS-1, from *c*. 100- 500 mbsf.

Eponides bradyi Earland
Plate 1, figs. 17, 18

Eponides bradyi Earland. Boltovskoy, 1978, p. 15, Pl. 4. Figs. 1-3; Leckie & Webb, 1985, p.1115, Pl. 23, Figs. 11-13.

Specimens from CRP-2/2A closely resemble Leckie & Webb's (1985) figures, also Boltovskoy's figured specimen. They have a more lobulate periphery than Earland's specimens, but his drawings appear to be somewhat diagrammatic. At DSDP 270, *E. bradyi* ranges down into Unit G, which is tentatively dated as early Miocene (Leckie & Webb 1985). *E. bradyi* is a characteristic species of Foraminiferal Unit II, and occurs rarely in Unit III.

Fissurina bisulcata (Heron-Allen & Earland)

Fissurina bisulcata (Heron-Allen & Earland). Leckie & Webb, 1985, p. 1112, Pl. 4, Fig. 13, 14.

The single specimen, recovered from uppermost Unit II, was lost in transit from Antarctica.

Fursenkoina schreibersiana (Czjzek)
Plate 1, fig. 21

Fursenkoina schreibersiana (Czjzek). Leckie & Webb, 1985, p. 1115, Pl. 12, Fig. 3; Violanti 1996, p.33, Pl. 9, fig. 16.

The species has a small, very slender, slightly twisted, biserial test, with chambers that tend to become higher as added. It occurs sporadically in Foraminiferal Units I and II.

***Lenticulina* sp.** - Plate 2, fig. 1

The species is represented by a single large (0.95 mm) specimen from the lower part of Foraminiferal Unit I. The smoothly finished test consists of about 7 chambers, and has a sharp periphery. Sutures are flush, oblique, and slightly curved.

***Marginulina tumida* Reuss**
Plate 2, fig. 2

Marginulina tumida Reuss. Leckie & Webb, 1985, p. 1111, Pl. 19, Figs. 8, 9.

This very robust species is represented by a single large specimen from the lower part of Foraminiferal Unit I.

***Marginulina* sp.** - Plate 2, fig. 3

The species, from Unit II, has an unornamented, rectilinear test, ovate in cross-section, and consisting of 6-8 chambers. Sutures are flush and oblique; aperture is radiate and located at the peripheral margin.

***Marginulinopsis* sp.**

The single specimen, recovered from 444.78 mbsf (Unit III), was lost in transit from Antarctica.

***Melonis affinis* (Reuss)**

Melonis affinis (Reuss). D'Agostino, 1980, p. 89, Pl. 10, Fig. 8; Leckie & Webb, 1985, p. 1116, Pl. 14, Figs. 5-7.

The species is characterised by its broad, somewhat flattened periphery.

***Melonis barleeanum* (Williamson)**
Plate 2, fig. 4

Melonis barleeanus (Williamson). D'Agostino, 1980, p. 88, Pl. 10, Fig. 5; Leckie & Webb, 1985, p. 1116, Pl. 14, Figs. 1-4.

M. barleeanum has a biumbilicate, involute, planispiral test with a broadly rounded periphery and about 8 chambers in the outer whorl. In New Zealand basins (temperate water mass) it is considered to represent depths of mid-upper bathyal or deeper (Hayward 1986).

Large Miliolidae
Plate 2, fig. 5

Free specimens of large miliolid foraminifers were recovered from 3 levels in the core, and cross-sections of large specimens observed *in situ* at a further 6 levels. They have biloculine coiling, and probably are referrable to one or more *Pyrgo* species. The largest specimen observed was some 6 mm in diameter. A recent study (Gudmundsson, 1998) of twelve North Atlantic and Arctic *Pyrgo* species shows that their distribution is strongly linked to water depth and temperature. The genus shows a wide depth range, from *c.* 20 m to >2500 m, although many species occur only within more restricted depth limits. *Pyrgo lucernula* (Schwager), the largest species recorded in the study, attained a maximum length of 4.9 mm, comparable with some CRP-2/2A specimens. The species occurs in North Atlantic assemblages, and is most common between *c.* 100 and 1500 m, and over a temperature range of 3-7 ° C.

***Nonionella bradii* (Chapman)**
Plate 2, fig. 6

Nonionella bradii (Chapman). Fillon, 1974, p. 118, Pl. 5, Fig. 42; D'Agostino, 1980, p. 86, Pl. 9, Figs. 1-3; Leckie & Webb, 1985, p. 1115, Pl. 13, Fig. 3-4, Pl. 23, Fig. 1-2.

***Nonionella iridea* Heron-Allen & Earland**
Plate 2, figs. 7, 8

Nonionella iridea Heron-Allen & Earland. Leckie & Webb, 1985, p. 1115, Pl. 13, Figs. 3-4, Pl. 23, Figs. 5-7; Ward & Webb, 1986, p. 198, Pl. 7, Fig. 4.

Melonis sp. B, Strong & Webb, 1998, p. 520, Pl. 1.10, 11.

N. iridea is characterised by its slightly asymmetrical test and curved, deeply incised sutures. It is most common in the lower part of Foraminiferal Unit I, and the upper part of Foraminiferal Unit II.

***Nonionella magnalingua* Finlay**
Plate 2, fig. 9

Nonionella magnalingua Finlay. Leckie & Webb, 1985, p. 1115, Pl. 13, Fig. 5, Pl. 23, Figs. 3-4.

***Oolina apiculata* Reuss** - Plate 2 fig. 10

Oolina apiculata Reuss. D'Agostino, 1980, p. 64; Leckie & Webb, 1985, p. 1112, Pl. 4, Fig. 11.

***Oolina globosa* (Montagu)** - Plate 2, fig. 11

Oolina globosa (Montagu). D'Agostino, 1980, p. 65; Leckie & Webb, 1985, p.1112, Pl. 4, Fig. 10, Pl. 18, Fig. 17.

Parafissurina lateralis (Cushman)

Parafissurina lateralis (Cushman). Leckie & Webb, 1980, p. 1112, Pl. 18, Fig. 22-23.

***Pseudonodosaria symmetrica* (Stache)**
Plate 2, fig. 12

Pseudonodosaria symmetrica (Stache). Hornibrook, 1971, p. 35, Pl. 10, fig. 172.

***Pullenia subcarinata* (d'Orbigny)**
Plate 2, figs. 13, 14

Pullenia subcarinata (d'Orbigny). Leckie & Webb, 1985, p. 1116, Pl. 13, Figs. 7-9.

Pullenia cf. *subcarinata* (d'Orbigny). Mead, 1985, p. 236, Pl. 4, Fig. 9-10.

Melonis sp. A Strong & Webb, 1998, p. 520, Pl. 1.9.

These 6 to 7 chambered forms appear to be identical to those figured by Leckie & Webb (1985), but tend to have a more evenly rounded periphery, rather than the sharply compressed periphery as figured by d'Orbigny (*fide* Ellis & Messina) and Ward & Webb (1986).

***Pyrulinoides* sp.** - Plate 2, fig.15

Pyrulinoides sp., Strong & Webb, 1998, p. 520, Pl. 1.14.

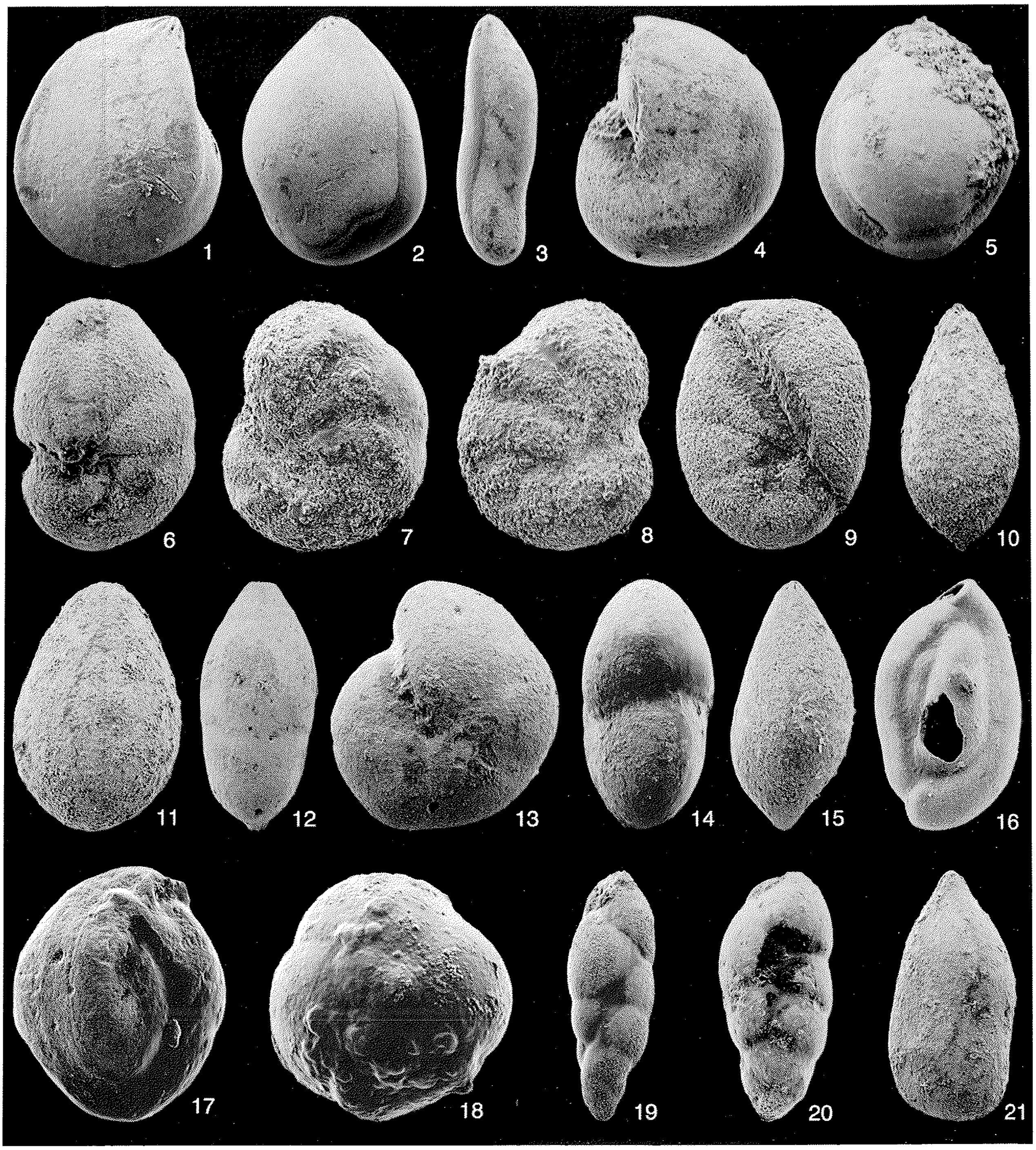


Plate 2
Figure
1. *Lenticulina* sp. FP4811, side view, diameter 0.950 mm, 164.42 mbsf.
2. *Marginulina tumida.* FP4812, side view, length 0.910 mm, 168.96 mbsf.
3. *Marginulina* sp. FP4813, side view, length 0.475 mm, 200.80 mbsf.
4. *Melonis barleeanum.* FP 4814, side view, diameter 0.380 mm, 231.72 mbsf.
5. Large miliolid (*Pyrgo* sp.). FP4815, front view, diameter 1.74 mm, 94.79 mbsf.
6. *Nonionella bradii.* FP4816, dorsal & ventral views of same specimen, diameter 0.320 mm, 71.13 mbsf.
7, 8. *Nonionella iridea.* 7, FP4817, dorsal view, diameter 0.355 mm, 61.38 mbsf; 8, FP4818, ventral view, diameter 0.425 mm, 61.38 mbsf.
9. *Nonionella magnalingua.* FP4819, dorsal view, diameter 0.250 mm, 71.13 mbsf.
10. *Oolina apiculata.* FP4820. side view, length 0.840 mm, 61.38 mbsf.
11. *Oolina globosa.* FP4821, side view, length 0.457 mm, 54.28 mbsf.
12. *Pseudonodosaria symmetrica.* FP4822, side view, length 0.865 mm, 71.13 mbsf.
13, 14. *Pullenia subcarinata.* 13, FP4823, side view, diameter 0.640 mm, 114.72 mbsf; 14, FP4824, apertural view, diameter 0.485 mm, 139.44 mbsf.
15. *Pyrulinoides* sp. FP4825. side view, length 0.340 mm, 71.13 mbsf.
16. *Quinqueloculina seminula.* FP4826, side view, length 0.300 mm, 64.67 mbsf.
17. *Quinqueloculina triangularis.* FP4827, side view, length 0.255 mm, 338.92 mbsf.
18. *Rosalina globularis.* FP4828, ventral view, diameter 0.105 mm, 209.72 mbsf.
19, 20. *Stainforthia* sp. 19, FP4829, side view, length 0.600 mm,345.50 mbsf; 20, FP4830, side view, length 0.455 mm, 482.50 mbsf.
21. *Vaginulinopsis* sp. FP4831, side view, length 0.645 mm, 181.33 mbsf.

Quinqueloculina seminula **(Linné)**
Plate 2 , fig. 16

Quinqueloculina seminula (Linné). Leckie & Webb, 1985, Pl. 4, Figs. 1-2, Pl. 17, Figs. 2-5.

Specimens from CRP-2/2A compare well with reference specimens held in GNS collections.

Quinqueloculina triangularis **(d'Orbigny)**
Plate 2, fig. 17

Quinqueloculina triangularis (d'Orbigny). Leckie & Webb, 1985, Pl. 4, Fig. 3, Pl. 17, Figs. 6-10.

A single specimen, recovered from 338.82 mbsf, is tentatively referred to *Q. triangularis*.

Rosalina globularis **d'Orbigny** - Plate 2, fig. 18

Rosalina globularis d'Orbigny. Leckie & Webb, 1985, p. 1113, Pl. 6, Fig. 6-7.

Stainforthia **sp.** - Plate 2, figs. 19, 20

Stainforthia sp. is one of the characteristic forms of Foraminiferal Unit III, and a single specimen was also observed in Foraminiferal Unit IV. The species has an elongate, fusiform test, the initial one-third consisting of a distinctly twisted, triserial early stage, and the remainder of biserial chambers. It lacks the apical spine often seen in the genus. *Stainforthia* sp. resembles the Recent species *S. feylingi* Knudsen & Seidenkrantz, but is more elongate, with a less rapid height increase in the later chambers. The latter species is reported from Saanich Inlet, British Columbia, where it occurs in mud and sand in low oxygen environments with slightly subnormal salinity, at a water depth of *c.* 90 m (Blais-Stevenson & Patterson, 1998).

Vaginulinopsis **sp.** - Plate 2, fig. 21

The single specimen, from 181.33 m, has a compressed, unornamented, test consisting of a partial, planispiral initial whorl, followed by 3 uniserial chambers. Aperture is radiate,at the peripheral margin. Sutures are flush and oblique.

ACKNOWLEDGEMENTS

Hugh Morgans and Graeme Wilson read an earlier version of this manuscript and suggested a number of improvements. Wendy St George carried out the SEM photomicrography of foraminiferal specimens and prepared figure 1 and plates 1 and 2. The assistance of these individuals is gratefully acknowledged. This research was supported by the New Zealand Foundation for Research, Science and Technology (Contract CO5815) and by internal GNS funding. Peter Webb received support from NSF grant OPP 9420475.

REFERENCES

Blais-Stevens A. & Patterson R.T., 1998. Environmental indicator potential of foraminifera from Saanich Inlet, Vancouver Island, British Columbia, Canada. *Journal of Foraminiferal Research*, **28**, 201-219.

Bernhard J.A., 1987. Foraminiferal biotopes in Explorers Cove, McMurdo Sound, Antarctica. *Journal of Foraminiferal Research*, **17**, 286-297.

Boltovskoy E., 1978. Late Cenozoic benthonic foraminifera of the Ninetyeast Ridge (Indian Ocean). *Marine Geology* **26**, 139-175

Cape Roberts Science Team, 1998. Initial Report on CRP-1, Cape Roberts Project, Antarctica. *Terra Antartica*, **5**(1), 187 p.

Cape Roberts Science Team, 1999. Initial Report on CRP-1, Cape Roberts Project, Antarctica. *Terra Antartica* **6**(1/2), 173 p.

Carter A.N., 1964. Tertiary foraminifera from Gippsland, Victoria and their stratigraphical significance. *Geological Survey of Victoria Memoir*, **23**, 157 p., 17 pls.

D'Agostino A.E., 1980. Foraminiferal biostratigraphy, paleoecology, and systematics of DSDP Site 273, Ross Sea, Antarctica. M.S. thesis, Northern Illinois University.

Earland A., 1934. Foraminifera, part III. The Falklands sector of the Antarctic (excluding South Georgia). *Discovery Reports*, **10**, 208 p.

Ellis B.F. & Messina A., *Catalogue of Foraminifera*. American Museum of Natural History.

Fillon R.H., 1974. Late Cenozoic foraminiferal paleoecology of the Ross Sea, Antarctica. *Micropaleontology*, **20**, 129-151.

Gudmundsson G., 1998. Distributional limits of *Pyrgo* species at the biogeographic boundaries of the Arctic and the North-Atlantic boreal regions. *Journal of Foraminiferal Research*, **28**, 240-256.

Hayward B.W., 1986. A guide to paleoenvironmental assessment using New Zealand Cenozoic foraminiferal faunas. *New Zealand Geological Survey report* **PAL 10**, 73 p.

Hayward B.W., Hollis C.J., Grenfell H.R., 1997. Recent Elphidiidae (Foraminiferida) of the southwest Pacific and fossil Elphidiidae of New Zealand. *Institute of Geological & Nuclear Sciences monograph*, **16**, 166 p.

Hornibrook N. deB., 1971. A revision of the Oligocene and Miocene foraminifera from New Zealand described by Karrer and Stache in the Reports of the "Novara" Expedition (1864). *New Zealand Geological Survey Paleontological Bulletin* ***43***, 85 p.

Leckie M.A. & Webb P.-N., 1985. Late Paleogene and early Neogene foraminifers of Deep Sea Drilling Project Site 270, Ross Sea, Antarctica. In: Kennett J.P., Von der Borch, C.C. et al. (eds.), *Initial Reports of the Deep Sea Drilling Project*, **XC**, 1093-1142.

Mead G.A., 1985. Recent benthic foraminifera in the Polar Front region of the southwest Atlantic. *Micropaleontology*, **31**, 221-248.

Morgans H.E.G., Scott G.H., Beu A.G., Graham I.J., Mumme T.C., StGeorge W., Strong C.P., 1996. New Zealand Cenozoic Timescale (Version 11/96). *Institute of Geological & Nuclear Sciences science report*, **96/38**, 12 p.

Murray J.W.. 1973. *Distribution and ecology of living benthic foraminiferids*. Heinemann Educational Books, London, 274 p.

Parr W.J., 1931. A new species of the foraminifera—*Cassidulilnoides chapmani*. *Victorian Nat.* **48**, 99-100.

Stott L.D., Kennett, J.P., 1990, Antarctic Paleogene planktonic foraminifer biostratigraphy: ODP Leg 113, Sites 689 and 690. In: Barker, P.F., Kennett, J.P., et al., *Proceedings of the Ocean Drilling Program, Scientific Results*, **Vol. 113**, 549-564.

Strong C.P., Webb P.-N., 1998. Lower Miocene foraminifera from CRP-1 drillhole. *Terra Antartica*, **5**(3), 515-520.

van Morkhoven F.P.C.M., Berggren W.A., Edwards A.S., 1986. *Cenozoic cosmopolitan deep-water benthic foraminifera*. Bulletin des centres de recherches exploration-production Elf-Aquitaine, Memoir 11, 421 p.

Violanti D., 1996. Taxonomy and distribution of recent benthic foraminifers from Terra Nova Bay, (Ross Sea, Antarctica), Oceanographic Campaign 1987/1988. *Paleontographia Italica*, **83**, 25-71.

Ward B.L., Webb P.-N., 1986. Late Quaternary foraminifera from raised deposits of the Cape Royds-Cape Barne area, Ross Island, Antarctica. *Journal of Foraminiferal Research*, **16**, 176-200.

Webb P-N., 1989. Benthic foraminifera. In: Barrett P.J. (ed.), Antarctic Cenozoic History from the CIROS-1 drillhole, McMurdo Sound. *DSIR Bulletin*, **245**, 99-118.