

# Mid-Pleistocene Extinction of Deep-Sea Ostracoda?

---

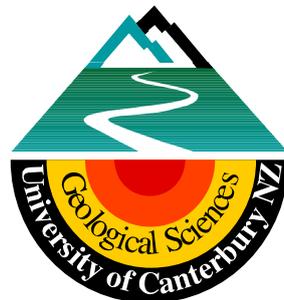
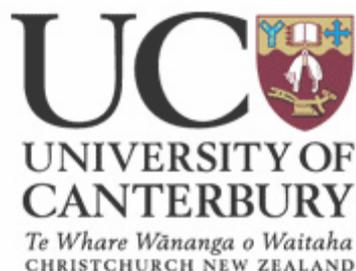
A thesis submitted in fulfilment of  
the requirements for the degree of

Master of Science  
in Geology

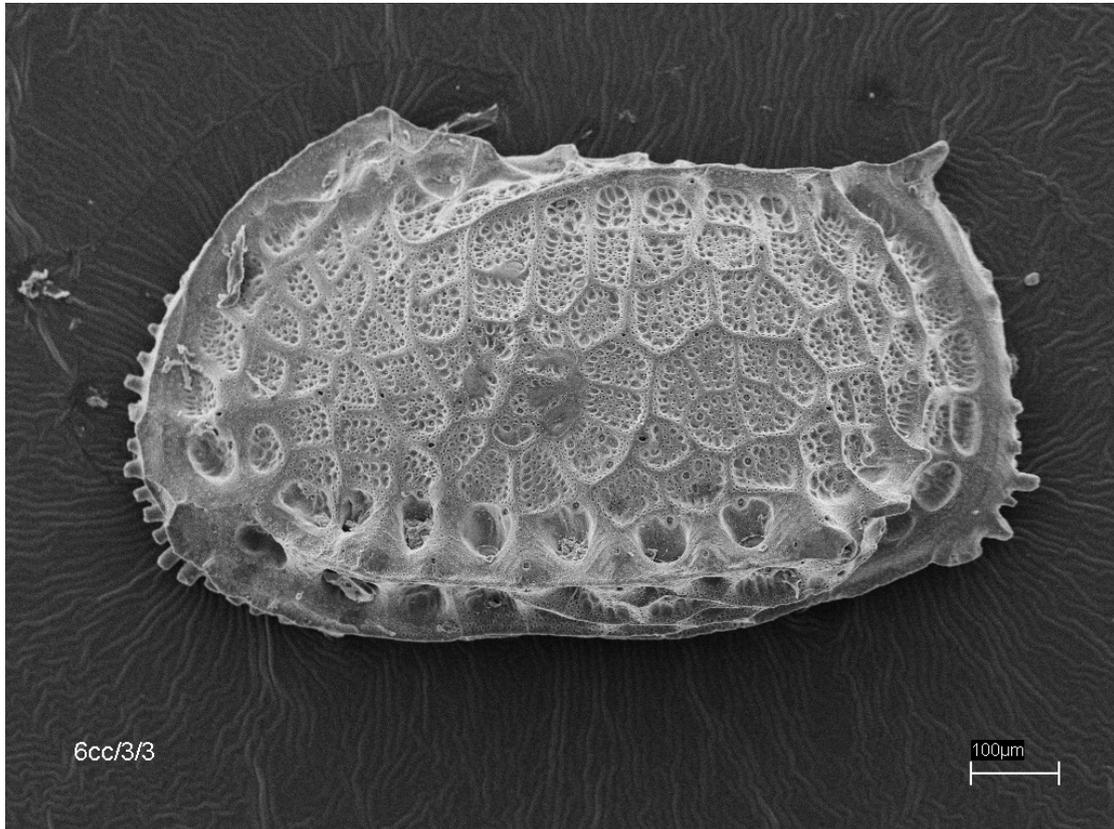
at the  
University of Canterbury  
By

Frances J. Gaiger

---



July 2006



Scanning Electron Microscope image of *Bradleya* sp. aff. *silentium* from Pleistocene sample, ODP Site 1125. *Bradleya* is a key genus in terms of our understanding of the induction of shallow water species into the abyss

## **ABSTRACT**

---

A global extinction event has been documented in protozoan foraminifera in the late Pliocene to Pleistocene. The timing of the extinction event varied depending on location, however for Ocean Drilling Project Site 1125, disappearances occurred between 2.5 and 0.57 Ma, with the major decline approximately 1.1 Ma. In order to determine if this event affected benthic organisms other than protozoans, this study was undertaken to determine how podocopid ostracods (Crustacea) recovered Ocean Drilling Program Site 1125 responded.

The present study was hindered by the small number of valves recovered; the fact that a large proportion of taxa found were undescribed and new to science; and the current state of taxonomic scheme that is under significant revision. These factors meant that a comprehensive comparison could not be achieved. Despite this, counts of ostracod valves and assessments of diversity from this study reveal a significant increase in both parameters from approximately 900-600 ka. Three possible causes were investigated to account for this increase, sediment type and sample size; affects of taphonomy, mainly dissolution; or an actual biotic 'event'.

Statistical analyses showed that although sample size did have some effect, it was not the sole reason for the increase in ostracod numbers. Dissolution had an expected affect on the percentage of juveniles but no correlations were found with other sample characteristics. Sedimentation rate was investigated but this also proved unrelated. Therefore, it is suggested that the increase in total ostracod valves and diversity which occurs between 900 and 600 ka was in fact a natural, biotic 'event'. This preliminary evidence suggests that an oceanographic event that has negatively impacted on the foraminifers has had the reverse affect on the ostracod assemblage, in the sense that both population size and diversity increase during that time.

# TABLE OF CONTENTS

---

Title Page .....	i
Frontispiece .....	ii
Abstract .....	iii
Table of Contents .....	iv
List of Figures .....	vii
List of Tables .....	ix
Acknowledgments .....	x

## CHAPTER 1

### Introduction

1.1 Research Objectives.....	1
1.2 Marine Ostracoda .....	2
1.3 Chatham Rise tectonic and sedimentation history .....	4
1.4 Oceanography .....	9
1.5 Paleoceanography .....	12
1.6 Ocean Drilling Program core 1125.....	13
1.7 Chronostratigraphy .....	17
1.8 <i>Stilostomella</i> Extinction Event .....	20

## CHAPTER 2

### Methods

2.1 Core drilling and subsampling .....	23
2.2 Sample preparation and picking .....	25
2.3 Scanning Electron Microscopy .....	27
2.4 Transmitted Light Microscopy .....	29
2.5 Assessment of dissolution .....	30
2.6 Statistical analyses .....	31
2.7 Cataloguing of specimens and sample residues.....	32

## CHAPTER 3

### Taxonomy

<b>3.1</b>	<b>Systematics.....</b>	<b>33</b>
	<i>Cytherella</i> sp. a.....	33
	<i>Cytherella</i> sp. b.....	33
	<i>Bythocypris</i> sp. ....	34
	<i>Propontocypris</i> sp.....	34
	<i>Argilloecia</i> sp.....	34
	<i>Cytheropteron</i> sp. aff. <i>dibolos</i> .....	35
	<i>Cytheropteron</i> sp. aff. <i>garganicum</i> .....	35
	<i>Cytheropteron</i> sp. aff. <i>quadrata</i> .....	36
	<i>Cytheropteron posteroreticulata</i> .....	36
	<i>Cytheropteron sianae</i> .....	37
	<i>Cytheropteron testudo</i> SARS 1869.....	37
	<i>Cytheropteron</i> sp. aff. sp. 1 AYRESS 1996 .....	39
	<i>Cytheropteron</i> sp. a .....	39
	<i>Cytheropteron</i> n. sp. ....	39
	<i>Cluthia</i> sp. a.....	40
	<i>Cluthia</i> sp. b.....	40
	<i>Taracythere</i> n.sp.....	41
	<i>Legitimocythere</i> sp. ....	41
	<i>Apatihowella</i> sp. ....	41
	<i>Fallacihowella</i> sp. aff. F. sp. a MAZZINI .....	42
	<i>Philoneptunus provocator</i> .....	42
	<i>Ambocythere</i> sp. aff. <i>recta</i> .....	43
	<i>Rugocythereis horrida</i> .....	43
	<i>Bradleya opima</i> . ....	44
	<i>Bradleya pelagica</i> .....	44
	<i>Bradleya perforata</i> .....	45
	<i>Bradleya pygmaea</i> .....	45
	<i>Bradleya</i> sp. aff. <i>silentium</i> .....	46
	<i>Bradleya</i> n. sp. a .....	46
	<i>Poseidonamicus major</i> .....	47
	<i>Pseudeucythere</i> n.sp.....	47
	<i>Krithe</i> sp. a.....	48
	<i>Krithe</i> sp. b.....	48
	<i>Krithe</i> sp. c.....	48
	<i>Krithe</i> sp. d.....	49
	<i>Parakrithe</i> sp. ....	49
	<i>Xestoleberis</i> sp.....	50

## CHAPTER 4

### Results and Discussion

<b>4.1</b>	<b>Ostracod dominance and diversity.....</b>	<b>51</b>
<b>4.2</b>	<b>Sampling problems .....</b>	<b>54</b>

<b>4.3</b>	<b>Dissolution and taphonomy</b> .....	<b>58</b>
<b>4.4</b>	<b>Taxonomy</b> .....	<b>64</b>
4.4.1	<i>Cythereis/Philoneptunus</i> .....	66
4.4.2	<i>Cytheropteron testudo</i> .....	67
4.4.3	<i>Adult versus juvenile valves</i> .....	67
<b>4.5</b>	<b>Benthic ostracods and the MPT</b> .....	<b>69</b>
 <b>CHAPTER 5</b>		
<b>Conclusions</b>		
<b>5.1</b>	<b>Conclusions</b> .....	<b>73</b>
 <b>References</b> .....		
<b>76</b>		
 <b>Plates 1-8</b> .....		
<b>82</b>		
 <b>APPENDICES</b>		
 <b>Appendix 1 – Introduction</b>		
<b>1.1</b>	<b>Macroscopic tephra for ODP 1125</b> .....	<b>90</b>
<b>1.2</b>	<b>Nannofossil datum levels for ODP 1125</b> .....	<b>91</b>
<b>1.3</b>	<b>Significant foraminiferal and bolboformid datums for ODP 1125</b> .....	<b>92</b>
 <b>Appendix 2 -Methods</b>		
<b>2.1</b>	<b>Details from ODP Site 1125 samples used in this study</b> .....	<b>90</b>
<b>2.2</b>	<b>Database of all picked specimens</b> .....	<b>91</b>
<b>2.3</b>	<b>Database of juveniles picked from each sample</b> .....	<b>92</b>
<b>2.4</b>	<b>Graphical comparison of a range of variables</b> .....	<b>96</b>
<b>2.5</b>	<b>UCF catalogue listing of</b>	
	a) all taxa referred to .....	<b>100</b>
	b) assemblage slides .....	<b>101</b>

# LIST OF FIGURES

---

## CHAPTER 1

Figure 1. Image of platycopine ostracod, including soft anatomy.....	5
Figure 2. Location map of bathymetric highs and Mernoo Gap.....	6
Figure 3. Location of core sites on ODP leg 181 and oceanography .....	7
Figure 4. Location of seismic lines, drill cores and seismic profile Mobil 72-8.....	8
Figure 5. Seismic section from Mobil 72-8.....	8
Figure 6. Basement structure of Chatham Rise .....	9
Figure 7. A) Location of DSDP and ODP sites and the surface and deep water current systems and surface sediment types east of New Zealand. B) cross section .....	12
Figure 8. The ODP research vessel, <i>JOIDES Resolution</i> .....	15
Figure 9. Stratigraphic column for ODP Site 1125A.....	17
Figure 10. Stratigraphic column for ODP Site 1125B.....	17
Figure 11. Legend for stratigraphic columns (figs 9 & 10) .....	18
Figure 12. Spliced composite reflectance curve for ODP Site 1125 .....	20

## CHAPTER 2

Figure 13. Examples of numbered core sections .....	24
Figure 14. Author working on Scanning Electron Microscope .....	28

## CHAPTER 4

Figure 15. Total number of valves vs depth, raw data .....	52
Figure 16. Total number of species vs depth, raw data.....	52
Figure 17. Total number of valves vs depth, stacked plot, raw data.....	53
Figure 18. Total number of valves vs depth, normalised and stacked .....	53

<b>Figure 19. Sample weight and total number of valves vs depth .....</b>	<b>55</b>
<b>Figure 20. Total number of valves vs sample weight.....</b>	<b>57</b>
<b>Figure 21. Total number of valves vs sample weight.....</b>	<b>57</b>
<b>Figure 22. Dissolution profile for samples from this study .....</b>	<b>61</b>
<b>Figure 23. Comparison of % juveniles and dissolution for top 21 m of core. .</b>	<b>61</b>
<b>Figure 24. Comparison of % mud, % juveniles and foraminiferal Fragmentation Index. ....</b>	<b>70</b>

# LIST OF TABLES

---

## CHAPTER 1

Table 1. Foraminiferal datums and age estimates used at ODP Site 1125 .....18

Table 2. Nannofossil datums and age estimates used at ODP Site 1125 .....18

## CHAPTER 2

Table 3. Dissolution index for podocoid ostracod valves .....30

## CHAPTER 4

Table 4. Summary of genera picked, total valves and percentage of juveniles .....51

Table 5. Dissolution index for podocoid ostracod valves .....58

## ACKNOWLEDGEMENTS

---

Firstly I would like to thank Dr. Bruce Hayward of Geomarine Research for making this project possible and for being a great supervisor. Even though he is in the far away land of Auckland, he always managed to reply to my requests for data and answer the plethora of questions without hesitation.

I give my most heartfelt appreciation to my supervisor Kerry Swanson, with his never-ending support and faith in me. He has been an outstanding role model, teacher and friend, especially over the past year and a half. He was always available for the many visits I paid him and constantly had words of encouragement since I first became interested in micropaleontology in my 2<sup>nd</sup> year at university.

Kari Bassett, who even after having cute wee Charlie has been a great support for me in terms of my general degree as well as a wonderful supervisor. Kari has also always had faith in me and my abilities and was able to remind me of this when it was needed.

The staff of the Department of Geological Sciences who have helped me in any way possible when I came knocking at the door. You have all been wonderful friends and colleagues, although there are a few who deserve a special mention.

- Jane Guise who gave me many ideas and much advice during my time at university and always had her door open if I needed a rant!
- When Jane left halfway through my Masters, Jennifer Jackson stepped into her job in the department as well as my friend and ‘surrogate mother’ for the last few months of my thesis – I could not have done it without her.
- Margaret Bradshaw, my wonderful mentor throughout my geology career. She has always encouraged me in my demonstrating, my work, the talks I have given and always made me feel that I can achieve anything.
- Alison Johnston, our wonderful, always smiling librarian! We have enjoyed many a fieldtrip and lecture together, there was always something to laugh about! And thank you for all your quick responses to my requests for the bizarre and often unobtainable references.
- Neil Andrews for constantly battling with the SEM to get the quality of images that I insisted on getting.

To my friends within and out of the department, thank you for all your faith and encouraging words. I am very lucky to have people who will stick by me and encourage me through it all and wait patiently for me to finish so we can spend time together!! A special thanks to my best friend Katy – you’ve always been there when I needed a chat, a hug or just to sit down and watch Bond! Thanks heaps babe, you are a wonderful person and a most special friend.

Most importantly, thanks to my family. Mon, Dad, Mum, John, Grandma, David and Heidi, you never cease to amaze me with the endless support you give me in every possible way. Words cannot describe it, but I love you all and thank you for everything.

# 1 INTRODUCTION

---

## 1.1 RESEARCH OBJECTIVES

A global extinction event occurring approximately 600-900 thousand years ago (ka) has been identified in foraminifera (a single-celled organism which precipitates a preservable calcareous or test [Bé, 1979]). Foraminifera have been routinely used as tools for paleoceanographic and biostratigraphic research for many years. It is becoming increasingly evident that Ostracoda (Crustacea) can also make a significant contribution to this ongoing research, with a special emphasis on paleothermometry and geochemistry. Ostracods are metazoans (multi-celled) with both planktic and benthic species; planktic forms however, are only rarely preserved in the fossil record. Ostracods have, in the past, been used as environmental indicators in many studies providing proxy information on paleodepth (Ayress, 1994), water-mass interaction (Swanson, 1994) and tectonic and oceanographic events (e.g. Benson, 1990; Keen, 1990; Whatley, 1996).

In an attempt to determine if the foraminiferal extinction event also impacted on other benthic organisms in the deep sea, a comparison with ostracods was undertaken. Although the identification of a global extinction event is beyond the scope of this thesis, it was possible to describe a significant, though at this stage local, increase in ostracod dominance and diversity coincident with the Mid Pleistocene Transition (see p.52 for additional discussion). That result is based on a detailed examination of variations in the ostracod population in samples from 0 to 47.6 metres below sea floor (mbsf), which represents an almost continuous 2.5 million year (my) history of oceanographic change over the Chatham Rise.

If changes, appearances or disappearances were discriminated, then as part of this project an attempt would be made to relate these to (for example) paleoceanographic, climatic and/or productivity fluctuations, which may be localised and restricted to the area around ODP Site 1125, (located on the Chatham Rise, east of New Zealand), or of regional or global significance. Because equivalent ostracod assemblage data is not available for cores taken on the Chatham Rise or elsewhere in the New Zealand region, determination as to the regional or global importance of such an 'event' would, at this stage, be speculative.

Even if significant variations in the ostracod fauna were not found, one important outcome of this study will be a significant improvement to the knowledge of the taxonomy and distribution of deep-sea podocopid ostracods, with the expected discovery of species new to science and a contribution to the knowledge of ostracod faunal responses to Pleistocene paleoceanographic change east of New Zealand. The nearest equivalent sites for which ostracod data is available are on the Campbell Plateau, south of the Chatham Rise but located in a very different water-mass configuration (Ayress, 1988). Additionally, with respect to the present study, sample spacings from that previous work were selected to ensure a broad coverage of a record representing 50 Ma and as a result short-term oceanographic biotic events were not isolated.

## **1.2 MARINE OSTRACODA**

Ostracods are a microscopic (usually 0.3-3.0 mm long), bivalved crustacean. As well as occurring in all types of marine environments, they are commonly found in fresh and brackish-water systems (van Morkhoven, 1979). Benthic ostracods have a carapace (consisting of two valves) made of calcite that usually preserves well, meaning these animals have a good fossil record that extends back to the Ordovician, about 500 my.

Although there are planktic and benthic ostracods, only rarely are the planktic organisms preserved in the fossil record. As a result, this study will examine only ostracods from the benthic order Podocopida, one of five orders in the class Ostracoda.

The carapace usually presents a wealth of structural details, which provide key taxonomic indicators (figure 1). These are the external carapace structure (misleadingly sometimes called 'ornament'), carapace size and shape, hinge type, normal and marginal pore type and distribution and the muscle scars. The soft anatomy is also increasingly being used, but is rarely preserved in the fossil assemblages and almost never in specimens recovered from cores of bathyal or abyssal sediments.

Another characteristic of ostracods is that their valves often display sexual dimorphism (Sylvester-Bradley, 1969; Shaver, 1953). The males are usually smaller and the size and shape of the hemipene and the copulatory style can be key determinants of carapace shape (Cohen & Morin, 1990; Kesling, 1969; McGregor & Kesling, 1969). In terms of the female, brooding does occur in females of some species, which has also had a significant affect on evolution of carapace shape, and may be expressed both internally and externally. In *Cytherella* for example, females are broader and more inflated posteriorly than males and often possess brood cavities interiorly. *Xestoleberis* also broods and females of that genus possess a carapace in which the posterior of the carapace is inflated, allowing up to half of the domiciliar space to be occupied by early juveniles (instars).

An ostracod moults approximately eight times during its development from the initial instar to adult. Phylogenetic development is generally more rapid than, for example,

foraminifera, meaning that ostracod species potentially have much shorter vertical ranges and should therefore be useful in chronostratigraphy (van Morkhoven, 1979).

With respect to podocopid ostracods especially, almost all current taxonomic descriptions and determinations are based on morphological detail of the adult valves and as a consequence, very little, if any information is available to assist taxonomic discrimination of pre-adult instars.

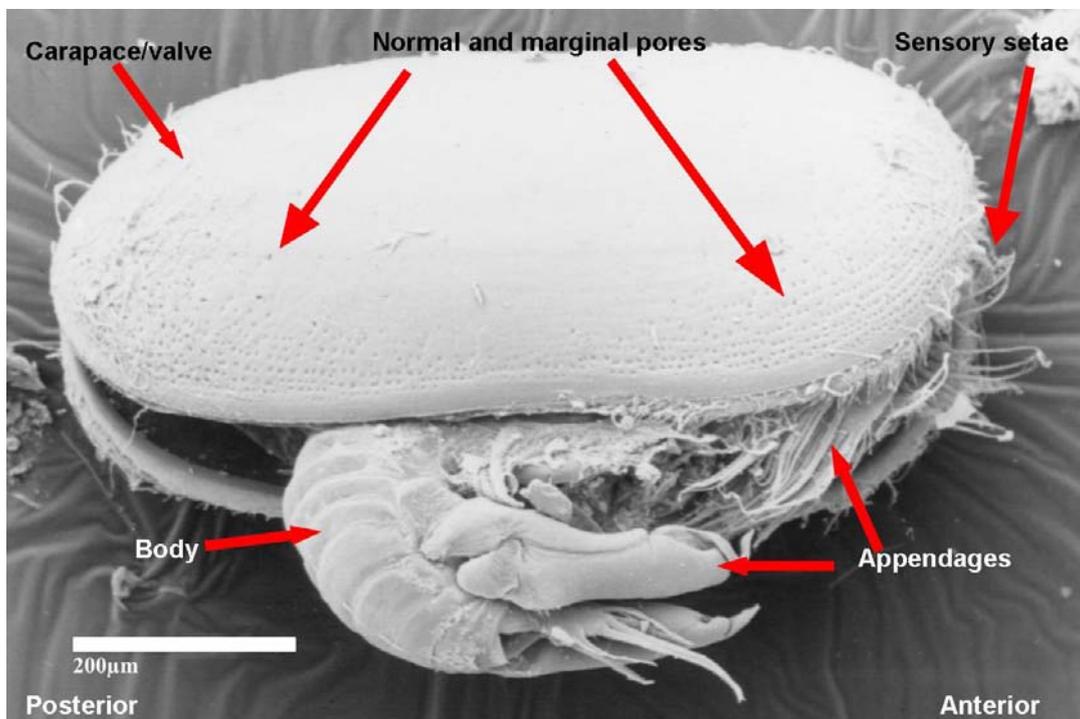


Figure 1. Image of platycopine ostracod, including soft anatomy. Note key indicators - carapace, marginal and normal pores. (photo courtesy of K. Swanson)

### 1.3 CHATHAM RISE TECTONIC AND SEDIMENTATION HISTORY

The Chatham Rise is a submerged part of the New Zealand micro-continent and extends from the coast of New Zealand due east for over 1000 km (Wood & Herzer, 1993). On average, the crest of the Rise is 400 m below sea level, with several shallower banks including the Chatham Islands, the only land area on the Rise (Norris, 1964).

Norris (1964) divided the Rise into three main topographic units. One to the east consisting of the Chatham Island Group and defined by the 250 m contour (figure 2); a western most unit which extends from where the Rise is separated from the mainland (by the Mernoo Saddle) to about 177° 30' E and includes the three main submerged topographic highs (Mernoo, Veryan and Reserve Banks). The central unit is located between 177° 30' E and the 250m bathymetric contour to the east and is for the most part gently undulating with only about 100 m of relief (Norris, 1964), except for a small topographic high (Matheson Bank) (figure 2).

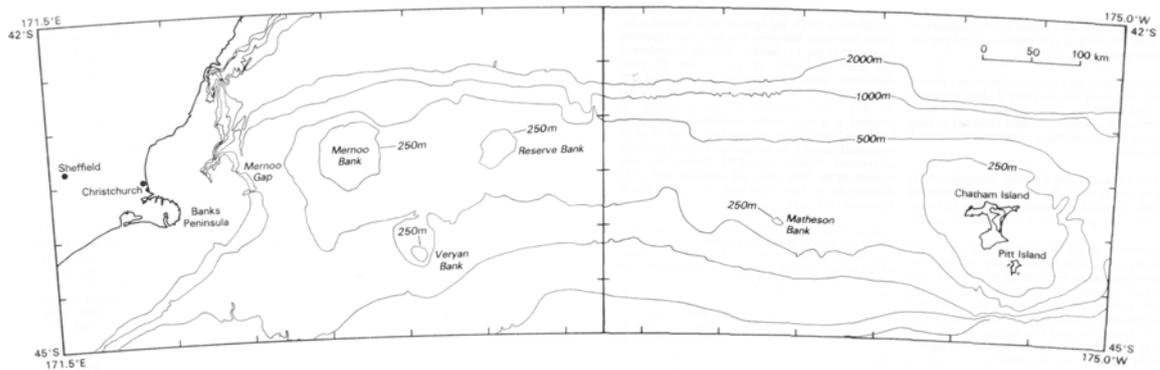


Figure 2. Location map of bathymetric highs and Mernoo Gap (from Campbell *et al.*, 1993)

Knowledge of the stratigraphy of the Chatham Rise is very restricted as a result of limited outcrop and little supplementary core data. Apart from the Chatham Islands and the banks mentioned previously, most interpretations are based on seismic reflection profiles, a few boreholes and some dredge samples (Wood *et al.*, 1989). The most detailed information is as a result of work carried out during the Deep Sea Drilling Program's (DSDP) Leg 90, Site 594, and more recently on drill sites 1123 and 1125 of the Ocean Drilling Program (ODP) Leg 181 (figure 3).

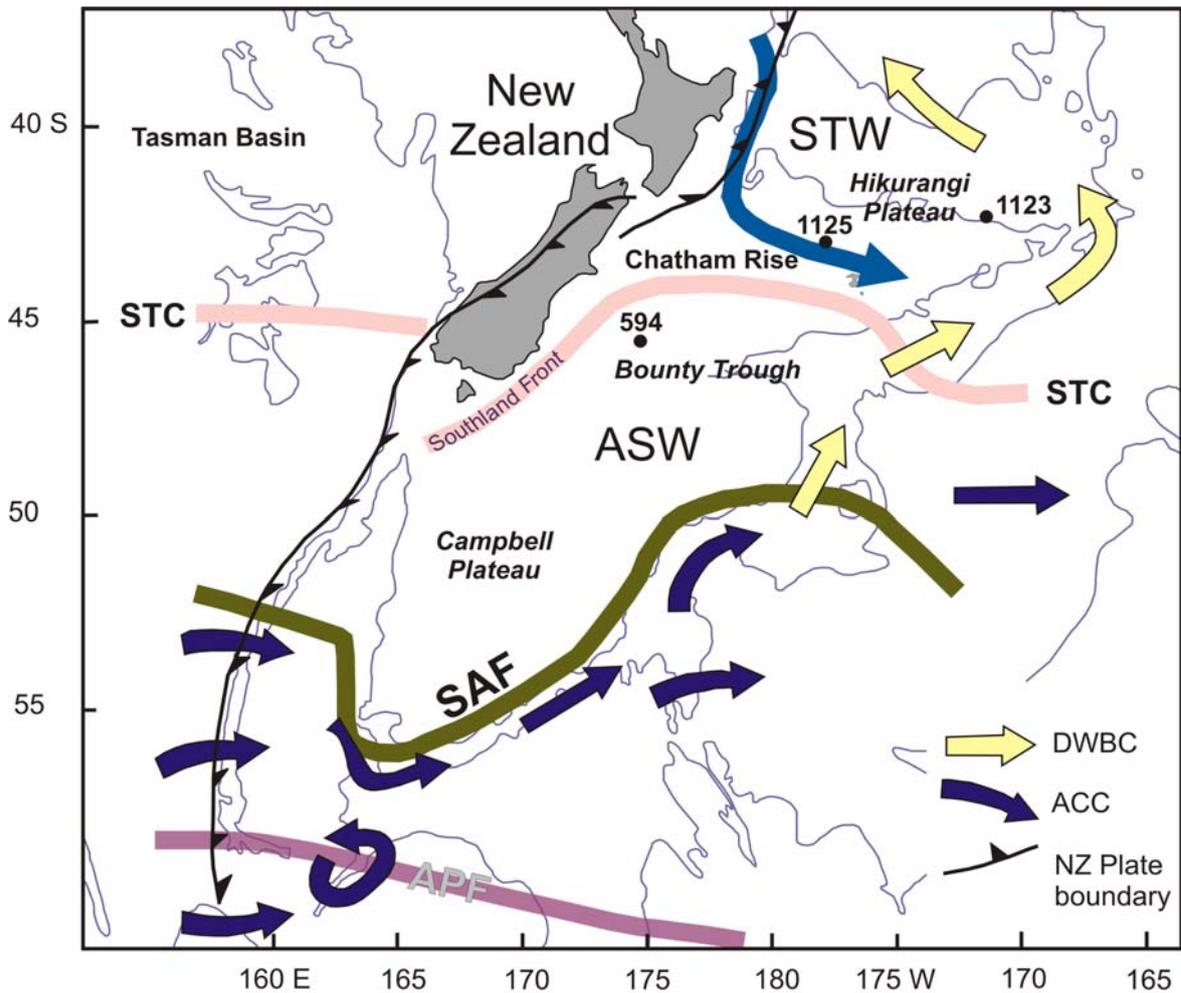
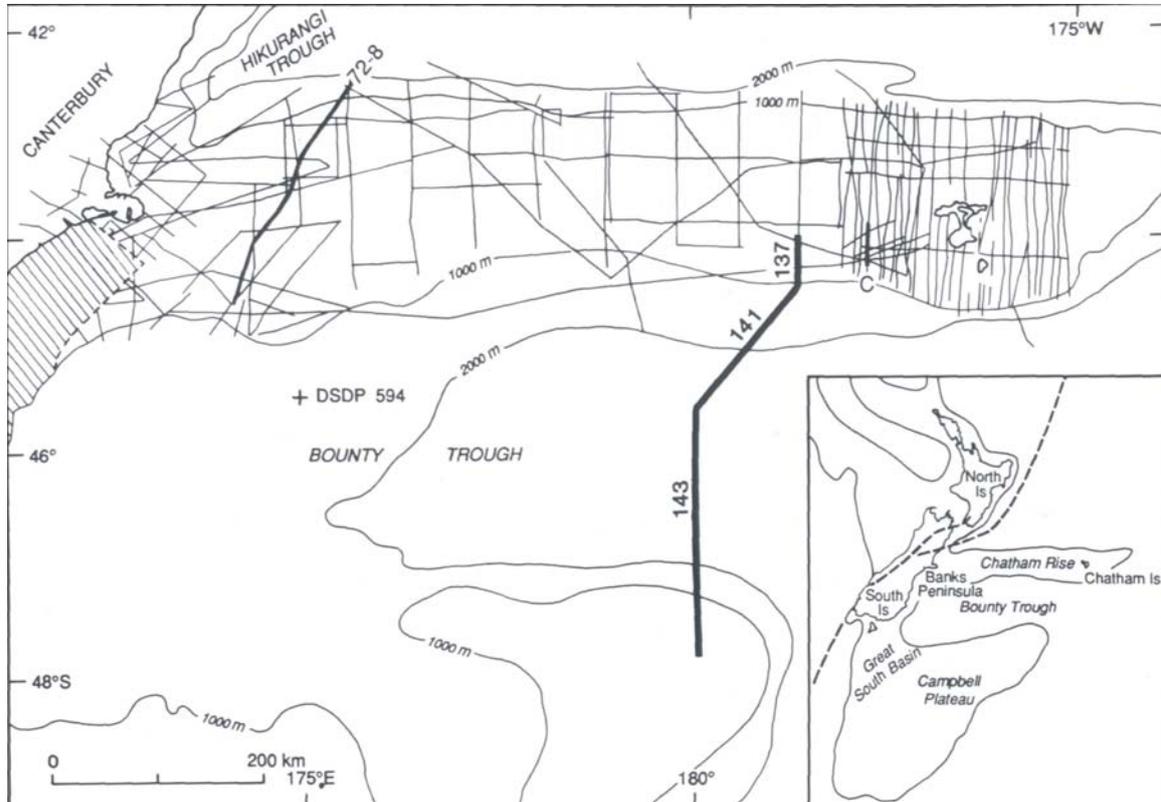


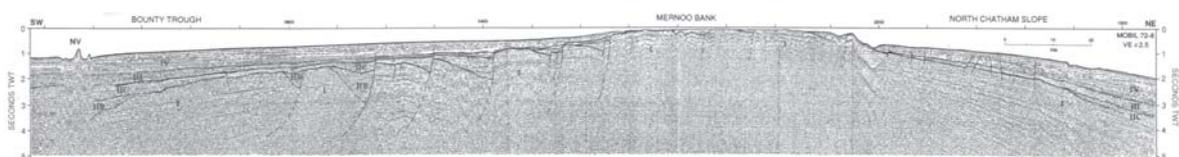
Figure 3. Location of core sites on ODP leg 181 showing major surface (summer temperatures) and deep ocean currents. Abbreviations are as follows: STW, Subtropical Surface Waters; STC, Subtropical Convergence; SAF, Subantarctic Front; DWBC, Deep Western Boundary Current; ACC, Antarctic Circumpolar Current. (adapted from ODP initial results, Carter *et al.*, 1999)

Other geophysical data were obtained from regional surveys carried out by a number of oil companies. Figure 4 shows the location of the seismic survey lines. Four units were identified in the seismic survey (figure 5) by correlating relationships and vertical spacings of key reflectors with outcrop data from the Chatham Islands, results from the DSDP core and some dredge samples (Wood *et al.*, 1989). These correlations identify the four units as: Unit I, acoustic basement of Torlesse rock with listric, normal faults; Unit IIB, Mid- to Upper Cretaceous deposits of either volcanic material or conglomerates infilling the half-grabens of Sequence I; Sequence IIC, Latest Cretaceous transgressive sequence which unconformably onlaps basement and Sequence IIB; Sequences III and IV, Lower and

Upper Cenozoic sediments draped over the Rise, which thicken downslope and are often absent on the crest (Wood & Herzer, 1993).



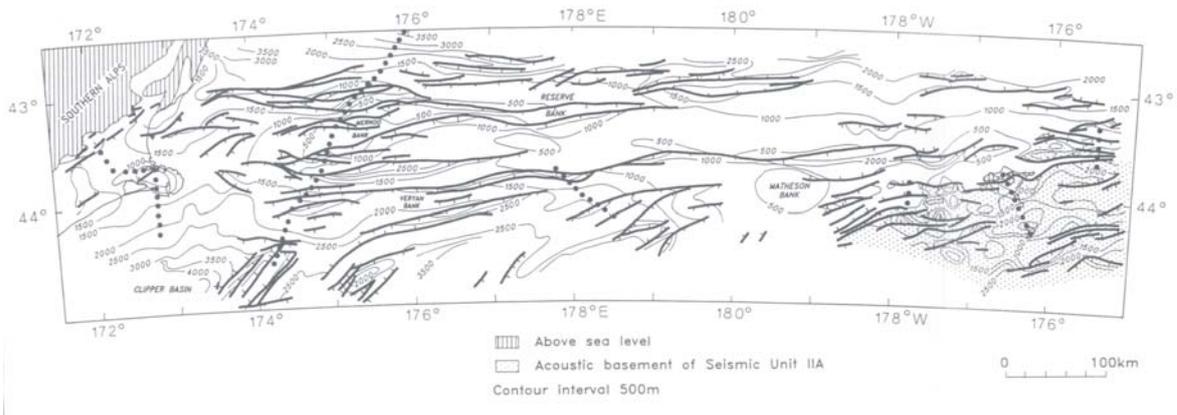
**Figure 4. Location of seismic lines and drill cores and seismic profile Mobil 72-8 (from Wood *et al.*, 1989)**



**Figure 5. Seismic section from Mobil 72-8 showing Sequence I-IV (from Wood *et al.* 1989)**

The Chatham Rise was once part of the Gondwana margin (Wood & Herzer, 1993) and its northern edge was probably part of a subduction zone. Separation from Antarctica occurred during the Late Cretaceous, about 85 million years ago (Ma), during breakup of Gondwana, (Luyendyk, 1995). Once separated from Antarctica, the Rise was stable throughout the Cenozoic, apart from intermittent relative sea level changes, volcanism and

faulting. Figure 6 presents an interpretation of the basement structure, showing extensive normal faulting that trends E-W along the extent of the Rise (Wood *et al.*, 1989). These faults are down-thrown in a series of half grabens into the Bounty Trough, which is interpreted as a rift structure. At around 50 Ma (Early Eocene), a proto-plate boundary appeared through New Zealand representing a precursor to the development of the high strain zone associated with the transpression along the Australia and Pacific Plate boundary. Regional subsidence had all but ceased in the east and remained stable for the rest of the Cenozoic (Wood & Herzer, 1993).



**Figure 6. Basement structure of Chatham Rise (from Herzer & Wood, 1992)**

Despite the fact that the Tasman Gateway opened about 30 Ma when Australia and Antarctica separated, the Antarctic Circumpolar Current (ACC) could not fully develop until separation of South America and Antarctica resulted in the formation of the Drake Passage at ~28 Ma (Late Oligocene). The associated dramatic change to global circulation created a regional unconformity and altered sedimentation patterns in New Zealand and on the Chatham Rise, with the Rise becoming sediment starved. At around 28-23 Ma (Late Oligocene), pure strike-slip motion on the Alpine Fault initiated uplift of the Southern Alps and renewed sedimentation on the western flank of the Rise, which has continued

since Mid-Miocene times (Campbell *et al.*, 1993). Thin, patchy sequences of biogenic and authigenic sediments dominate the Neogene deposits, indicating predominantly tectonically stable, submarine conditions. Local basaltic volcanism, sea-level changes, ocean currents and minor faulting were the only major factors that affected the Rise during this time (Campbell *et al.*, 1993).

From ODP Site 1125 a thick (552.10 m) succession of Late Miocene to Recent sediments was recovered. During the Pliocene and Quaternary on the seafloor around Site 1125, a thick succession (3-20 cm/kyr) of clay-rich nannofossil ooze with interbeds of more terrigenous silty-clay accumulated (Carter *et al.*, 1999). The terrigenous sediment had been transported by currents from the west, with several paraconformities representing short erosive intervals (Carter *et al.*, 1999). Although there was an increase in the influx of sediment from the New Zealand continent as a result of increasing compression and uplift on the Alpine Fault in the South Island, it appears that this sediment was preferentially transported away from the Rise by the ocean currents. Twenty-six macroscopic (<1 cm to ~20 cm) tephra layers are present in Subunit IA, in all probability sourced from a series of eruptions in the central volcanic region of the North Island and the few smaller volcanic centres of Banks Peninsula and the Chatham Islands (Wood *et al.*, 1989).

#### **1.4 OCEANOGRAPHY**

ODP Site 1125 is located on the northern flank of the Chatham Rise in the south west Pacific Ocean. The location of the Rise creates a geographical barrier to local ocean circulation (Heath, 1985). The surface Subtropical Water (STW) as described by Heath (1985), lies to the north of the Rise and is mainly derived from the East Australian Current (Heath, 1985). This current flows from the east coast of Australia, around the top of the

North Island where it forms the East Cape Current (ECC), which moves down the eastern margin of the North Island and is then deflected east when it impacts with the Chatham Rise (figure 7). The STW is warm, with mean annual temperatures of  $>15^{\circ}\text{C}$  and high salinity ( $>35$  psu) but is nutrient depleted (Carter *et al.*, 1999). To the south of the Rise, Sub Antarctic Surface Water (SAW), characterised by low salinity (34.5 practical salinity unit [psu]) and annual surface temperature ranges of  $8^{\circ}$ - $15^{\circ}\text{C}$ , flows from the south of New Zealand (Carter *et al.*, 1999). These two water bodies meet at the Subtropical Convergence (STC), which is coincident with the Chatham Rise.

To the south of the STC, the Southland Current generally flows north-eastward, passing below the South Island then paralleling the east coast of the South Island to a point below Banks Peninsula where it splits. In terms of the resultant branches, the first flows through the Mernoo Saddle, a 550 m depression that separates the Chatham Rise from the New Zealand continental shelf (figure 2), while the other flows east along the southern flank of the crest of the Rise (Heath, 1985).

Below the surface waters, Antarctic Intermediate Water (AAIW) occurs between *c.* 700-1450 m (Heath, 1985). AAIW originates as low-salinity surface water south of the ACC and subsequently sinks below the ACC and migrates north (Heath, 1985). East of New Zealand, AAIW is characterised by temperatures of  $3$ - $7^{\circ}\text{C}$  and salinities of 34.3-34.5 psu.

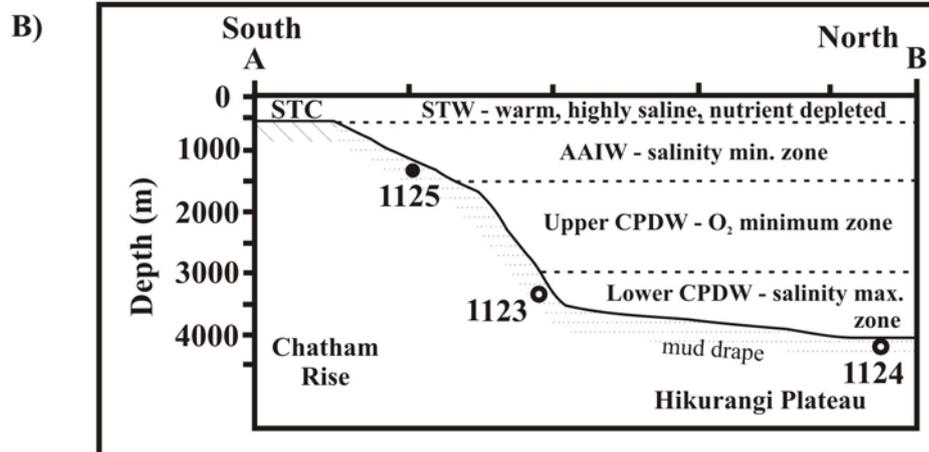
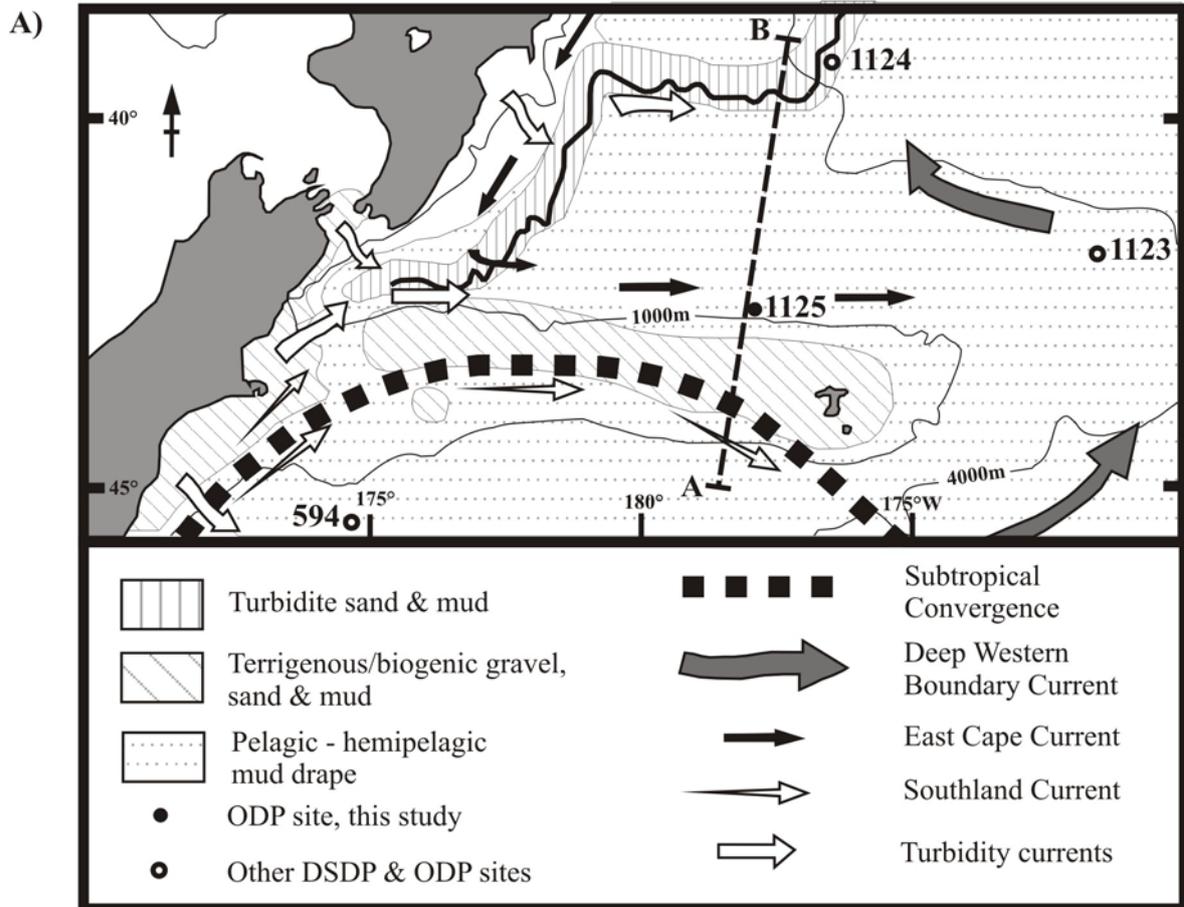


Figure 7. A) Location of DSDP and ODP sites and major aspects of the surface and deep water current systems and surface sediment types east of New Zealand. B) South to North cross section showing modern water mass distribution. Abbreviations: STC, Subtropical Convergence; STW, Subtropical Water; AAIW, Antarctic Intermediate Water; CPDW, Circumpolar Deep Water (adapted from Hayward *et al.*, 2002)

The deepest water in the study area is Circumpolar Deep Water (CPDW), the source of which can be traced to the Antarctic and the Deep Western Boundary Current (DWBC). This water flows northwards (Carter *et al.*, 1999) along the eastern margin of the New

Zealand continental landmass, around Campbell Plateau, the Chatham Rise and the Hikurangi Plateau (figures 3 & 7). CPDW is separated into two units, upper CPDW occurring at 1500-2900 metres with salinities of 34.5-34.7 psu, (including the oxygen minimum zone of 3.03-3.45 mol/kg and temperatures of 1.8-3.0°C), and lower CPDW which has a distinct salinity maximum that extends from 2500-2900 m to the seafloor, or to a maximum of 3800 m (Carter *et al.*, 1999). ODP site 1125 is located in the lowermost AAIW portion.

## **1.5 PALEOCEANOGRAPHY**

Our knowledge of the last 150 ka (Mid to Late Pleistocene) paleoceanography in the study area is relatively well constrained as a result of previous DSDP (594) and ODP (1119, 1123 & 1125) cores, with records of older sediments being based almost entirely on the latter (Carter *et al.*, 1999).

Around 6.4 Ma there was a major reorientation of the New Zealand plate boundary movement from almost pure strike slip to having a large component of compression (Walcott, 1998). This resulted in more rapid uplift and erosion, thus a significantly increased supply of terrigenous sediment from the eastern South Island became available for transport to and deposition in marine environments to the east. However, at ODP Site 1125, the change in sedimentation with the first appearance of terrigenous mud came at approximately 5.5 Ma (Carter *et al.*, 1999). The reason for this 0.9 Ma lag time is not clear, however it is possible that the influx of terrigenous sediment reflects a change in oceanographic conditions, for example the path of the Southland Current may have altered to carry more sediment to the Rise (Carter *et al.*, 1999). However, in contrast to other regions such as the Tasman Sea, in which a north-south migration of the STC has been

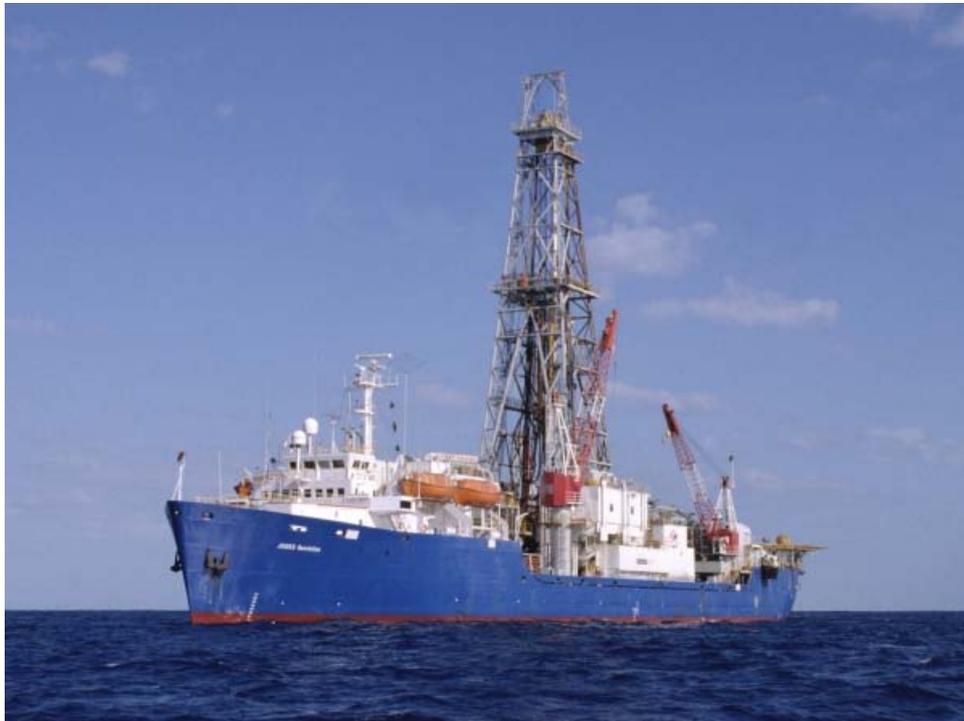
documented (e.g. Passlow *et al.*, 1997; Kawagata, 2001), diatomaceous and foraminiferal assemblages at various latitudes east of New Zealand indicate the STC has remained on or near the crest of the Rise throughout the climate cycles, except during some warm peaks (Weaver *et al.*, 1998; Schafer *et al.*, 2005).

At about 5 Ma, there was a reduction of carbonates to a general level (Carter *et al.*, 1999), which remained stable until the Holocene (Carter *et al.*, 1999). This was accompanied by a gradual decline in the overall sedimentation rate. The sedimentation rate continued to drop steadily into the Pleistocene, when there was yet another increase in terrigenous sedimentation from increased uplift on the Southern Alps of New Zealand. It appears that after this influx of sediment, there was a marked drop in the supply of sediment to the Rise, but it may be that there was local exchange of sediment from the crest of the rise to site 1125, especially during lower sea level when the storm wave base and currents would have affected the rise (Carter *et al.*, 1999). Additionally, there is an evident cyclicity superimposed on a general decrease in sedimentation that is a reflection on the impact of a series of glacial and interglacial cycles during that time (Weaver *et al.*, 1998).

## **1.6 OCEAN DRILLING PROGRAM CORE 1125**

The core used in this study was collected by the US research vessel, The *JOIDES Resolution* (figure 8) as part of the ODP. This project is an ongoing international research program drilling cores of sediment from the floor of the world's oceans to study the history of the oceans and the earth, with an emphasis on the study of the evolution of ocean systems from the Cretaceous to Cenozoic (Carter *et al.*, 1999).

For this study, sub-samples from Site 1125 of ODP leg 181 (cruise track from Sydney, Australia to Wellington, New Zealand) were used. The scientific objectives of this drilling programme were to enhance the knowledge of the history of the Southwest Pacific Ocean and in particular to examine the development of the Antarctic Convergence Current-Deep Western Boundary Current (ACC-DWBC) through time. A total of 7 sites were drilled during Leg 181 (11<sup>th</sup> August to 8<sup>th</sup> October 1998) in water depths ranging from 393 to 4460 m, between latitudes 39°S to 51°S (figures 3 & 7).



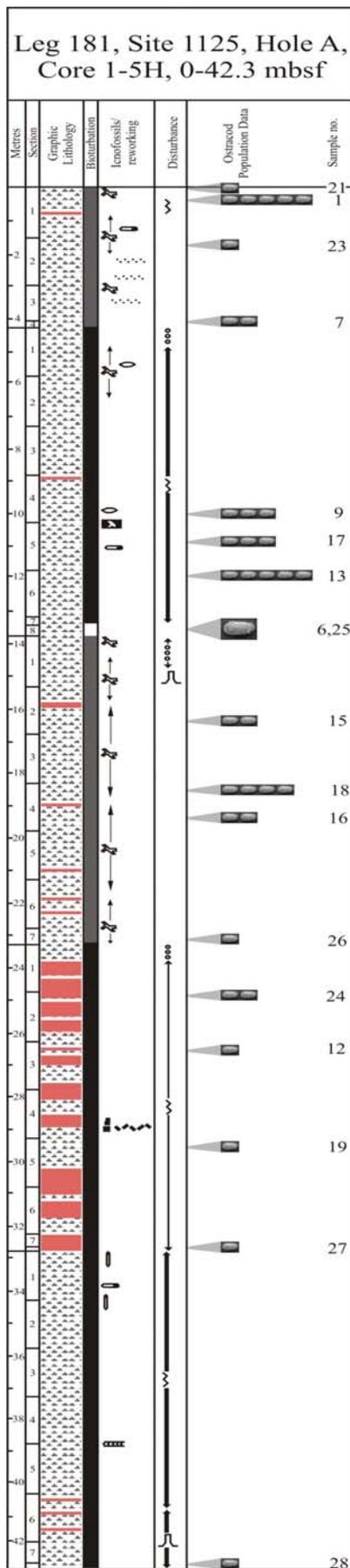
**Figure 8. The ODP research vessel, *JOIDES Resolution*. (taken from [www-odp.tamu.edu](http://www-odp.tamu.edu))**

The main reasons for targeting eastern New Zealand during this drilling project were to examine the Pacific DWBC (one of the biggest contributors to deep waters of the world's oceans); to interpret the history of Southern Ocean water masses by studying the stratigraphic record; to investigate the movement and any resulting environmental changes of the Subtropical Convergence (STC) and Subantarctic Front (SAF); and to analyse the

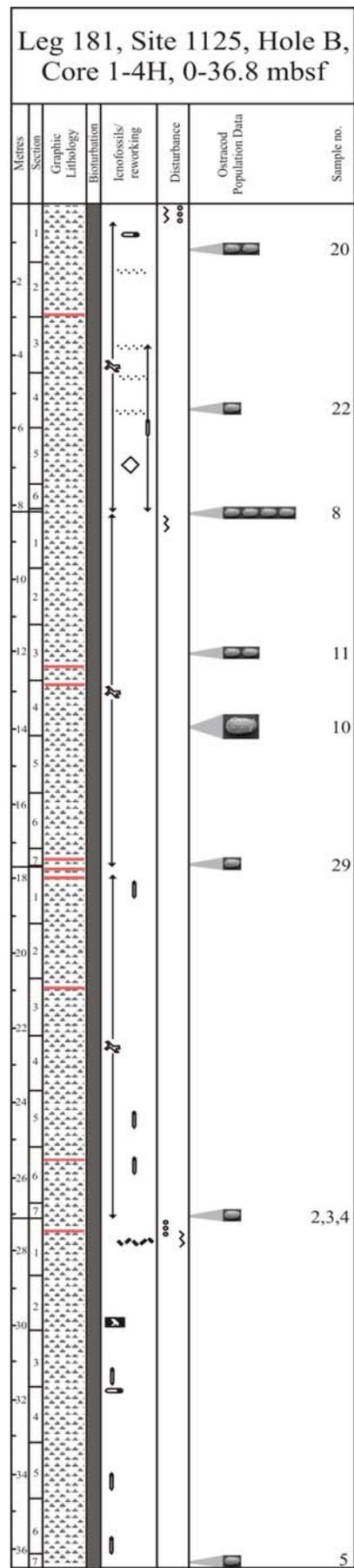
Eastern New Zealand Oceanic Sedimentary System (ENZOSS), “a major geological and sedimentary system within which sources, sinks, and material fluxes can all be quantified.” (Carter *et al.*, 1999).

ODP Site 1125 was on the northern flank of the Chatham Rise, 610 km east of Kaikoura, South Island, New Zealand, at a water depth of 1359 m. Two cores (A and B) were taken, 1125A at 42°32.996'S, 178°9.989'W and 1125B approximately 30 m north at 42°32.979'S, 178°9.988'W. The total core length recovered was 203.50 m in core 1125A (figure 9) and 552.10 m in core 1125B (figure 10).

The two cores (1125A and B) have been stratigraphically divided into two sections; the uppermost Unit I (Pliocene to Pleistocene in age) and the lower Unit II (Late Miocene to Pliocene). Additionally, within Unit I two subunits have been identified (IA and IB), the uppermost of which (IA – above 74.8 m) was defined on the basis of the presence of occasional sandy glauconitic layers. Because this study was to focus on a history representing approximately the last 2 my, samples used were selected from the top 48 m (1125A) and 41 m (1125B) only (i.e. all samples are from Subunit IA). This unit consists of clayey nannofossil ooze with alternating layers of nannofossil-bearing silty clay containing foraminifera and biosiliceous microfossils and frequent tephras up to 17 cm thick (Carter *et al.*, 1999).



**Figure 9. Stratigraphic column for ODP Site 1125A. Note: only top 42 m of core sampled for this study, age range of 2.5 Ma to ~1 ka (adapted from Carter *et al.*, 1999)**



**Figure 10. Stratigraphic column for ODP Site 1125B. Note: only top 37 m of core sampled for this study, age range of 2.2 Ma to ~1 ka ((adapted from Carter *et al.*, 1999)**

# Legend

<b>Lithology</b>  Foraminiferal Ooze  Tephra		<b>Relative Bioturbation</b>  Abundant  Common	
<b>Ichnofacies/reworking</b>  Chondrites  Planolites		 Skolithos  Thalassinoides  Zoophycos	 Graded bedding  Sand lamina  Lenticular bedding
<b>Core Disturbance</b>  Disturbed  Extreme  Moderate		 Thin ash layer  Lithoclast  Soupy  Flow in	<b>Ostracod population</b>  0-20 specimens  21-40 specimens  41-60 specimens  61-80 specimens  81-100 specimens  100+ specimens

Figure 11. Legend for stratigraphic columns (figs 9 & 10)

## 1.7 CHRONOSTRATIGRAPHY

The age of the cores from ODP Site 1125 is not tightly constrained as dates are mostly based on core catcher samples, which are located at the bottom of the core barrel and therefore represent a ‘homogenised’ record of each cored section. The late Pliocene and Quaternary chronostratigraphy for ODP Site 1125 for this study follows that of Hayward (2002), who used nannofossil and planktic foraminiferal data of Carter *et al.* (1999); Sabaa (2000) and tephra data cross-correlated with Site 1123 (Alloway *et al.*, 2005), as well as the spliced reflectance curve (Carter *et al.*, 1999) with cross-referenced isotopic stages attributed to (figure 12). Foraminiferal and bolboformid datums for the top 50 m of core sampled for this study are:

		Age (Ma)	mbsf
LO	<i>Globorotalia puncticuloides</i>	~0.60	4.2
LO	<i>Stilostomella</i> spp.	0.60-0.80	13.4
LO	<i>Plectofrondicularia advena</i>	0.60-0.80	13.4
FO	<i>Globorotalia truncatulinoides</i>	~0.80	23.6
LO	<i>Globorotalia inflata triangular</i>	~2.00	42.6
FO	<i>Globorotalia crassula</i>	2.6	42.6

**Table 1. Foraminiferal datums and age estimates used at ODP Site 1125 (from Carter *et al.*, 1999)**

		Age (Ma)	mbsf
LO	<i>Helicosphaera inverse</i>	0.16	2.05
LO	<i>Pseudoemiliana lacunose</i>	0.42	4.53
LO	<i>Reticulofenestra asanoi</i>	0.85	23.6
FO	<i>Gephyrocapsa parallela</i>	0.95	23.6
LO	<i>Helicosphaera sellii</i>	1.26	28.22
FO	<i>Gephyrocapsa (medium)</i>	1.67	35.8
LO	<i>Discoaster brouweri</i>	1.96	42

**Table 2. Nannofossil datums and age estimates used at ODP Site 1125 (from Carter *et al.*, 1999)**

Within the core, regionally recognised tephra and both regional and international microfossil datums have been isolated and these are presented in appendix 1. The top ~20 m has been relatively well constrained as a result of detailed microfossil studies (Schaefer *et al.*, 2005) and well-documented tephra data (Alloway *et al.*, 2005), but below that depth, six tephra occur which are less well defined with respect to age and relationships to other equivalent sequences elsewhere. Magnetostratigraphy was carried out at this site (Carter *et al.*, 1999) and although the results were poor quality, it does appear to generally agree with other data.

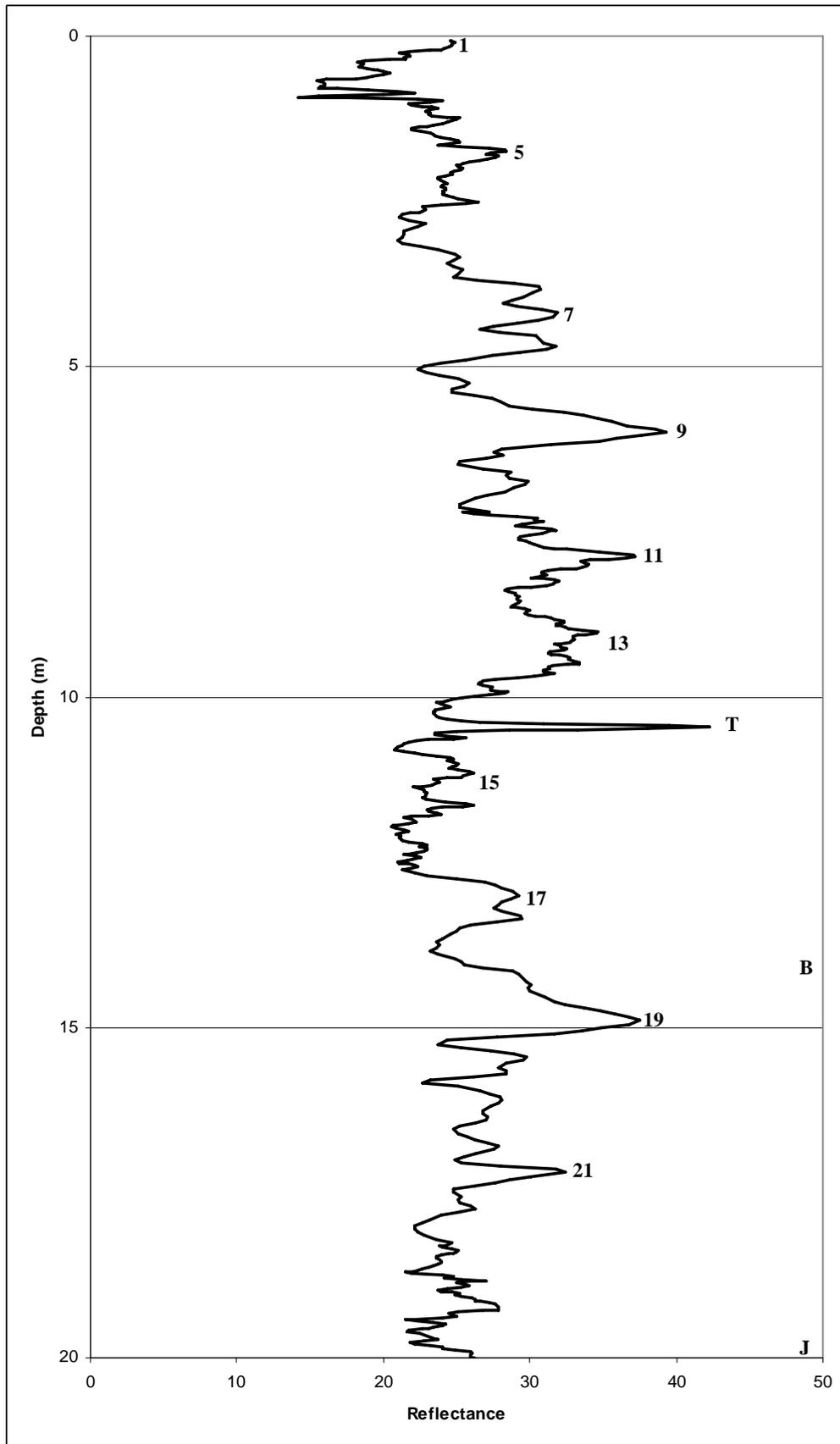


Figure 12. Spliced composite reflectance curve for ODP Site 1125 showing isotope stages 21-1 (last 1 Ma), Brunhes (B = 0.78 Ma) and Jaramillo (J = 0.99 Ma) magnetic polarity chrons from Carter *et al.* (1999). Tephra age from correlation with tephra in the climatically tuned ODP 1123 (Alloway *et al.*, 2005)

## 1.8 *STILOSTOMELLA* EXTINCTION EVENT

The Earth's climate is affected by three different orbital fluctuations, obliquity, precession and eccentricity. Obliquity is the tilt of the Earth's axis which has a strong influence on the climate – the greater the tilt the more sunshine the poles receive in summer and the less the tilt the colder it gets (Philander, 1998). Precession is related to the way the Earth 'wobbles' on its axis and eccentricity is the difference in the intensity of sunlight the Earth gets due to the difference in its orbit around the Sun, with an almost constant amount over the year during a circular orbit but varying when the orbit is elliptical (Philander, 1998). The obliquity varies over about 40,000 years, with more pronounced seasonal variation when the angle of tilt is high ( $24.36^\circ$ ). Approximately 1.2-0.6 Ma there was a major change to the Earth's orbital obliquity pattern, now commonly referred to in the literature as the Mid Pleistocene Transition (Head & Gibbard, 2005). The Mid Pleistocene Transition (MPT) represents a time when the 41 ka cycle altered to a 100 ka interglacial-glacial cycle (Maslin & Ridgwell, 2005). This resulted in a significant increase in the size of the northern hemisphere ice cap and a period of severe glaciation (Maslin & Ridgwell, 2005).

The exact cause of this alteration and the oceanic consequences are still being studied, but one outcome was a marine extinction event representing the final phase in a gradual decline in the abundance of elongate, bathyal to upper abyssal benthic foraminifera. It resulted in the global extinction of at least 88 species, including 2 families (Kawagata *et al.*, 2006).

This event was first described in 1979 as a result of work carried out on sediments from DSDP Site 397, off the northwest coast of Africa (Lutze, 1979). That author isolated a major faunal break at the NB 5/6 datum, coincident with the Brunhes/Matuyama

boundary. In the later DSDP leg 108, sites 658 & 659, Weinholz and Lutze (1989) confirmed the presence of that event thus extending the area affected by 1000 km to the south of DSDP Site 397. Weinholz and Lutze (1989) initially characterised the event by the extinction of *Stilostomella*, *Orthomorphina*, *Plectofrondicularia* (almost simultaneously); and *Pleurostomella brevis* and *Ellipsoglandulina laevigata* naming the event the “*Stilostomella* extinction” after the most prominent family of foraminifera that died out at the time. Since then, the *Stilostomella* extinction has been shown to be truly global (Schoenfield, 1995), with records of which are now available for all the world’s oceans. (e.g. Pacific, Atlantic and Indian Oceans)

There are studies in progress which are attempting to determine both the geographic distribution and the floral and faunal impact of the extinction (e.g. Kawagata *et al.*, 2005, 2006; Hayward *et al.*, 2006). Particularly relevant to this study is the work on ODP Site 1125. Hayward (2002) has noted that in this core and in other sites (DSDP 593, 594; ODP 1119, 1120 and 1123), a slight decline in abundance of some foraminifera between 2.5 and 1.2 Ma, with the biggest decline in ODP Site 1125 around 1.1 Ma. At ODP Site 1125, there was then a steady decrease in abundance between 0.85 and 0.57 Ma. It is also apparent that “the rate of decline was not uniform, but pulsed often with major declines associated with the onset of cold intervals” (Hayward, 2002). These pulses were not recorded at the same time in all of the cores and ODP Site 1125 recorded the latest local disappearances. Hayward (2002) stated that the pulses of decline coincided with the climatic patterns, with partial (although generally decreasing) recovery in abundance and diversity of foraminifera occurring during the warmer periods. He suggested that the declines and extinctions could be a result of bottom-water characteristics as well as or instead of changes in food supply.

To date, effort has been focussed on protozoans (single celled organisms) only. The current study will examine podocopid ostracods in an attempt to determine whether more complex, metazoan life was also affected. Ostracods are especially useful as they are the only deep-sea metazoan with a reliable stratigraphic record.

## 2 METHODS

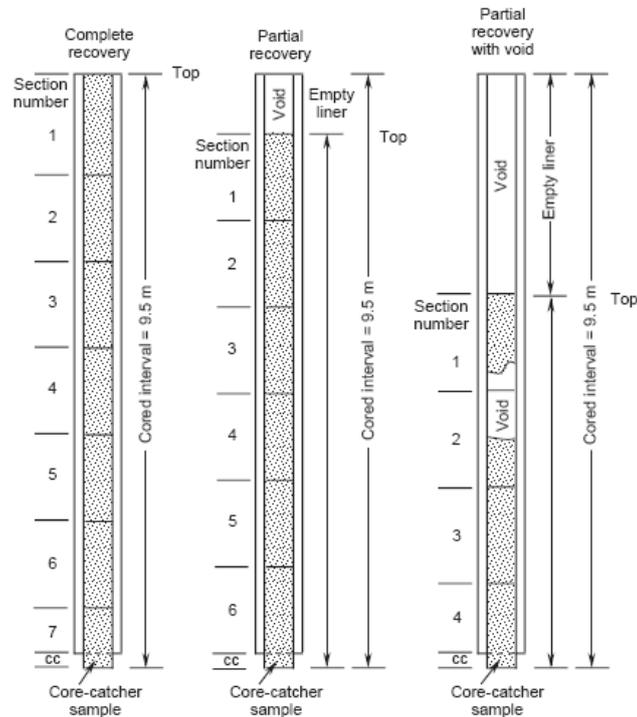
---

### 2.1 CORE DRILLING AND SUBSAMPLING

The cores from ODP Site 1125 were taken in 1998 by the oceanographic research vessel *JOIDES Resolution* (the author was not involved in this cruise). The cores studied herein were obtained using an advanced hydraulic piston corer (APC), which recovers 9.5 m of 62 mm diameter core with a 20 cm core catcher attached at the base of the core barrel ensuring the core does not slide out during retrieval of the barrel (Carter *et al.*, 1999). On board *JOIDES Resolution*, the sediment core is cut into 1.5 m lengths (figure 13), usually seven from each barrel unless full recovery is not achieved. Core sections are numbered from 1 to 7, starting from the top. The core catcher samples are conventionally placed beneath the last section and labelled core catcher (CC). Samples are systematically catalogued using the leg, site, hole, core number, core type, and section number, followed by the interval from which it was taken below that section. For example, ‘sample 181-1125B-2H-3, 85-87’ indicates a sample from 85-87 cm below the top of section 3, core 2 of hole 1125B during leg 181. The H indicates that this core was collected using the APC. (Carter *et al.*, 1999).

Once on deck, one core catcher subsample is immediately taken for paleontological age assessment (Carter *et al.*, 1999). All core sections are passed through a multisensor track (MST), which includes sensors to detect natural gamma-ray emission, gamma ray, magnetic susceptibility and a *P*-wave logger (core catcher samples do not pass through this machine).

Once these analyses are completed, the core is split lengthwise, one half which will be archived and the other a working half; hard cores were split using a diamond saw whereas soft sediment cores are cut using a taught, fine wire (Carter *et al.*, 1999). The working halves are sub-sampled for paleomagnetic and physical properties, then additional sub-samples are taken for onboard determination of stratigraphic relationships using siliceous and calcareous microfossils. Sampling for more detailed work was completed onshore using the entire suite of core data to select the location of the subsamples.



**Figure 13. Examples of numbered core sections (From Explanatory notes section, Carter *et al.*, 1999)**

All samples were archived into the shipboard database using age, location and the name of the investigator receiving the sample as the key catalogue descriptors. Any sample subsequently removed is recorded by the curator at the ODP administrative centre (College Station, Texas). On board, all archived cores are photographed (with both black & white and colour film), visually described and passed through a cryogenic magnetometer (Carter

*et al.*, 1999). Both core halves (archive and working) are then placed in sealed, labelled, plastic tubes and stowed in cold storage. At the completion of the cruise, the cores are transferred to the ODP cold storage repository in refrigerated air freight containers.

## **2.2 SAMPLE PREPARATION AND PICKING**

Samples used in this study are all from ODP Site 1125, leg 181 (appendix 2.1). A total of 29 samples were received from Geomarine Research after they had been used for foraminiferal research. The samples were originally received by B. Hayward of Geomarine Research, who was a member of the shipboard scientific party. All preparatory methods used by Geomarine Research were replicated for this project, thus ensuring that concentrates were exposed to similar methods of sieving. Twelve of the samples were from the core catcher (CC), which is located at the bottom of each section of core and usually consists of a larger volume of sediment than samples from the core itself. The CC samples were washed onboard the ship but not weighed, and although there is no way to know the exact depth of each of these samples, the larger volumes of sediment usually means larger numbers of specimens are available for study. The remaining core samples have a pre-washed volume of approximately 20cc. The samples received by the author were selected to give a good coverage of the entire Pleistocene, including glacial and interglacial periods covering at least the Middle and Late Pleistocene.

The process to wash the samples used by Geomarine Research was as follows. Samples were first weighed, then soaked in distilled water overnight to disaggregate and subsequently washed over a 63  $\mu\text{m}$  sieve. On arrival at the Department of Geological Sciences (University of Canterbury), the coarser than 63  $\mu\text{m}$  fractions were again dry sieved through a 125  $\mu\text{m}$  sieve.

For this project, each sample processed at the University of Canterbury was treated in the following way: The sieve was rinsed with a strong jet of water directed through the underside to remove particles larger than 125  $\mu\text{m}$  which were attached to the upper surface of the mesh. The sieve was then placed in an ultrasonic bath for approximately 3 minutes at full power to dislodge or destroy any remaining particulate contaminant. The sieve was then rinsed with a high pressure jet of water from the underside and saturated with ethanol to speed drying. After approximately 2 minutes in a dryer ( $\sim 40^\circ$ ), the upper edge of the sieve was banged squarely onto a sheet of paper on a solid wooden bench surface, thus ensuring any residual particles were removed from the sieve. This cleaning process was repeated prior to each sample sieving. For each sample, the finer than 125 $\mu\text{m}$  fraction was retained on a clean sheet of paper (new sheet for each sample), placed in the original vial and returned to Geomarine Research. The coarser portions were placed into new, unused vials and labelled, ready for sorting.

A single-grain layer of sediment was spread over a picking tray and all ostracods (entire carapaces and valves, as well as large fragments) were systematically picked from each sample for taxonomic determinations and population counts under a Zeiss binocular microscope, using a wet nylon brush to extract each specimen. Juveniles were also removed and in case of rarer species, fragments representing 1/3 of the carapace or more were retained. Initially specimens were coarsely sorted into broad taxonomic groupings (e.g. Genera), each 'taxon' being allocated an appropriate number of spaces on a standard 60 square micropaleontological slide, one slide per sample.

A decision was made as to whether the specimens were mature or not (see introduction re moulting and instars, p. 3 & 4) by examining the thickness and dimensions of the valve,

hinge, ornamentation and width of the marginal area. In 'normal' circumstances, a measure of all valves of one species will give a range of sizes and reflecting a sequential size increase through ontogeny, from valves of earliest instars to the adult. However, due to the small number of specimens recovered, this is not possible. There are also some samples in which only juveniles have been recovered for some 'species' (especially for *Krithe*), in which case a best guess is made with respect to identification and this taxon then included into the assemblage database (Appendix 2.2 & 2.3).

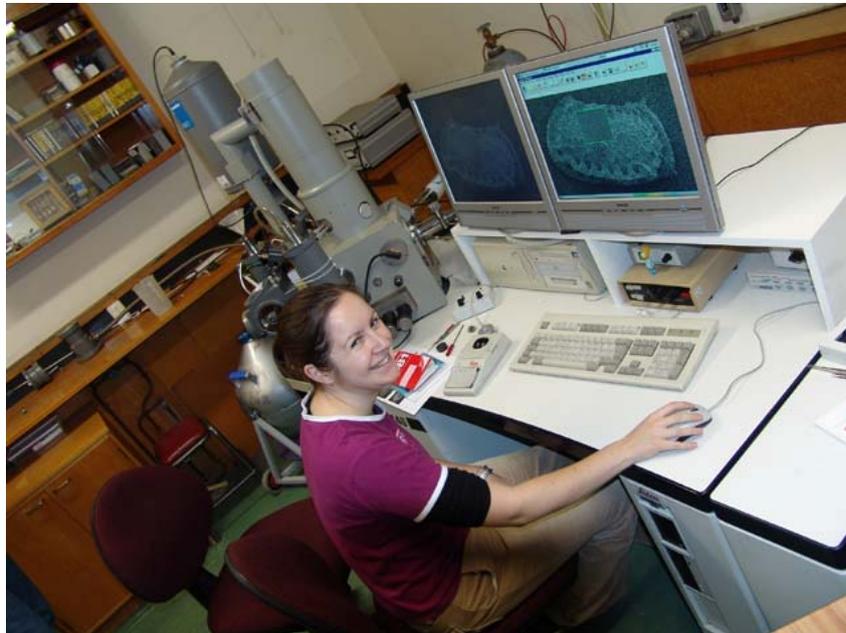
Adult specimens of each 'taxon' for Scanning Electron Microscope examination were selected from each of these pools, with additional material being removed as increasing taxonomic precision demanded.

### **2.3 SCANNING ELECTRON MICROSCOPY**

The Scanning Electron Microscope (SEM) is now routinely used for examination and illustration of general shape and morphology of most calcareous-shelled microfossils. It also makes possible the examination of the microfabric and normal pore type and position (genetically defined) for the purposes of taxonomy and carapace alteration and dissolution for taphonomic studies. From the 'sorted' assemblage, whole specimens with little or no evidence of dissolution were selected for the production of micrographs used to illustrate the overall characters of each 'species'. Subsequently, some work on carapace microfabric was also undertaken.

All SEM work was carried out on the Leica S440 Scanning Electron Microscope in the School of Biological Sciences Department, University of Canterbury. New, unused stubs were labelled using a sharpened steel probe, numbering each stub according to the sample

the specimens were taken from (usually one stub per sample). Specimens were attached using a self adhesive carbon dot and then sputter coated for 8 minutes with gold at 1.2 kV at 20 mA. SEM images were taken using a working distance of 10 mm for most of the detailed photos, with longer distances between 15-20 mm for whole valve/carapace images. The aperture was maintained at a constant 20  $\mu$ m, and voltage at 10 kV. Images for plates in this thesis were taken using a Robinson Backscatter Detector at 20 kV and 100 pA, at a working distance of 17 mm.



**Figure 14. Author working on Scanning Electron Microscope, School of Biological Sciences Department, University of Canterbury.**

Once all SEM work was completed and all taxa were classified to genus level and to species where possible, a formal systematics list was prepared. The style and systematic order follow the format established by Jellinek & Swanson (2003) and Mazzini (2005). Note that the distribution data is arranged in an order which reflects the date of publication rather than a stratigraphical sequence or relationships in terms of region of origin.

## 2.4 TRANSMITTED LIGHT MICROSCOPY

For most smooth-valved species especially, differentiation of 'species' is most effectively achieved through a detailed examination of marginal and normal pores and of the muscle scars. The position and shape of these structures are determined genetically and as a result are routinely used as key taxonomic indicators.

In order to look at these tools, Transmitted Light Microscopy (TLM) was carried out in the following manner. Selected specimens of *Krithe* and *Parakrithe* were picked and placed into a small amount of glycerol on a glass slide, one specimen per slide. The mounted material was then left for approximately 4-48 hours (depending on preservation state and opaqueness) to improve valve transparency and thus enhance TLM. Appropriate times with respect to soaking are determined by trial and error, but it should be noted that glycerol does have the ability to dissolve (slowly)  $\text{CaCO}_3$ . For this project, valves were soaked on average for 4-6 hours.

Using a Leica DMXRP TLM, digital images were taken at a series of focus levels through the specimen to allow the position, shape and number of normal and marginal pores and muscle scars to be determined. Moderately high contrast digital images were then printed and these used as the basis for line drawings of valve pore and muscle scar detail using mylar sheets. These line images were first used to compare and contrast closely-related species and then for use as plate illustrations.

## 2.5 ASSESSMENT OF DISSOLUTION

By examining all adult valves of *Krithe* and *Bradleya* under a Leica M32 stereomicroscope, a dissolution index for some ODP Site 1125 samples was able to be assessed. The scale for the degree of degradation, or 'preservation index' (table 3) of the carapace was based on that used by Swanson (1994). Only *Krithe* and *Bradleya* were included in the data set because they are relatively common and have the most continuous vertical distribution in ODP Site 1125.

Scale (CI)	Carapace Preservation
0	Transparent, excellent condition
1	Translucent and or bored/grooved
2	Translucent-opaque
3	White
4	White, normal pore exits enlarged and or some delamination
5	Heavily etched, often incomplete, thin, fragile
6	Chalky, often collapses during wetting/manipulation

Table 3. Dissolution index for podocopid ostracod valves (from Swanson, 1994)

However, from a total of 29 samples, eight were not included as although *Krithe* and *Bradleya* were moderately well preserved, the number of valves in these samples was too low. Therefore, the incomplete, non-continuous dissolution record for ostracods for this core is inadequate for comparison with foraminiferal fragmentation indices or ostracod dissolution profiles from elsewhere.

## 2.6 STATISTICAL ANALYSES

A database was created listing the number of each species, the number of juveniles recovered, post-picking sample weight, sample number and depth for each sample (appendix 2.2 & 2.3). From this, a variety of statistical analyses were undertaken and graphs produced to determine stratigraphic trends and relationships through the core. After plotting the first series of graphs, it was apparent that because the sample positions are not equally spaced in the vertical core section, the graphs were giving a false representation of the data. Therefore, the sample spacing's were adjusted to a regular depth scale resulting in a much clearer indication of down-hole changes. As sample weight had, from the outset, been seen as a possible cause of bias with respect to valve recovery, the data was normalised to post-picking sediment weight. A range of different combinations of variables were graphed in order to determine correlations, or lack thereof.

A statistical coefficient commonly used in ecology called the Shannon-Weiner index was used in an attempt to document downhole variations of dominance and diversity, one of many different diversity indices that measures the biodiversity of an ecosystem ([www.wikipedia.com](http://www.wikipedia.com)). This index is a measurement that attempts to quantify both the proportionate contribution made by each species and the overall diversity within a sample. Using the equation  $H(S) = -\sum_1^n p_i \ln(p_i)$ , (where  $p_i$  is the proportion of the  $i$ th species,  $\ln$  is the natural log and  $n$  is the total number of species), an index of diversity is produced. This index takes into account the number of species and their relative proportions, so when all species are equally distributed in the sample it would be its maximum value. Additional supporting stratigraphic data not used in the discussion section of this text can be found in appendix 2.4.

## 2.7 CATALOGUING OF SPECIMENS AND SAMPLE RESIDUES

All picked samples of sediment were returned to Geomarine Research and will eventually be lodged in the collection of Geological and Nuclear Sciences, Lower Hutt.

SEM images were systematically labelled by sample number/stub number/specimen number/image number, e.g. 10/2/3a identifies the first picture taken of specimen 3 on stub 2 from sample 10. TLM images were numbered by sample number/specimen number/image number and pore map drawings numbered by sample number/specimen number.

Specimens from the stubs used for SEM were removed by a brush with acetone (which dissolves the carbon adhesive). Each specimen was then placed in a single hole micropaleontology slide for cataloguing, as were the specimens used for TEM. These slides and the micropaleontology slides with sorted specimens have been catalogued and filed in the University of Canterbury Fossil (UCF) catalogue at the University of Canterbury, Christchurch, New Zealand (appendix 2.5). All SEM and TEM images and the *Krithe* line drawings have been filed in the collections of K.M. Swanson.

## 3 TAXONOMY

---

### 3.1 SYSTEMATICS

Order **Podocopida** G.W. MULLER 1894  
Suborder **Platycopina** SARS 1866  
Superfamily **Cytherellacea** SARS 1866  
Family **Cytherellidae** SARS 1866

Genus *Cytherella* JONES 1849

*Cytherella* sp. a

DIMENSIONS: ALV: 0.736/0.409 (Plate 1, Figure 1)

CAT. NO: UCF 1416

DISTRIBUTION: This thesis      S.W. Pacific Ocean      ODP Site 1125 Pleistocene

REMARKS: Closely related to a number of cytherellid species described from the SW Pacific (see SWANSON, JELLINEK & MALZ, 2005). Discrimination of the present species from *C. corpusculum* and *C. intonsa* would, however, require microscopic examination of soft anatomical detail. Because of the lack of valves, there is some question about the maximum size of this 'species' (i.e. the question of the size of mature adults is unresolved).

*Cytherella* sp. b

DIMENSIONS: ALV: 0.911/0.467 (Plate 1, Figure 2)

CAT. NO: UCF 1417

DISTRIBUTION: This thesis      S.W. Pacific Ocean      ODP Site 1125 Pleistocene

REMARKS: Because of the lack of valves there is some question about the maximum size of this 'species' (i.e. the question of the size of mature adults is unresolved).

Suborder **Podocopina** SARS 1866  
Superfamily **Bairdiacea** SARS 1888  
Family **Bythocyprididae** MADDOCKS 1969

Genus *Bythocypris* BRADY 1880

*Bythocypris* sp.

DIMENSIONS: ALV: 1.600/0.760 (Plate 1, Figure 3)

CAT. NO: UCF 1418

DISTRIBUTION: This thesis      S.W. Pacific Ocean      ODP Site 1125 Pleistocene

Superfamily **Cypridacea** BAIRD 1845  
Family **Pontocyprididae** G.W. MULLER 1894

Genus *Propontocypris* SYLVESTER-BRADLEY, 1947

*Propontocypris* sp.

DISTRIBUTION: This thesis      S.W. Pacific Ocean      ODP Site 1125 Pleistocene

Genus *Argilloecia* SARS 1866

*Argilloecia* sp.

DIMENSIONS: ARV: 0.593/0.236 (Plate 1, Figure 4)

CAT. NO: UCF 1419

DISTRIBUTION: This thesis      S.W. Pacific Ocean      ODP Site 1125 Pleistocene

REMARKS: There are probably three or four species of this genus in the ODP Site 1125 material. However, this group is one of the most taxonomically neglected with respect to the deep-sea ostracod assemblage and therefore further refinement was not possible.

Family **Cytheruridae** G.W. MULLER 1894  
Subfamily **Cytheropterinae** HANAI 1957

Genus ***Cytheropteron*** SARS 1866

***Cytheropteron*** sp. aff. ***dibolos***

1988 *Cytheropteron sianae* Smith 1983. – AYRESS: 498, pl. 17 figs 15-17. (= nomen nudum)

2003 *Cytheropteron dibolos* n. sp. MAZZINI: 37, pl. 6 fig. 3-4

DIMENSIONS: ALV: 0.450/0.300 (Plate 1, Figure 5)

CAT. NO: UCF 1420

DISTRIBUTION: SMITH, 1983	S.W. Pacific Ocean	Pleistocene
MAZZINI, 2003	South of Tasman Rise SO136 site 30	Holocene
This thesis	S.W. Pacific Ocean ODP Site 1125	Pleistocene

REMARKS: This specimen lacks the cusped ridge and reticulation illustrated below the dorsal cardinal angle by AYRESS (1988) and MAZZINI (2005).

***Cytheropteron*** sp. aff. ***garganicum***

1975 *Cytheropteron garganicum* BONADUCE, CIAMPO & MASOLI: 91, pl. 55 figs 7-13, text-fig. 35

1985 *Cytheropteron* sp. 17 DOWNING: 413, pl. 27 figs 6-8

1985 *Cytheropteron garganicum* BONADUCE et al – HARPUR: 76

1988 *Cytheropteron garganicum* – AYRESS: 500, pl 17 fig 18

DIMENSIONS: ARV: 0.371/0.200 (Plate 1, Figure 6)

CAT. NO: UCF 1421

DISTRIBUTION: AYRESS, 1988	S.W. Pacific Ocean	DSDP site 207	Pliocene
	S.W. Pacific Ocean	DSDP site 208	Pliocene
	S.W. Pacific Ocean	DSDP site 209	Pliocene
	S.W. Pacific Ocean	DSDP site 289	Pliocene
	S.W. Pacific Ocean	DSDP site 64	latest Pleistocene
	S.W. Pacific Ocean	DSDP site 203	late to latest Pleistocene
	S.W. Pacific Ocean	DSDP site 209	early and latest Pleistocene
	E. Indian Ocean	DSDP site 259	Pleistocene

	E. Indian Ocean	DSDP site 262	latest Pliocene? and latest Pleistocene
	S.W. Pacific Ocean Adriatic Sea N. Atlantic Ocean	DSDP site 289	early Pleistocene Recent late Quaternary
This thesis	S.W. Pacific Ocean	ODP Site 1125	Pleistocene

REMARKS: Originally described by BONADUCE, CIAMPO & MASOLI (1975) from the Adriatic Sea and subsequently recorded as a cosmopolitan, deep-water taxon by the Aberystwyth ostracod group. However, see discussion of cosmopolitanism in this text (section 4.4, p. 63)

*Cytheropteron* sp. aff. *quadrata*

DIMENSIONS: ALV: 0.371/0.224 (Plate 1, Figure 7)  
ARV: 0.437/0.253 (Plate 1, Figure 8)

CAT. NO: UCF 1422  
UCF 1423

DISTRIBUTION: AYRESS, 1988	S.W. Pacific Ocean	DSDP site 207	Pliocene
	S.W. Pacific Ocean	DSDP site 208	Pliocene
	S.W. Pacific Ocean	DSDP site 64	Pleistocene
	S.W. Pacific Ocean	DSDP site 203	Pleistocene
	E. Indian Ocean	DSDP site 259	Pleistocene
	S.W. Pacific Ocean	DSDP site 289	Pleistocene
This thesis	S.W. Pacific Ocean	ODP site 1125	Pleistocene

REMARKS: The present specimens are less quadrate than those figured by AYRESS (1988). However, he did not discriminate males and females and therefore the level of variability in shape in either DOWNING'S (1985) or AYRESS'S (1988) definitions is not known. This 'species' was established in a thesis by DOWNING (1985) but was never subsequently formally described, as evidenced by the fact that this and numerous other 'species' listed by AYRESS (1988) do not appear as entries in the 'Index and Bibliography of Marine Ostracoda' by KEMPF (1986).

*Cytheropteron posteroreticulata*

- 1983 *Cytheropteron posteroreticulata* DOWNING – SMITH MS: 67, pl. 6 figs 5,6
- 1985 *Cytheropteron posteroreticulata* DOWNING, MS: 379, pl. 25 figs 4-6
- 1988 *Cytheropteron posteroreticulata* DOWNING – AYRESS: 452, pl. 15 figs 17-18

DIMENSIONS: ALV: 0.433/0.272 (Plate 2, Figure 1)

CAT. NO: UCF 1124

DISTRIBUTION: AYRESS, 1988	S.W. Pacific Ocean	Sites unknown	Miocene
	S.W. Pacific Ocean	DSDP site 207	Pliocene
	S.W. Pacific Ocean	DSDP site 208	Pliocene
	S.W. Pacific Ocean	DSDP site 208	Upper Pliocene
	S.W. Pacific Ocean	DSDP site 207	Pleistocene
	S.W. Pacific Ocean	DSDP site 208	Pleistocene
	S.W. Pacific Ocean	DSDP site 209	early Pleistocene
	E. Indian Ocean	DSDP site 254	Pleistocene
	E. Indian Ocean	DSDP site 259	Pleistocene
	This thesis	S.W. Pacific Ocean	ODP Site 1125 Pleistocene

REMARKS: This is an informal species name in the sense that it appears in the thesis of DOWNING (1985) and AYRESS (1988), but subsequent formal descriptions have never been published.

*Cytheropteron sianae*

1982 *Cytheropteron* sp. G. AINSWORTH: 122, pl. 10, figs 4,5  
1983 *Cytheropteron sianae* SMITH: 70, pl. 6 figs 10-12  
1985 *Cytheropteron* sp. 3 DOWNING: 369, pl. 24 figs 15-16  
NON 1988 *Cytheropteron sianae* SMITH 1983 – AYRESS: 498, pl 17 figs 15-17

DIMENSIONS: ARV: 0.364/0.245 (Plate 2, Figure 2)

CAT. NO: UCF 1125

DISTRIBUTION: AYRESS, 1988	E. Indian Ocean	DSDP site 253	Pleistocene
	E. Indian Ocean	DSDP site 259	Pleistocene
	This thesis	S.W. Pacific Ocean	ODP Site 1125 Pleistocene

REMARKS: MAZZINI (2005) indicates this species is synonymous with AYRESS (1988) *C. sianae* from Miocene-Pleistocene of SW Pacific and Miocene of Indian Ocean. However, in that original description at least two morphotypes (species) were included. In his remarks, AYRESS (1988) presents additional data indicating this species was also isolated by other Aberystwyth researchers in the Miocene, Pliocene and Pleistocene sediments from the SW Pacific.

*Cytheropteron testudo* SARS 1869

- 1868 *Cytheropteron testudo* SARS: 29, pl. CV 1 fig. 1.  
 1889 *Cytheropteron testudo* – BRADY & NORMAN: 219, pl. 21 figs. 1-2  
 1928 *Cytheropteron testudo* – SARS: 230, pl. 106 fig. 1.  
 1969 *Cytheropteron wellmani* HORNIBROOK – SWANSON: 46, pl. 6 figs. 88-89.  
 1975 *Cytheropteron testudo* – BREMAN: 74, pl. 12 fig. 174.  
 1980 *Cytheropteron testudo* – COLALONGO & PASINI: 56, pl. 19 fig. 7.  
 1983 *Cytheropteron testudo* – WHATLEY & DOWNING: 371, pl. 5 fig. 2.  
 1985 *Cytheropteron testudo* – GUILLAUME, PEYPOUQUET & TETART: 357, pl. 106  
 figs. 9-10.  
 1985 *Cytheropteron testudo* – BONADUCE & SPROVIERI: 133, pl. 1 fig. 1.  
 1988 *Cytheropteron testudo* – WHATLEY & AYRESS: 741, pl. 1.  
 1989 *Cytheropteron testudo* – MOSTAFAWI: 130, pl. 2 fig. 48.  
 1996 *Cytheropteron testudo* – AIELLO, BARRA & BONADUCE: pl. 2 figs. 13-18, pl. 3  
 fig. 6.  
 1993 *Cytheropteron wellmani* – AYRESS: 18, figs 3D-E.  
 1993 *Cytheropteron whatleyi* – DINGLE: 64, figs. 37D-F, 40A-D.  
 1994 *Cytheropteron whatleyi* – DINGLE: 391, fig. 3H.  
 1995 *Cytheropteron* sp. aff. *testudo* SARS – YASSINI & JONES: 375, figs. 552, 555.  
 1995 *Cytheropteron tabukii* IKEYA & ZHOU – ZHOU: 85, pl. 5 fig. 2.  
 1999 *Cytheropteron testudo* – SWANSON & AYRESS

DIMENSIONS: ARV: 0.506/0.294 (Plate 2, Figure 3)  
 ALV: 0.533/0.267 (Plate 2, Figure 4)

CAT. No: UCF 1126  
 UCF 1127

DISTRIBUTION: AYRESS, 1988	S.W. Pacific Ocean	Miocene
	S.E. Australia	Miocene
	S.W. Pacific Ocean	DSDP site 208 Pliocene
	S.W. Pacific Ocean	DSDP site 209 Pliocene
	West coast Tasmania	DSDP site 282 Pleistocene
	S.W. Pacific Ocean	DSDP site 277 Pleistocene
	S.W. Pacific Ocean	DSDP site 207 Pleistocene
	S.W. Pacific Ocean	DSDP site 208 Pleistocene
	S.W. Pacific Ocean	DSDP site 284 Pleistocene
	S.W. Pacific Ocean	DSDP site 209 Pleistocene
	E. Indian Ocean	DSDP site 262 Pleistocene
	Mediterranean Sea	Pleistocene
	Taranto, Italy	Pleistocene
	Calabra, Italy	Pleistocene
	W. of Straits of Gibralter	Quaternary
	Norwegian Waters	Recent
	Mediterranean Sea	Recent
	N.E. Atlantic Ocean	Recent
	E. Greenland, Spitsbergen	Recent
	Skagerrak	Recent
	Bay of Biscay	Recent

This thesis S.W. Pacific Ocean ODP Site 1125 Pleistocene

REMARKS: See discussion section 4.4.2 of this thesis (pg 66)

*Cytheropteron* sp. aff. sp. 1 AYRESS 1996

1993a *Cytheropteron* sp. 3 AYRESS, appendix 1-7.

1994 *Cytheropteron* sp. 1 AYRESS, fig. 11H, 12A-E.

DIMENSIONS: ARV: 0.579/0.364 (Plate 2, Figure 5)

ALV: 0.615/0.323 (Plate 2, Figure 6)

CAT. NO: UCF 1428

UCF 1429

DISTRIBUTION: This thesis S.W. Pacific Ocean ODP Site 1125 Pleistocene

REMARKS: Closely related to *Cytheropteron* sp. 1 (AYRESS, 1996) but the punctae on the caudal process are smaller and distributed in a different geometric pattern. The present species is less arched dorsally than the specimens figured by AYRESS (1996).

AYRESS dimensions:

ARV L=0.58 H=0.39

ALV L=0.60 H=0.37

*Cytheropteron* sp. a

DIMENSIONS: ALV: 0.476/0.276 (Plate 2, Figure 7)

CAT. NO: UCF 1430

DISTRIBUTION: This thesis S.W. Pacific Ocean ODP Site 1125 Pleistocene

REMARKS: This specimen has affinities with MAZZINI'S (2005) *C.* sp. D, but ridges and proportions of alar process behind sub-central sulcus are different. Note also that punctae occur on the sulcus wall. Also has affinities with *C. parawellmani* (WHATLEY & DOWNING, 1983). In their remarks, those authors indicated this species as closely related to *C. wellmani* (HORNIBROOK, 1952), however that species and others of the testudo-group lack the prominent median sulcus found on the dorsal surface of the alar process.

*Cytheropteron* n. sp.

DIMENSIONS: ALV: 0.450/0.228 (Plate 2, Figure 8)

CAT. NO: UCF 1431

DISTRIBUTION: This thesis      S.W. Pacific Ocean      ODP Site 1125 Pleistocene

REMARKS: Closely related to *C. pherozigzag* which occurs in the S.W. Pacific Ocean, late to latest Pleistocene (DSDP 203) and early and latest Pleistocene (DSDP 209), and in the E. Indian Ocean, latest Pliocene (DSDP 258), Pleistocene (DSDP 259) and late Pleistocene (DSDP 262). Probably a new species closely related to *pherozigzag*. However, because spines on trailing edge of the alar process have pores for setae (functioning either as tactile or support structures) the position and number of which are genetically determined, the presence of 11 spines on the present species clearly distinguishes it from WHATLEY, AYRESS & DOWNING'S (1986) species which has 8 or 9.

Family **Leptocytheridae** HANAI 1957

Genus *Cluthia* NEALE 1973

*Cluthia* sp. a

DIMENSIONS: ARV: 0.381/0.200 (Plate 3, Figure 1)

CAT. NO: UCF 1432

DISTRIBUTION: This thesis      S.W. Pacific Ocean      ODP Site 1125 Pleistocene

*Cluthia* sp. b

DIMENSIONS: ARV: 0.364/0.209 (Plate 3, Figure 2)

CAT. NO: UCF 1433

DISTRIBUTION: This thesis      S.W. Pacific Ocean      ODP Site 1125 Pleistocene

Superfamily **Cypridoidea** BAIRD 1845  
Family **Trachyleberididae** SYLVESTER-BRADLEY 1948

Genus *Taracythere* AYRESS 1995

*Taracythere* n.sp.

DIMENSIONS: ALV: 0.790/0.430 (Plate 3, Figure 3)  
ALV: 0.790/0.420 (Plate 3, Figure 4)  
ARV: 0.718/0.336 (Plate 3, Figure 5)

CAT. NO: UCF 1434  
UCF 1435  
UCF 1436

DISTRIBUTION: This thesis      S.W. Pacific Ocean      ODP Site 1125 Pleistocene

REMARKS: Most similar to *Taracythere* sp. JELLINEK and SWANSON (2003). The current specimen has a prominent row of three tubercles medially in the posterior half of the carapace, which are very well developed in *T. sp.*, but quite weak in present species. However, the first node immediately behind the subcentral tubercle (sct), slightly dorsal to the sct, (see plate 3 figs 3,4) is very reduced, and the nodes around the anterior margin are complex and broad, which extends the width of the marginal ridge. Subcentral nodes are more blade-like, whereas in the JELLINEK & SWANSON (2003) form they are more oval. The relative size and position of nodes make this taxon easily distinguishable.

Subfamily **Trachyleberidinae** SYLVESTER-BRADLEY 1948

Genus *Legitimocythere* COLES & WHATLEY 1989

*Legitimocythere* sp.

DIMENSIONS: ALV: 1.267/0.717 (Plate 3, Figure 6)

CAT. NO: UCF 1437

DISTRIBUTION: This thesis      S.W. Pacific Ocean      ODP Site 1125 Pleistocene

Genus *Apatihowella* JELLINEK & SWANSON 2003

*Apatihowella* sp.

DIMENSIONS: ARV: 0.675/0.408 (Plate 3, Figure 7)

CAT. No: UCF 1438

DISTRIBUTION: This thesis      S.W. Pacific Ocean      ODP Site 1125 Pleistocene

REMARKS: The present species has affinities with *Apatihowella* (*Apatihowella*) sp. of JELLINEK and SWANSON (2003) but the marginal spines located postero-dorsally and antero-ventrally are larger. Note also that MAZZINI (2005) raised *Apatihowella* (*Apatihowella*) to full generic status.

Genus *Fallacihowella* JELLINEK & SWANSON 2003

*Fallacihowella* sp. aff. *F.* sp. a MAZZINI

DIMENSIONS: ARV: 1.000/0.563 (Plate 3, Figure 8)

CAT. No: UCF 1439

DISTRIBUTION: MAZZINI, 2003      South Tasman Rise      Holocene  
This thesis      S.W. Pacific Ocean      ODP Site 1125      Pleistocene

Genus *Philoneptunus* WHATLEY, MILLSON & AYRESS 1992

*Philoneptunus provocator*

DIMENSIONS: ARV: 1.283/0.733 (Plate 4, Figure 1)

CAT. No: UCF 1440

DISTRIBUTION: JELLINEK & SWANSON (2003): Recent on the Challenger Plateau in samples EBS 002 and MUC 005 in water depth of 560 m to 958 m.

This thesis      S.W. Pacific Ocean      ODP Site 1125 Pleistocene

REMARKS: The description of this species was based on live material collected in 958 m of water on the Challenger Plateau. JELLINEK & SWANSON (2003) noted that it had also previously been recovered from Pleistocene sediments in DSDP core from Site 284 (Challenger Plateau) and Site 206 (Lord Howe Rise).

Subfamily **Buntoniinae** APOSTOLESCU 1961

Genus *Ambocythere* VAN DEN BOLD 1958

*Ambocythere* sp. aff. *recta*

? 1988 *Ambocythere* sp. 3. – AYRESS: 745, pl. 27 figs. 9.

2003 *Ambocythere recta* – JELLINEK & SWANSON

DIMENSIONS: ALV: 0.623/0.331 (Plate 4, Figure 2)

ARV: 0.623/0.315 (Plate 4, Figure 3)

CAT. No: UCF 1441

UCF 1442

DISTRIBUTION: JELLINEK & SWANSON (2003) recovered 18 valves from epi-benthic sledge sample EBS 02 (958 m), 10 valves from multi-corer sample MUC 005 (955 m) and one valve from box-corer sample BX 013 (1547 m); all samples are from the Challenger Plateau. An additional sample (Q699, 695 m, Challenger Plateau) from one of the authors (KMS) private collection produced 19 more individual valves.

This thesis      S.W. Pacific Ocean      ODP Site 1125 Pleistocene

REMARKS: The lower ridge system is significantly different from AYRESS (1988) *Ambocythere* sp. 3 plate 27.

Subfamily **Pennyellinae** NEALE 1975

Genus *Rugocythereis* DINGLE, LORD & BOOMER 1990

*Rugocythereis horrida*

\* 1987 '*Osycythereis*' *horrida* WHATLEY & COLES: 76-78, pl. 5 figs 18-22.

1990 *Rugocythereis horrida* – DINGLE et al.: 320-322, fig. 47B, D, E, F.

? 1990 *Rugocythereis horrida* – DINGLE et al.: 320-322, fig. 47C.

? 2001a *Rugocythereis horrida* – MAJORAN & DINGLE: 83, fig. 5k.

2001b *Rugocythereis horrida* – MAJORAN & DINGLE: 214, pl. 1 fig. 21 (juvenile).

DIMENSIONS: ARV: 0.727/0.418 (Plate 4, Figure 4)

ARV: 0.720/0.390 (Plate 4, Figure 5)

ARV: 0.718/0.409 (Plate 4, Figure 6)

CAT. No: UCF 1443

UCF 1444

UCF 1445  
UCF 1446 (not figured)

DISTRIBUTION: WHATLEY & COLES (1987) reported this species from the Miocene-Quaternary sediments of the North Atlantic, the Pliocene-Quaternary of the SW Pacific Ocean and the Miocene of the Indian Ocean. DINGLE *et al.* (1990) recorded it from the Quaternary of the SE Atlantic. MARJORAN & DINGLE (2001) reported it from the Late Miocene of the Southern Ocean.

Mazzini 2005	South Tasman Rise		Holocene
This thesis	S.W. Pacific Ocean	ODP Site 1125	Pleistocene

REMARKS: Flanges (antero-dorsal and antero-ventral) are not well developed in the present specimens. However, spec 8/1/3 (UCF 1446, not figured) is intermediate in width suggesting variability within species. Note that original species name was *horridus* as per WHATLEY & COLES (1987).

Family **Hemicytheridae** PURI 1953  
Subfamily **Thaerocytherinae** HAZEL 1967

Genus ***Bradleya*** HORNIBROOK 1952

***Bradleya opima.***

- \* 1979b *Bradleya opima* SWANSON. – 25, text-fig. 29.
- ? 1993b *Bradleya* sp. – AYRESS: 17, tab. 1, text-fig. 3I.
- 1995 *Bradleya opima.* – AYRESS: 900, text-fig. 9/1-2.

DISTRIBUTION: SWANSON (1979): various samples from the Otago Shelf, south-eastern South Island (100 -750 m; Recent); AYRESS (1993): North Otago, South Island (Middle Eocene); AYRESS (1995): South Canterbury, South Island (Eocene); JELLINEK & SWANSON (2003): Recent on the Campbell Plateau at depths of between 562-1107 m.

This thesis	S.W. Pacific Ocean	ODP Site 1125	Pleistocene
-------------	--------------------	---------------	-------------

***Bradleya pelasgica***

- 1983 *Bradleya pelasgica.* – WHATLEY *et al.*: 500ff., fig. 4. [nom. nud.]
- \* 1984 *Bradleya pelasgica* WHATLEY *et al.*: 276, pl. 1 figs. 7-11
- 1985 *Bradleya pelasgica.* WHATLEY: 110, text-fig. 5.
- 2003 *Bradleya pelasgica* – JELLINEK & SWANSON: 58, pl. 52 figs 1-5; pl. 53 figs. 1-2; pl. 54 figs 1-2; pl. 55 figs 1-2

DIMENSIONS: ARV: 1.000/0.538 (Plate 4, Figure 7)  
ARV: 0.975/0.563 (Plate 4, Figure 8)

CAT. NO: UCF 1447  
UCF 1448

DISTRIBUTION: WHATLEY *et al.* S.W. Pacific Ocean upper Pliocene-  
(1983, 1984) Recent

JELLINEK and SWANSON  
(2003) S.W. Pacific Ocean Recent

This thesis S.W. Pacific Ocean ODP Site 1125 Pleistocene

REMARKS: From the “*Bradleya dictyon*-group”. The outline is sub-rectangular with weak to medium reticulation and a complete ocular ridge.

### ***Bradleya perforata***

2003 *Bradleya perforata* n. sp. – JELLINEK & SWANSON: 62, pl. 64 figs. 1-4.

DIMENSIONS: ARV: 1.114/0.629 (Plate 5, Figure 1)

CAT. NO: UCF 1449

DISTRIBUTION: JELLINEK & SWANSON (2003): the species has so far only been found sub-Recent on the Challenger Plateau, W of South Island, New Zealand. The present text is the first fossil occurrence of this taxon.

This thesis S.W. Pacific Ocean ODP Site 1125 Pleistocene

REMARKS: Floor of puncta have stellate micropunctae but no larger, shallow, ovoid puncta. Note that the stellate micropunctae are often lenzoid dissected by fine ridge-like lineations. Note also the hinge ‘ear’, which in this form is larger and not arcuate to the posterior.

### ***Bradleya pygmaea***

- ? 1880 *Cythere dictyon* BRADY. – 99, pl. 24 fig. 1v.
- 1972 *Bradleya albatrossia*. – BENSON: 39, pl. 7 fig. 2.
- 1983 *Bradleya pygmaea*. – WHATLEY *et al.*: 500ff., fig. 4. [nom. nud.]
- 1983 *Bradleya* sp. 3. – WHATLEY *et al.*: 500ff., fig. 4.
- \* 1984 *Bradleya pygmaea* n. sp. WHATLEY *et al.*: 286, pl. 3 figs. 3-6.
- 1984 *Bradleya* sp. 3. – WHATLEY *et al.*: 288, pl. 3 fig. 9.
- 1985 *Bradleya pygmaea*. WHATLEY: 112, text-fig. 9.
- ? 1988 *Bradleya pygmaea*. – AYRESS: 758, pl. 28 figs. 8-10.

DIMENSIONS: ARV: 0.800/0.450 (Plate 5, Figure 2)

CAT. NO: UCF 1450

DISTRIBUTION: AYRESS 1988 S.W. Pacific Ocean DSDP site 209 early & latest  
Pleistocene  
E. Indian Ocean DSDP site 259 Pleistocene

JELLINEK & SWANSON (2003) made the following observations:  
“WHATLEY *et. al.*, (1983, 1984): Miocene-Recent, W and NW off South  
Island, New Zealand (Lord Howe Rise and Challenger Plateau); JELLINEK  
& SWANSON (2003): Recent, Challenger Plateau, W of South Island, New  
Zealand”

This thesis S.W. Pacific Ocean ODP Site 1125 Pleistocene

REMARKS: Part of the *B. dictyon* group

***Bradleya* sp. aff. *silentium***

2003 *Bradleya silentium* n. sp. – JELLINEK & SWANSON: 59, pl. 57 fig 1; pl. 58 figs.  
1-4; pl. 59 figs. 1-2

DIMENSIONS: ALV: 1.071/0.671 (Plate 5, Figure 3)

CAT. NO: UCF 1451

DISTRIBUTION: Originally described by JELLINEK & SWANSON (2003) from the Campbell  
Plateau (925 m). The present text is the first fossil occurrence of this taxon.

This thesis S.W. Pacific Ocean ODP Site 1125 Pleistocene

REMARKS: Reticulation is more strongly developed than JELLINEK & SWANSON’S (2003) *B. silentium*, the ocular ridge is different and the antero-dorsal platform is broader.

***Bradleya* n. sp. a**

DIMENSIONS: ALV: 0.878/0.544 (Plate 5, Figure 4)

CAT. NO: UCF 1452

DISTRIBUTION: This thesis S.W. Pacific Ocean ODP Site 1125 Pleistocene

REMARKS: In effect this specimen is an intermediate between *B. silentium* and *B. opima*.  
The primary reticulation is more strongly developed than on *B. silentium* but weaker than

*B. opima*. Also in *B. opima* JELLINEK & SWANSON (2003) figured that the secondary mesh-work created by forealae is deeply incised and prominent. On the present specimen, the floor of the solum parallels the carapace contour. Note also the present specimen has a prominent eye tubercle but *B. silentium* does not.

Genus *Poseidonamicus* BENSON 1972

*Poseidonamicus major*

- 1972 *Poseidonamicus major* BENSON: 52, pl. 8 fig 5, pl. 10 figs 1-6  
 1983 *Poseidonamicus* aff. *P. major* – BENSON & PEYPOUQUET: 813, pl. 3 fig. 1  
 1983 *Poseidonamicus major* – BENSON: 404, fig. 1A  
 1986 *Poseidonamicus major* – WHATLEY *et al*: 389, pl. 1 fig. 1 (= juvenile)  
 NON 1987 *Poseidonamicus* sp. cf. *P. major*. – WHATLEY & COLES: 81, pl. 6 fig. 11  
 1988 *Poseidonamicus* ex gr. *major* – AYRESS: 813, pl. 31 figs 1-6  
 1990 *Poseidonamicus major* – DINGLE *et al*: 325, figs 50A, D, F, 51  
 NON 1998 *Poseidonamicus major* – GUERNET: 525 ff, pl. 2 fig. 10  
 NON 2000 *Poseidonamicus* sp. cf. *P. major* – DIDIE & BAUCH: 111, pl. 4 figs. 6-7  
 2003 *Poseidonamicus major* – MAZZINI: 86, pl. 27 figs. 1-4, text-fig. 17A

DIMENSIONS: ARV: 0.718/0.409 (Plate 5, Figure 5)

CAT. NO: UCF 1453

DISTRIBUTION: AYRESS, 1988	S.W. Pacific Ocean	DSDP site 203	latest Pleistocene
	E. Indian Ocean	DSDP site 214	latest Pleistocene and throughout Pleistocene
	E. Indian Ocean	DSDP site 254	Pleistocene
This thesis	S.W. Pacific Ocean	ODP Site 1125	Pleistocene

Family *Cytherideidae* SARS 1925

Genus *Pseudeucythere* HARTMANN 1989

*Pseudeucythere* n.sp.

DIMENSIONS: ARV: 0.338/0.171 (Plate 5, Figure 6)  
 ALV: 0.333/0.163 (Plate 5, Figure 7)

CAT. NO: UCF 1454  
 UCF 1455

DISTRIBUTION: This thesis S.W. Pacific Ocean ODP Site 1125 Pleistocene

REMARKS: Closely related to *Pseudeucythere* sp. JELLINEK & SWANSON (2003) who figured a female but with a posterior which is differs from the present specimen. WHATLEY & DOWNING (1983) contrasted their new taxon *Eucythere (Eucythere) parapubera* with *E. Pubera* BONADUCE *et al* (1975) in that the new species from the Miocene was smaller. In that respect the present species conforms with the dimensions of *E.(E). parapubera*, however the system of faint ridges and reticulation differs significantly, especially posteriorly.

Family **Krithidae** MANDELSTAM 1958

Genus ***Kritha*** BRADY, CROSSKEY & ROBERTSON 1874

***Kritha*** sp. a

DIMENSIONS: AV: 0.915/0.474 (Plate 7, Figure 1)  
AV: 0.930/0.486 (Plate 7, Figure 2)  
AV: 0.930/0.491 (Plate 7, Figure 3)

CAT. No: UCF 1456  
UCF 1457  
UCF 1458

DISTRIBUTION: This thesis      S.W. Pacific Ocean      ODP Site 1125 Pleistocene

REMARKS: Only one or two specimens with marginal and normal pores in good condition were available for taxonomy.

***Kritha*** sp. b

DIMENSIONS: AV: 0.990/0.483 (Plate 7, Figure 4)  
AV: 1.020/0.553 (Plate 7, Figure 5)

CAT. No: UCF 1459  
UCF 1460

DISTRIBUTION: This thesis      S.W. Pacific Ocean      ODP Site 1125 Pleistocene

REMARKS: Only one or two specimens with marginal and normal pores in good condition were available for taxonomy.

*Krithe* sp. c

DIMENSIONS: AV: 0.915/0.384 (Plate 7, Figure 6)  
AV: 0.930/0.443 (Plate 7, Figure 7)  
AV: 0.975/0.416 (Plate 7, Figure 8)  
AV: 0.990/0.392 (Plate 8, Figure 1)  
AV: 1.065/0.451 (Plate 8, Figure 2)

CAT. No: UCF 1461  
UCF 1462  
UCF 1463  
UCF 1464  
UCF 1465

DISTRIBUTION: This thesis      S.W. Pacific Ocean      ODP Site 1125 Pleistocene

REMARKS: Only one or two specimens with marginal and normal pores in good condition were available for taxonomy.

*Krithe* sp. d

DIMENSIONS: AV: 0.495/0.226 (Plate 8, Figure 3)  
AV: 0.495/0.229 (Plate 8, Figure 4)

CAT. No: UCF 1466  
UCF 1467

DISTRIBUTION: This thesis      S.W. Pacific Ocean      ODP Site 1125 Pleistocene

REMARKS: Only one or two specimens with marginal and normal pores in good condition were available for taxonomy.

Genus *Parakrithe* VAN DEN BOLD 1958

*Parakrithe* sp.

DIMENSIONS: AV: 0.579/0.286 (Plate 5, Figure 8)  
AV: 0.579/0.236 (Plate 6, Figure 1)

CAT. No: UCF 1468  
UCF 1469

DISTRIBUTION: This thesis      S.W. Pacific Ocean      ODP Site 1125 Pleistocene

Family **Xestoleberididae** SARS 1928

Genus *Xestoleberis* SARS 1866

*Xestoleberis* sp.

DIMENSIONS: 0.395/0.240 (Plate 6, Figure 2)

CAT. NO: UCF 1470

DISTRIBUTION: This thesis      S.W. Pacific Ocean      ODP Site 1125 Pleistocene

Out of a total 37 species, 13 are new to science.

## 4 RESULTS AND DISCUSSION

### 4.1 OSTRACOD DOMINANCE AND DIVERSITY

After initial picking was completed, all valves were sorted into genera (and species where possible). Table 4 shows results associated with coarse taxonomic groupings (see section 4.4.3, p. 63 for further discussion), with the complete listing presented in appendix 2.1, 2.2

Sample no	sample weight (g)	Depth (mbsf)	Total no. valves	Total no. species	% juveniles	<i>Apatihowella</i> spp	<i>Philoneptunus</i> spp	<i>Rugocythereis</i> spp	<i>Bradleya</i> spp	<i>Krithe</i> spp	other
21	2.6	0.0	2	1	100%					2	
1	0.7	0.4	68	10	87%	8	9	2	37	10	8
23	2.7	1.8	67	12	82%	2	1	5	15	28	13
20	2.0	2.9	26	8	73%	1	1	1	6	14	3
7	5.5	4.1	25	6	65%	2		1	10	17	4
22	2.4	7.1	21	5	71%			3	2	14	2
8	5.2	9.8	74	9	61%			4	18	38	12
14	1.6	11.7	49	8	94%				7	14	15
9	3.2	12.5	58	8	79%	12		4	21	9	10
17	1.1	13.5	89	13	79%	1	7	2	20	43	18
13	2.5	13.9	14	5	64%	2	2		4	5	1
11	1.8	14.9	23	4	83%	8		4	2	9	
6,25	9.0	15.2	363	15	82%	13	8	13	81	156	76
15	2.3	16.5	36	7	64%	4			17	6	8
10	4.0	17.2	143	14	77%	7	1	5	20	75	42
18	1.6	18.5	95	5	38%			4	27	56	8
16	3.1	19.4	16	6	80%	4		2	3	10	2
29	1.8	20.9	20	5	45%		1		2	15	1
26	1.0	23.4	2	2	50%	1					1
24	1.7	28.0	23	9	74%	2	3		7	2	7
12	0.6	30.1	3	3	100%				1		2
2,3,4	8.6	31.3	13	4	85%	4			6	2	1
19	1.0	32.9	3	2	33%					1	2
27	1.4	35.9	4	3	75%				1	2	1
5	4.1	41.1	6	4	17%	1			3	1	1
28	0.9	47.6	9	4	78%				1	5	13

Table 4. Summary of genera picked, total valves and percentage of juveniles.

Graphs of the raw downhole census data of the total number of valves and ostracod diversity (figures 15 & 16) clearly indicate a significant increase in both variables between approximately 20 and 12 mcd. This peak coincides with the timing of the Mid Pleistocene Transition (MPT), about 1.2-0.6 Ma, as described by Head & Gibbard (2005) (see introduction, p. 20 for more detail)

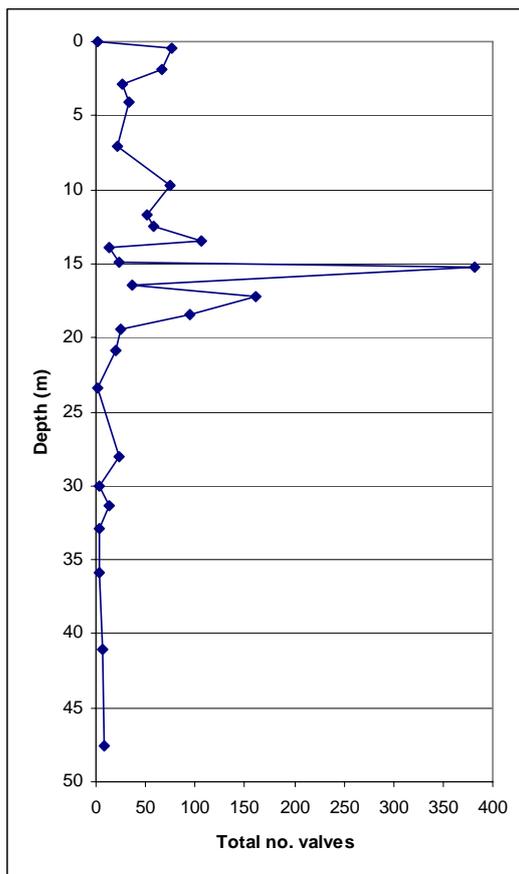


Figure 15. Total number of valves vs depth, raw data

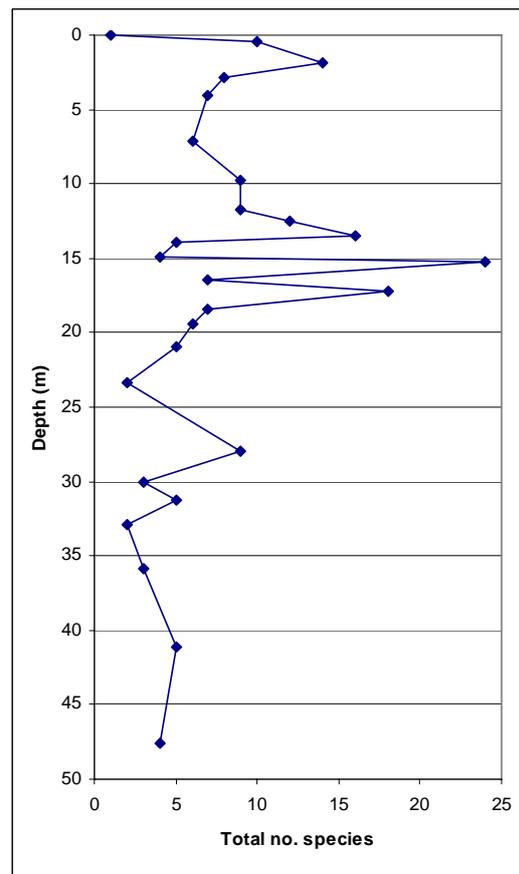
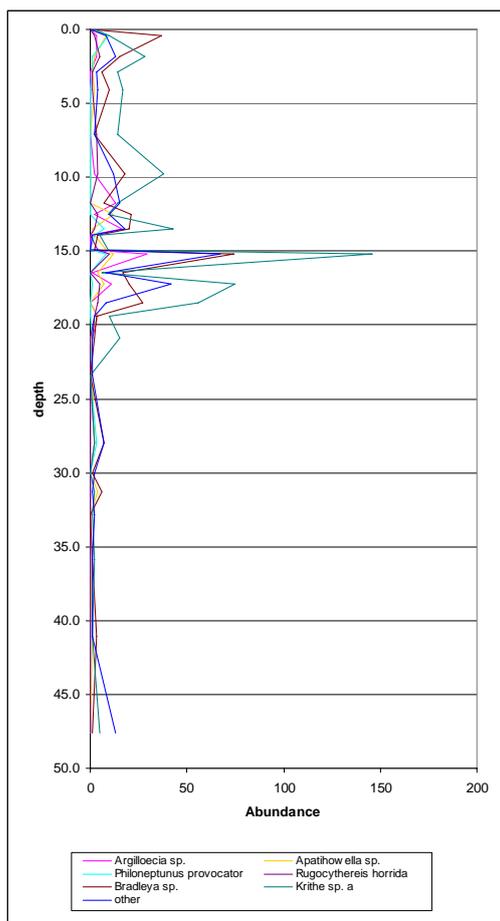


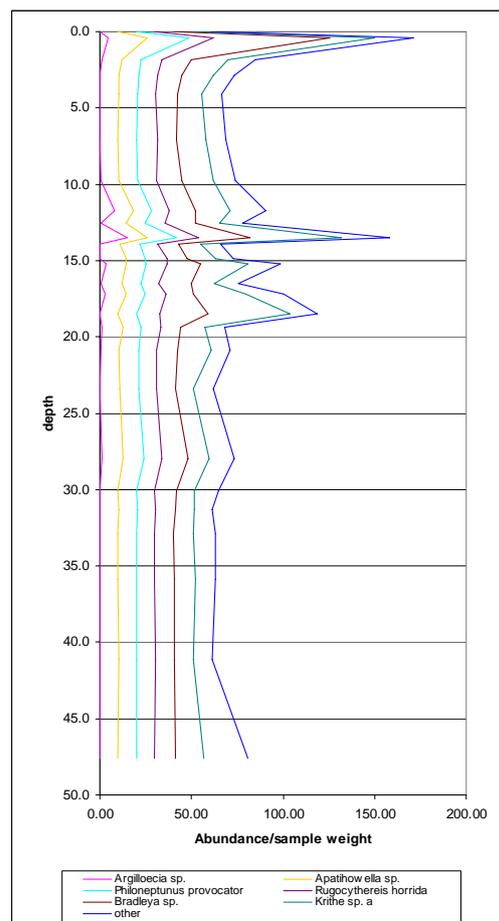
Figure 16. Total number of species vs depth, raw data

From the outset, it was expected that in the present study the large range of sample size would contribute significantly to a variation in the vertical yield of ostracod valves. Therefore, in an attempt to reduce any resultant statistical bias, valve numbers were normalised with respect to weight (grams of sediment) for each sample and new graphs plotted showing both the total number of valves and total number of species in

relation to sample depth. To determine that the peak was not a result of contributions by one particular genus changing (either disappearing from the record or becoming the dominant taxa), a second series of graphical summaries comparing those genera with the most abundant populations were produced (figure 17) and data was then normalised for sediment weight (g). A stacked plot (figure 18) of normalised data (with respect to sediment weight) shows more clearly that the main trends of the peaks and troughs are in fact replicated for all genera. Note that 'other' represents combined data of a number of species with minor and/or spasmodic contributions throughout the sampled core section.



**Figure 17. Total number of valves vs depth, stacked plot, raw data**



**Figure 18. Total no. valves vs depth. Number of valves normalised by dividing by the sediment weight, stacking done by adding 10 to each sample**

On the basis of these calculations, it can be concluded that the described ostracodal event at the MPT is 'real', i.e. between 612 ka and 916 ka benthic podocopid ostracods show a statistically significant increase in both total valves and diversity. However, there are at least three possible causes that may account for this significant population increase. These are: 1) sediment type and sample size; 2) affects of taphonomy, mainly dissolution; or 3) an actual natural event.

## **4.2 SAMPLING PROBLEMS**

There are many assumptions made when dealing with samples from a core. Figure 19 shows a comparison of sample weight and total valves (note that the weight is the >125  $\mu\text{m}$  fraction available for this study). It is apparent that although the total number of valves picked is generally proportional to the weight of the sample, smaller samples may produce apparently disproportionate numbers of specimens while some larger samples produce very few. Such variations may be the result of post-mortem sorting (winnowing) and/or the taphonomic effects of biotically induced carapace degradation at both the sediment-water interface and after burial. Both processes have the potential to negatively impact on the total number of valves and diversity.

The question then must be, can we assume that the ostracod assemblages extracted from each sample are 'natural'. Winnowing, dissolution and fragmentation of carapaces may result in a significant alteration of dominance and diversity and therefore give a false impression with respect to what a 'natural' assemblage might look like. If the impact of these assumptions is not acknowledged and assessed in terms of the population being studied, then any statistical assessment becomes meaningless.

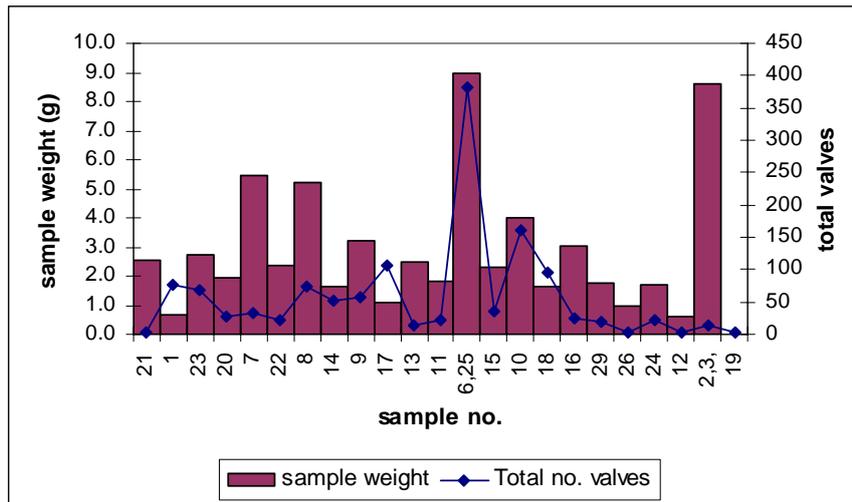


Figure 19. Sample weight and total number of valves vs depth

However, if we are aware of the possible biases induced as a result of taphonomic processes and/or laboratory methods then it may be possible to use these to gain a more accurate insight as to how those trends originated and more importantly, whether changes evident in the ostracod assemblage truly reflect a response to environmental change.

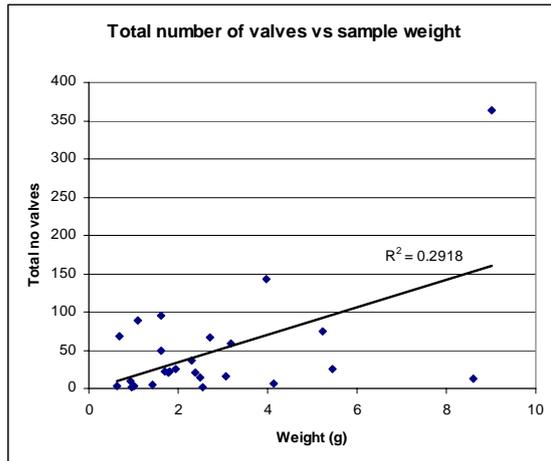
In this study, one of the main statistical methods used to analyse ostracod population data was the Shannon-Weiner Index. The coefficient used for this assesses the number of specimens in a sample relative to the number of species such that a maximum value (1.0) would be achieved when all species are equally distributed. However, because this index is normally used for studies of extant ecotypes, it undervalues absences with respect to an assemblage simply because only species present are scored in the coefficient. As a consequence, potentially significant indicators for a) a biotic (evolutionary/extinction/environmental) event; or b) a significant taphonomic (modifying existing extant assemblage or post burial modification of the sub-fossil assemblage) event will not be given weight in a downhole plot of variations of this

index. Cronin *et al.* (1999) even went so far as to say that, in terms of ostracods, it is “well known that the fewer individuals in a sample, the greater the chance that rare species are missed. In such cases, an ecosystem’s true diversity would be underestimated”.

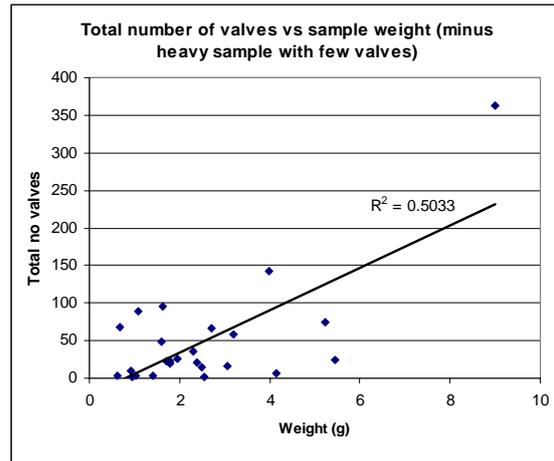
These observations have clear implications for the ostracods recovered for this study. Most of the samples yielded very low numbers of valves and species (an average of 45 valves per sample were retrieved, with no valves recovered from two samples and a maximum of 346 valves from one sample). For statistical analyses of ostracods, most workers require at least 100 specimens, with preference for up to 300. Additionally it is known that some genera common in recent samples have depleted or discontinuous fossil records, which reflect the impact of taphonomy rather than migration or extinction (Swanson, pers. Comm.; see section 4.3).

After identifying that the peak in the total number of valves and species (figures 15 & 16) was coincident with increased sample size, a comparison of sediment weight to total number of valves was undertaken (figure 20). This was in order to determine whether that peak was as a result of increased sample size rather than a biotic response by the living ostracod assemblage to environmental change. The very low  $R^2$  value of 0.29 indicates that variations in species and valve numbers are not significantly correlated to sediment size (weight) and therefore suggests that either there is extreme dissolution occurring above and below this peak, or there is a ‘natural’ event. The statistical comparison of two variables was repeated using a data set in which one large sample (8.6 g which returned few ostracod valves (13)) was removed from the data set. This resulted in the  $R^2$  value increasing to 0.50 (figure 21),

indicating that extremely variable returns with respect to sediment size and total number of valves can significantly affect the regression index. Additionally, there is substantial evidence indicating such indices become less reliable as the data sets shift away from a normal distribution pattern (see Norcliffe (1977) for example).



**Figure 20. Total number of valves vs sample weight**



**Figure 21. Total number of valves vs sample weight. Note that heavy sample with few valves recovered has been removed**

In order to establish what levels of diversity might be expected from equivalent water depths, a comparison of samples of the extant ostracod assemblage on the Campbell Plateau (Swanson, 1994), south Tasman Rise (Mazzini, 2005) and the North Atlantic (van Harten, 1990) was undertaken. Because different sampling methods were used in each of those studies, significant variations in the number of species recovered could be anticipated. The Campbell Plateau study focused on the top 1-2 cm of a box core, and from 3 samples averaged 9 species. Two active-layer dredge samples from the south Tasman Rise returned an average of 21.5 species, while two 1-2 cm thick core-top samples from the North Atlantic returned an average 28 species. This gives a clear indication how dominance/diversity figures for extant ostracod assemblages vary with sample size, sampling device and locality but suggests that somewhere between 10

and 20 species should be anticipated. The small core-top samples from the North Atlantic are anomalous simply because at an estimated sedimentation rate of 1cm/1000 years, those samples represent an accumulated assemblage profile spanning 1-2 thousand years.

### 4.3 DISSOLUTION AND TAPHONOMY

An assessment of overall dissolution was made by classifying each adult ostracod valve of the genera *Krithe* and *Bradleya* into one of six ‘preservation states’. These two genera were chosen as they have the most continuous vertical distribution in ODP Site 1125 and are relatively common in many samples, thus providing the best opportunity for comparison with ostracodal results derived from other core (e.g. Swanson, 1994) and with fragmentation profiles derived from foraminifera from the samples used in this study (Schaefer *et al.*, 2005).

The preservation states used as an assessment of carapace condition are:

Scale (CI)	Carapace Preservation
0	Transparent, excellent condition
1	Translucent and or bored/grooved
2	Translucent-opaque
3	White
4	White, normal pore exits enlarged and or some delamination
5	Heavily etched, often incomplete, thin, fragile
6	Chalky, often collapses during wetting/manipulation

Table 5. Dissolution index for podocypid ostracod valves (from Swanson, 1994)

Although *Bradleya* and *Krithe* were moderately well represented throughout all samples, eight samples were not included in this assessment simply because adult valve counts were too low. In fact, in his original study of ostracod dissolution, Swanson (1994) used between 150-300 valves per sample to calculate the dissolution index, compared to an average of only 12.5 valves per sample in this study. Therefore the incomplete, non-continuous record for ostracod dissolution for the core is considered inadequate with respect to comparison with the foraminiferal fragmentation index or with ostracodal dissolution profiles from elsewhere.

Figure 22 clearly shows the discontinuous nature of the dissolution curve. Because of this, the more 'complete' dissolution results from the samples in the top ~20 m of core only were used. The position of this data also coincides with the high resolution studies of foraminiferal fragmentation index, percentage mud and sea surface temperature (amongst others) on ODP Site 1125 by Schaefer *et al.* (2005). However, due to the overall low return of adult ostracod valves, indices calculated for many samples are still considered unreliable. Despite this, a correlation between the percentage juveniles and dissolution was anticipated and identified. No other correlation was apparent between dissolution and any other parameter (e.g. percentage mud, total valves and total species, see appendix 2.4 for these results).

As expected, ostracod dissolution and the recovery of juveniles are negatively correlated (figure 23). Where there is a high dissolution index, the percentage of juveniles is low and where the dissolution index is low, the percentage of juveniles is high. This is to be expected as dissolution is known to remove the finer portion of carbonate sediments first, i.e. the juveniles. However, it is also documented that

winnowing by bottom currents can actively remove the finer silt and mud particulates, in which case a correlation between the percentage mud and the percentage juveniles would be expected. Although there is a very coarse, general trend between percentage mud, percentage juveniles and foraminiferal fragmentation index (discussed later, section 4.1.4), this does not illustrate a low percentage mud and low recovery of juveniles that would be indicative of a winnowing event.

Comparison of the ODP Site 1125 dissolution profile and the foraminiferal fragmentation index is presented in appendix 2.4. Swanson (1994) and Swanson & van der Lingen (1997) provide evidence that for carbonate sediments in the Tasman Sea, the ostracod dissolution signal is out of phase with the foraminiferal fragmentation index, lagging by about 8 kyr in MIS 3 and then anticipating the foraminiferal signal by about the same amount in MIS 1. It must also be noted that the foraminiferal fragmentation index is based on breakage (due to preferential dissolution along the sutures) and the number of test fragments, which contrasts with the ostracod index as the latter is an assessment of carapace condition based on the 'preservation state'.

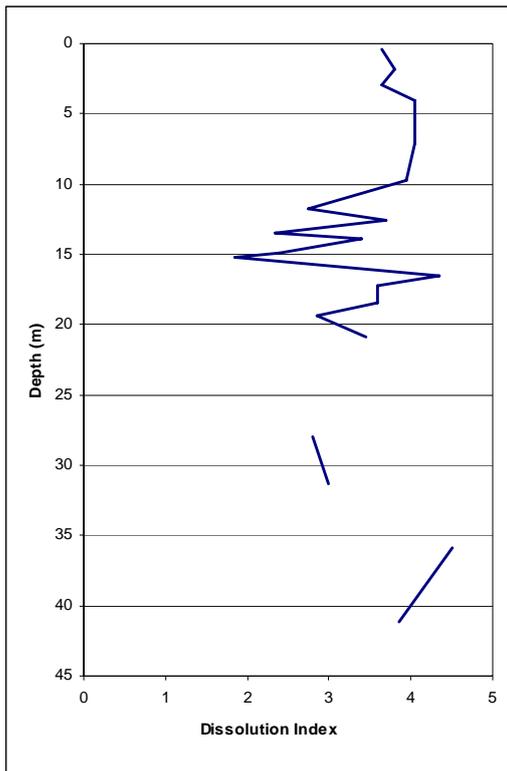


Figure 22. Dissolution profile for samples from this study. Note 8 samples not used due to lack of adult valves

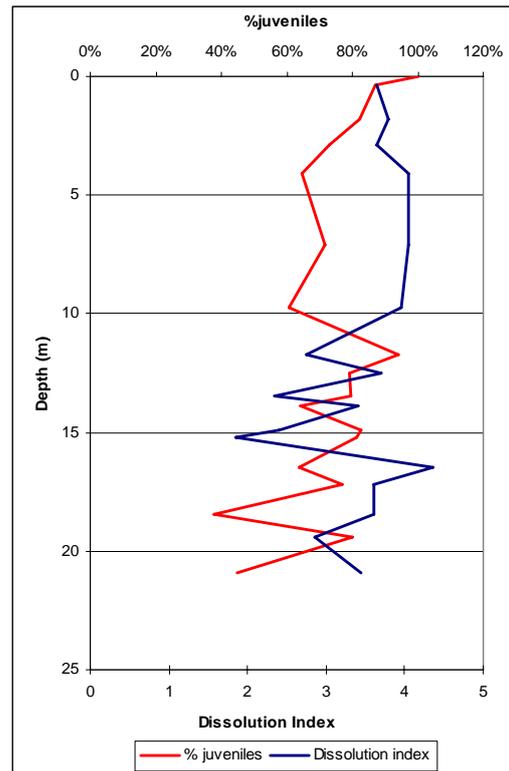


Figure 23. Comparison of % juveniles and dissolution for top 21 m of core (18 samples)

A major consideration with respect to dissolution is that it is selective, not necessarily affecting all species in the same way. Research examining the ecology, biophysics and geochemistry of deep-sea podocopid assemblage is continuing and there is increasing evidence to suggest that much carapace architecture in this group has evolved to minimise the corrosive effects of undersaturated water (Swanson, 1995). There is also convincing evidence to suggest that this evolutionary strategy has been more successful in some ostracod families than others, implying that as far as the fossil record is concerned, some taxa have a better chance of preservation than others (Swanson, 1995). The main problem is that although an extant species may be abundant in a dredge sample from the recent (e.g. *Cytherella*), evidence from some core samples suggests dissolution may remove most of the valves of that species from the fossil record. However, other genera such as *Krithe* appear to be resistant to

dissolution (Swanson, 1995) and therefore become dominant once the ‘dissolution prone’ taxa are removed.

Swanson (1995) suggests that one of the reasons that *Krithe* are so prevalent in the fossil record is because they are in fact resistant to dissolution due to “a thick layer of densely-interfingered laminar calcite crystals which make up the bulk of the carapace wall”. It is also helped by the existence of a chitinous envelope around each crystal lath, protecting the most dissolution prone crystal surfaces from attack by corrosive, under-saturated sea water. Swanson (1995) provides evidence that once this envelope has been compromised, dissolution will occur more rapidly, simply because surfaces of the calcite laths are now exposed. *Cytherella* is often selected as a prime example of this process and it has, in fact been suggested that degradation is so prevalent in this genus that it may account for the fact that in some marine sequences, that genus is ‘under-represented’.

If the effects of dissolution are not properly understood, or worse ignored, there is a probability that the effects of this process will be highlighted as an extinction event.

Corbari *et al.* (2005) examined the potential for using *Cytherella* as a tool to reconstruct deep-sea dissolved oxygen levels. This is because studies have shown (e.g. Whatley *et al.*, 2003) that the genus *Cytherella* dominates an ostracod assemblage when the ocean conditions were “kenoxic”, indicating very low levels of dissolved oxygen (but never total anaerobic conditions). Because cytherellids are filter feeders, large volumes of water are circulated in the internal carapace, thus achieving “a maximum and optimal state of oxygenation” (Corbari *et al.*, 2005). This would give

them an enhanced capability to survive periods of reduced oxygenation levels compared with other ostracods. These studies have shown that during periods of low O<sub>2</sub>, platycopine ostracods (e.g. *Cytherella*) appear to flourish and dominate the benthic ostracod assemblage and that when there is recharging of O<sub>2</sub>, the assemblage assumes a more 'normal' diversity profile in which podocopid species are dominant.

They (Corbari *et al.*, 2005) concluded that at the time of their study, *Cytherella* is "the only ostracod known to show signs of ventilatory adaptation, and hence of autonomy in respect of oxygenation of the internal medium, when facing variations in ambient oxygenation". Significantly, during that study of live material, they chose to work with only one genus from the platycopine family, rather than running additional parallel studies of living podocopid ostracods from the same environment as a control.

Hayward (2002) suggests that the period before the MPT is characterised by sluggish water circulation, low O<sub>2</sub> and also an undersaturation with respect to CaCO<sub>3</sub>, then an influx of well-oxygenated bottom waters occurred, recharging the low oxygen and overwhelming the foraminifera fauna, leading to the *Stilostomella* event. In terms of ostracods, the undersaturation of CaCO<sub>3</sub> implies taphonomic conditions which in all probability preferentially remove cytherellids by dissolution. This means that even if using that species as a tool for reconstructing deep-sea oxygen levels was appropriate, as a result of the effects of dissolution it is unlikely that there would be enough valves recovered to be able to reach any conclusions.

#### 4.4 TAXONOMY

Podocopid ostracod systematics is currently undergoing significant revision. One of the main problems is associated with the fact that for the Challenger expedition especially, many of the types represent an assemblage which is not monotypic include specimens from other species. Additionally, in the first monograph on benthic ostracods of the deep-ocean, Brady (1880) grouped many taxa into broad, generic categories (the genus *Cythereis* for example included a range of taxa which have now been progressively re-described and divided into at least six different families).

Prior to the adoption of the SEM as a tool for the routine investigations of microfossils, all paleontological descriptions were illustrated using hand drawn images, with interpretations and representation of much morphological detail often subjective. Hornibrook's (1952) study on New Zealand podocopids was innovative in the sense that the ostracods were examined in a regional/temporal context. As a result he was able to substantially revise many taxa and more importantly, redefine some existing broad generic groupings (e.g. *Cythereis* especially) into more precise and useful taxa (e.g. *Bradleya* and *Quadracythere*). This work established a series of protocols for ostracod research which were adopted by most palaeontologists and as a result, lead to increasing coherence with respect to ostracod systematics. Progress in that regard was given a significant thrust through the increasing use of SEM as an investigative tool.

In the 1970s, it became increasingly evident that in effect two classificatory schemes were being developed for ostracods, one developed by neontologists and based

primarily on the soft anatomy, the other palaeontological and based on carapace morphology.

In an attempt to resolve this problem, a number of workers initiated research in which the detail of both carapace and soft anatomy were compared and contrasted (e.g. Jellinek & Swanson, 2003). One significant impact of the work of Jellinek & Swanson (2003) especially, is a questioning of the well-established concept that most deep-sea ostracod species are cosmopolitan. Again, the coarse taxonomic groupings promoted by the Challenger report especially, meant that ostracods were seen as being “cosmopolitan” by most workers. Once cosmopolitanism was accepted, it affected both taxonomic determinations and the resultant descriptions – that tradition finding expression in many DSDP and ODP related ostracod publications and theses produced in the 1970’s and 80’s. However, recent studies (e.g. Swanson & Ayress, 1999; Jellinek & Swanson, 2003; Swanson, Jellinek & Malz, 2005; Jellinek, Swanson & Mazzini, 2006) have shown that there appear to be more endemic species than cosmopolitan species. Smith and Horne (2002) quoted publications by Cronin and Raymo (1997) and Didie and Bauch (2000) that showed how “the deep sea benthic environment is neither isolated nor completely stable, but in fact is a dynamic environment linked to ocean surface processes and orbital (Milankovitch) forcing.” (Smith and Horne, 2002).

That cosmopolitan deep-sea species exist is not in question, but rather that these cosmopolitan species dispersed into each ocean basin via sweepstake routes, subsequently acting as ‘seeds’ for the development of an endemic assemblage in each ocean (Jellinek, Swanson & Mazzini, 2006). Jellinek, Swanson & Mazzini (2006)

have recommended that a shift in thinking occur “from a methodology in which recovery of a few ‘cosmopolitan’ species (for example *C. testudo* or *C. perlaria*) is expected, to one which recognises those taxa as a persistent accompaniment to ‘regional’ diversification which is the norm for deep-ocean podocopid ostracod assemblages.” *Bradleya* is a very good example of this – it originated as a sighted, shallow-water species in the Tasman Sea, but by late Mid-Cenozoic times, tectonically-induced dispersal resulted in blind species of *Bradleya* being distributed into all ocean basins. The following examples are an illustration of this much bigger problem.

#### 4.4.1 *Cythereis/Philoneptunus*

*Cythereis* was originally described in Europe by Jones (1849) and one of the key aspects of this genus is that he described it as being confined to the Cretaceous. During the Challenger expedition, most ornate ostracods with a ‘trachyleberid’ aspect were placed into what was, in effect, the ‘*Cythereis* bin’ and this initiated a taxonomic rationale which remained operative for about 100 years. In Hornibrook’s (1952) study of Tertiary and Recent ostracoda in New Zealand, he described six species as *Cythereis*, including *Cythereis gravizea*. Then, after a detailed examination of species of *Cythereis*, Whatley *et al.* (1992) concluded that at least two of Hornibrook’s species could more appropriately be accommodated in a new genus. Whatley *et al.* (1992) established *Philoneptunus*, with *Philoneptunus gravizea* as the type species for this SW Pacific genus which now includes 16 species. Whatley then looked further at Hornibrook’s type material and concluded that the specimens Hornibrook had described as *P. gravizea* from the Eocene were in fact a different species. Whatley re-

named this species *P. reticulata*, a move which reduced the age range of *P. gravizea* to Oligocene to Recent.

#### 4.4.2 *Cytheropteron testudo*

*Cytheropteron testudo* is also routinely recorded as being a ‘cosmopolitan’ species. The identification of *C. testudo* is apparently quite straightforward, and yet there have been some major problems with it in the past. It was originally described from the Norwegian fiords and was therefore assumed to be a cold water species. The first appearance of this cold-water ‘guest’ in Plio-Pleistocene sequences in Italy was interpreted as an indication of the onset of glaciation. After a detailed study of this species using the carapace and soft anatomy and an examination of the type material, Swanson and Ayress (1999) developed the concept of the ‘*Cytheropteron testudo* group’. This group consists of seven closely related, though sometimes hard to distinguish (from *C. testudo*), similarly shaped species. Of these seven species, four were new and extant, for which as a result, there is currently no information with respect to their stratigraphic distribution.

#### 4.4.3 *Adult versus juvenile valves*

Additional taxonomic uncertainty is introduced as a result of the difficulty of identifying juvenile valves. For example, from the current study, almost 30% of samples have more than 80% juveniles. There are many bradleyinid and krithinid juveniles, but these can only be attributed to the genus level, specific determinations are not possible. During the final stages of ontogeny it may be possible to attribute

valves to a species, but increasingly juvenile instars are less and less like the adult equivalent. Additionally, for many podocopids, earliest instars look very similar.

At the onset of this study, many new species were anticipated and this has been confirmed. However, because of the lack of adult valves there are not enough specimens to accurately describe carapace morphology and variability, let alone to determine a stratigraphic range within the series of samples from ODP Site 1125. Approximately 35% (13 out of 37) of the species recovered are new to science and as a result, provide no information with respect to confirming or disproving the MPT extinction event. In recent Southern Ocean cruises, it was anticipated that 50-60% of the benthic podocopid ostracod assemblage would be new to science (Swanson, pers. comm.), giving clear indication that much of the deep-ocean podocopid assemblage remains undescribed.

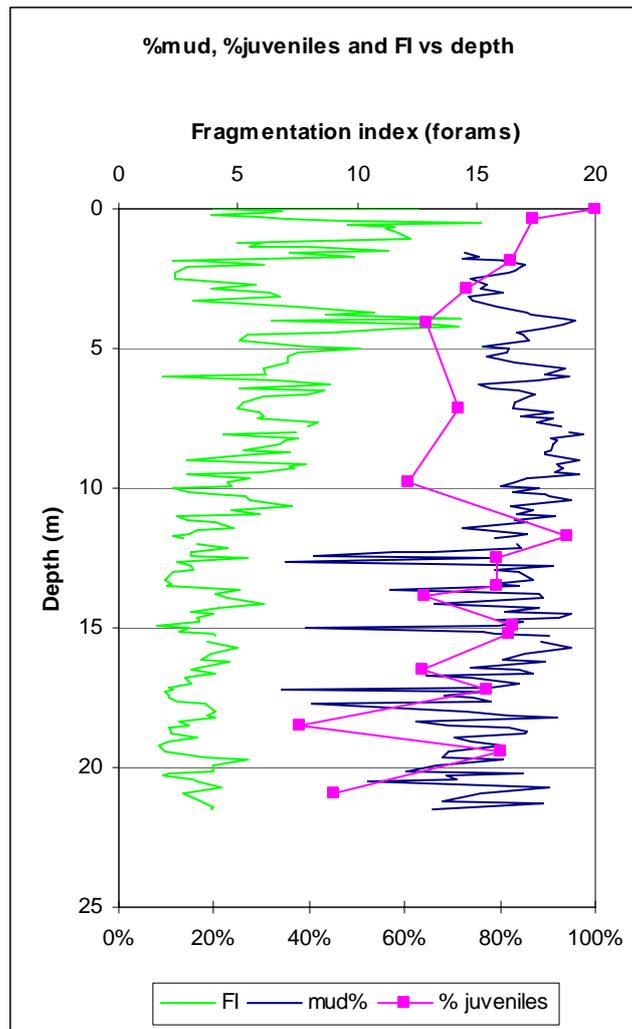
There has not been enough taxonomy done on the Chatham Rise sector of the Southern Ocean and no older drill cores exist near the location and depth of Site 1125 for comparison. DSDP Site 594 is the closest but was sited in a completely different watermass regime. Location of a local extinction, let alone a global one, is beyond the scope of this thesis. That objective will only be achievable when taxonomic precision allows the distribution of commonly preserved taxa to be documented with respect to both their intra-basinal and stratigraphic distribution.

#### **4.5 BENTHIC OSTRACODS AND THE MPT**

To examine the impact of taphonomic affects on ODP Site 1125 data for ostracods used to produce figure 15, the association between the percentage of mud, foraminiferal fragmentation index and the percentage of juvenile ostracods was assessed graphically (figure 24). Although very coarse, two general trends are evident in figure 24. From 0-12 mcd there is an overall increase in the percentage of mud and a gradual decline in the percentage of juveniles and the fragmentation index. Below this, there is a change to a gradual decrease in the percentage of mud; and the percentage of juveniles and fragmentation indices stabilise.

As stated earlier, the MPT occurs at approximately 1.2-0.6 Ma, or 23-12 mcd. The end of the MPT, or the switch to 100 ka cyclicity, is approximately coincident with the change from decreasing mud and steady numbers of juveniles and the fragmentation index to an increase in mud and decline in juveniles and foraminiferal fragmentation index. The graph of percentage juveniles and dissolution (figure 22) also shows this two-phase trend.

The significant change in ostracod population structure in figure 15 may therefore reflect a deep-sea ostracod assemblage responding positively in terms of population density and diversity, to increased dissolved oxygen content during the MPT. Also, pre and post MPT samples reflect a combination of a taphonomic response and an ostracod assemblage depleted because of prevailing, unfavourable oceanographic conditions. It should be noted however, that if this 'event' is related to the MPT, that there is a lag time of about 0.3 my between the beginning of the MPT (1.2 Ma) and when the ostracod assemblage begins to increase (0.9 Ma).



**Figure 24. Comparison of % mud, % juveniles and foraminiferal Fragmentation Index for top 23 m of core (19 samples)**

It is possible that a variation in sedimentation rate during cold and warm cycles could create the illusion of an ‘event’ in the sense that during periods of rapid or increased sediment accumulation, ostracod valves will be ‘diluted’ in terms of their proportionate contribution to the sediment. There are however, two reasons why this is not the case for the present study. Firstly, the peak in data (19.4-11.7 mbsf) covers multiple isotope stages and cannot, therefore, coincide with isolated glacial or interglacial cycles. Secondly, the sedimentation rate at ODP Site 1125 has been stable at ~19 m/m.y. for the last 2 m.y (Carter *et al.*, 1999). In order to confirm this for the present study, sedimentation rates for the period before the MPT, the MPT itself and

the period after the MPT in ODP Site 1125 were calculated. If sedimentation rate was responsible, we would expect to see a lower sedimentation rate during the MPT and a higher sedimentation rate before and after (diluting the numbers of ostracod valves recovered). Results showed that there was an increase in sedimentation rate at the beginning of the MPT about 1.2 Ma (rather than the decrease needed if sedimentation rate was responsible), from 18.6 mm/ka to 19.5 mm/ka. Additionally, the rate did not increase at the end of the MPT, but rather has remained stable through to the present day. One aspect of these calculations that must be taken into account is the fact that the MPT covers several glacial and interglacial periods. It is documented that interglacial and glacial periods have variable sedimentation rates (higher during glaciations), but by calculating these rates for the entire MPT, any variation in sedimentation for those periods is, in effect, averaged out.

Additionally, published results suggest that some ostracod groups (especially *Cytherella*) which dominate assemblages during periods of low oxygen might be a useful tool for further investigation of the MPT. However, that potential is significantly compromised by the apparent dissolution prone nature of the carapace of *Cytherella*. Where *Cytherella* is present, it is not possible to tell if the numbers recovered are low because of dissolution or because ambient environmental conditions favoured podocopid species over the more 'primitive' platycopines.

It is also known that the shape of a valve can significantly influence the ease with which an ostracod valve is transported by bottom currents. For example, during the process of winnowing, the finer particles are selectively removed (this may include juveniles and other small-valved ostracod species) preferentially. Additionally, if the

currents are strong enough to move the adult valves then some species are moved preferentially depending on carapace shape, architecture and the proportion of the assemblage in which the valves are co-joined. (Kontrovitz, 1975).

Kontrovitz (1975) found that entire carapaces moved more easily than valves of the same species. There is evidence which suggests that fossil populations composed entirely of carapaces have been buried rapidly, since prior to burial dead ostracod soft tissue is rapidly degraded by bacterial activity, resulting in the separation of both valves. Concentration of small valves or juveniles may represent an assemblage that has been transported in some way or “represent a manifestation of different hydraulic behaviour and constitute transported or residual fossil communities” (Kontrovitz, 1975). These results were based on flume tank experiments and may or may not have direct application to our understanding of the impact of bottom-current winnowing on deep-sea biogenic sediment.

As stated in section 2.2, taxonomic determinations for a number of ‘species’ have been left open due to the lack of specimens. The question of identifying an ‘extinction’ event has been hugely compromised by this fact, especially as the foraminiferal *Stilostomella* extinction event involves species of only two families rather than the entire foraminiferal fauna. The low return of valves in this study means that the populations are too small to identify changes within ostracod families which may only involve the disappearance of one or two taxa.

## 5 CONCLUSIONS

---

### 5.1 CONCLUSIONS

The primary aim of this study was to investigate the presence or absence of an event in the ostracod assemblage from ODP Site 1125 which might coincide with the documented *Stilostomella* extinction event in foraminifers. In an attempt to answer this question, all ostracod valves were picked from 29 samples taken from the top ~47 m of the ODP Site 1125 core. Once this was completed, ostracods were described and attributed to generic status and where possible, then assigned to a specific determination.

Preliminary examination and graphical interpretation of numbers of valves recovered gave clear indication of a significant population increase/peak between 612 and 916 ka (11.7-19.4 mcd). Because sediment weight was variable (ranging between 0.1 g and a maximum of 8.7 g), this was seen as potentially a major determinant with respect to the number of valves recovered. Therefore, data was normalised by dividing the total number of valves by the sediment weight and statistical analysis carried out to compare these two variables (number of valves and sediment weight). Interpretation of the resultant data (discussed in section 4.2) indicates that although sample size had some affect on the results, it was not the only contributing factor.

A decision was therefore reached to examine two other possibilities which could account for the observed increase in valve numbers. Either taphonomic processes (e.g. dissolution) had significantly affected the assemblage, also indicating a major oceanographic change; or that the increase indicated a 'real' biological event. To that end, a study of dissolution was carried out. Dissolution is an important tool for determining how taphonomic affects

have impacted on an ostracod assemblage; however the numbers of valves retrieved in this study were too small to follow recommended procedures for the creation of an accurate and reliable ostracod dissolution profile. Only adult valves of *Bradleya* and *Krithe* were used as these taxa had the most continuous vertical distribution, with some samples excluded from the 'analysis' because of the recovery of only one or two valves, or in some cases no adult valves. As expected, a negative correlation was observed between the percentage of juveniles and dissolution, but no other correlation was found. Although no correlations were found, there was no significant indication that dissolution was affecting those samples taken between 20 and 12 mcd. This implies that the ostracod data in fact confirms the occurrence of a biotic or oceanographic 'event' in ODP Site 1125.

In order to further confirm the existence of the event, an additional set of variables were compared and contrasted (e.g. percentage of mud, percentage of juveniles and foraminiferal fragmentation index). Interpretation of the results indicated two coarse trends occurring at approximately 12 mcd between the percentage of mud, percentage of juveniles and foraminiferal fragmentation index, (a change at ~12 mcd from an overall increase in mud and gradual decline in juveniles and fragmentation index to a gradual decrease in mud and the juveniles and fragmentation index stabilise) as well as between the percentage juveniles and dissolution (both variables stable above 12 mcd and variable below). This change also coincides with a reduction in numbers of valves (the top of the peak) and with the end of the MPT, about 0.6 Ma. It is therefore suggested that the increase in numbers of ostracods is related to, and potentially caused by the changes that occur during the MPT (discussed in section 4.5). The MPT begins at 1.2 Ma (~23 mcd) implying that if this 'event' is related then there was a lag between the start of the MPT and the significant increase in ostracod dominance and diversity as described in this report.

The results from this thesis indicate that ostracods are reacting positively (represented by a significant increase in population size) at a similar time to the occurrence of an extinction event in foraminifera. It is recommended that future research expand (with respect to methodology and sample base) the current study of ostracods to further investigate this 'event' in terms of its extent (i.e. if it is local, regional or global), and to examine why these two different organisms (ostracods and foraminifera) are being affected in such contrasting ways. In order to do this, it is essential that potential biases (e.g. the number and size of samples, statistical analysis results and what the sample being studied actually represents) are taken into account as they can easily affect results. In terms of ostracods, the only way for a much needed comprehensive taxonomy to be completed is through continued comparison and description of live (carapace and soft anatomy) specimens. Once that is complete, taxonomic determinations based on fossil ostracod valves must then have comparative referencing of that type material as a key component of that research. Future studies would hopefully recover larger assemblages, which would help to support and confirm the results of this study.

As such, the results of this study have been positive and have led to the development of a series of additional questions that require further investigation, the most interesting of which relates to the concept that an oceanographic event that is clearly fatal to one group of single-celled protozoans appears to have afforded a group of metazoans an opportunity for population increase and diversification.

## REFERENCES

---

- ALLOWAY B., PILLANS B. J., CARTER L., NAISH T. R. and WESTGATE J. A. (2005) Onshore-offshore correlation of Pleistocene rhyolitic eruptions from New Zealand: implications for TVZ eruptive history and paleoenvironmental construction. *Quaternary Science Reviews* **24**, 1601-1622.
- AYRESS M. (1988) Late Pliocene to Quaternary deep-sea Ostracoda from the Eastern Indian and Southwestern Pacific Oceans. Unpublished Thesis of the University of Wales, pp. 1088 Aberystwyth.
- AYRESS M. (1993) Ostracod biostratigraphy and palaeoecology of the Kokoamu Greensand and Otekaike Limestone (Late Oligocene to Early Miocene), North Otago and South Canterbury, New Zealand. *Alcheringa* **17**, 125-151.
- AYRESS M. (1994) Cainozoic palaeoceanographic and subsidence history of the eastern margin of the Tasman Basin based on Ostracoda. In *Evolution of the Tasman Sea* (eds. G. J. VAN DER LINGEN, K. M. SWANSON AND R. J. MUIR), 139-157. A. A. Balkema, Brookfield, Vt.
- AYRESS M. (1995) Late Eocene Ostracoda (Crustacea) from the Waihao District, South Canterbury, New Zealand. *Journal of Paleontology* **69**(5), 897-921.
- AYRESS M. (1996) New Species and Biostatigraphy of Late Eocene Cytherurid Ostracoda From New Zealand. *Revista Espanola de Micropaleontologia* **28**(3), 11-36.
- BÉ A. W. H. (1979) An Ecological, Zoogeographic and Taxonomic Review of Recent Planktonic Foraminifera. In *Second Short Course in Micropaleontology* (ed. P. R. KRUTAK), 1-50. The University of Nebraska, Lincoln, Nebraska.
- BENSON R. H. (1990) Ostracoda and the discovery of global Cainozoic palaeoceanographical events. In *Ostracoda and Global Events* (eds. R. C. WHATLEY AND C. MAYBURY), 41-58. Chapman and Hall, Cambridge.
- BONADUCE G., CIAMPO G. and MASOLI M. (1976) Distribution of Ostracoda in the Adriatic Sea. *Pubblicazione della Stazione Zoologica di Napoli, Suppl.* **40**, 1-304.
- BRADY G. S. (1880) Report on the Ostracoda - Report on the scientific cruise of the voyage of H.M.S Challenger during the years 1873-76. *Zoology* **1**(3), pp. 184.
- CAMPBELL H. J., ANDREWS P. B., BEU A. G., MAXWELL P. A., EDWARDS A. R., LAIRD M. G., HORNIBROOK N. D., MILDENHALL D. C., WALTERS W. A., BUCKERIDGE J. S., LEE D. E., STRONG C. P., WILSON G. J. and HAYWARD B. W. (1993) Cretaceous-Cenozoic geology and biostratigraphy of the Chatham Islands, New Zealand. *Institute of Geological and Nuclear Sciences Monograph* **2**, pp. 269.
- CARTER R. M., MCCAVE I. N., RICHTER C., CARTER L. *et al.* (1999) *Proceedings of the Ocean Drilling Programme, Initial Reports Volume* **181**.

- COHEN A. C. and MORIN J. G. (1990) Patterns of Reproduction in Ostracodes: A Review. *Journal of Crustacean Biology* **10**(2), 184-211.
- CORBARI L., MESMER-DUDONS N., CARBONEL P. and MASSABUAU J.-C. (2005) *Cytherella* as a tool to reconstruct deep-sea paleo-oxygen levels: the respiratory physiology of the platycopid ostracod *Cytherella* cf. *abyssorum*. *Marine Biology*, 1377-1386.
- CRONIN T. M., DEMARTINO D. M., DWYER G. S. and RODRIGUEZ-LAZARO J. (1999) Deep-sea ostracode species diversity: response to late Quaternary climate change. *Marine Micropaleontology* **37**(3-4), 231-249.
- CRONIN T. M. and RAYMO M. E. (1997) Orbital Forcing of Deep-Sea Benthic Species Diversity. *Nature* **385**, 624-627.
- DINGLE R. V., LORD A. R. and BOOMER I. (1990) Deep-water Quaternary Ostracoda from the continental margin off south-western Africa (SE Atlantic Ocean). *Annals of the South African Museum* **99**(9), 245-366.
- DIDIE C. and BAUCH H. A. (2000) Species composition and glacial-interglacial variations in the ostracoda fauna of the northeast Atlantic during the past 200,000 years. *Marine Micropaleontology* **40**, 105-129.
- DOWNING S. E. (1985) The Taxonomy, Paleocology, Biostratigraphy and Evolution of Pliocene Ostracoda from the W Pacific. Unpublished PhD thesis of the University College of Wales, pp 1073. Aberystwyth.
- HAYWARD B. W. (2002) Late Pliocene to middle Pleistocene extinctions of deep-sea benthic foraminifera ("Stilostomella Extinction") in the southwest Pacific. *Journal of Foraminiferal Research* **32**(3), 274-307.
- HAYWARD B. W., GRENFELL H. R., SABAA A. and SIKES E. (2006) Deep-sea benthic foraminiferal record of the mid-Pleistocene transition in the SW Pacific. In *Early-Middle Pleistocene Transitions: The Land-Ocean Evidence*. (eds. M. J. HEAD, AND P.L. GIBBARD), 85-115. Geological Society of London Special Publications
- HAYWARD B. W., NEIL H., CARTER R. M., GRENFELL H. R. and HAYWARD J. J. (2002) Factors influencing the distribution patterns of Recent deep-sea benthic foraminifera, east of New Zealand, Southwest Pacific Ocean. *Marine Micropaleontology* **46**, 139-176.
- HEAD M. J. and GIBBARD P. L. (2005) Early-Middle Pleistocene transitions: an overview and recommendation for the defining boundary. In *Early-Middle Pleistocene Transitions: The Land-Ocean Evidence*. (eds. M. J. HEAD, AND P.L. GIBBARD), 1-18. Geological Society of London Special Publications
- HEATH R. A. (1985) A review of the physical oceanography of the seas around New Zealand - 1982. *New Zealand Journal of Marine and Freshwater Research* **19**, 79-124.

- HERZER R. H. and WOOD R. A. (1992) Tectonic History, Sedimentation, and Changes in Relative Sea Level Chatham Rise, New Zealand. In *Geology and Geophysics of Continental Margins* (eds. J. S. WATKINS, F. ZHIQIANG AND K. J. MCMILLEN), 55-73.
- HORNIBROOK N. D. B. (1952) Tertiary and Recent marine Ostracoda of New Zealand. *New Zealand Geological Survey, Palaeontological Bulletin* **18**, pp. 82.
- JELLINEK T. and SWANSON K. (2003) Report on the taxonomy, biogeography and phylogeny of mostly living benthic Ostracods (Crustacea) from deep-sea samples (Intermediate Water Depths) from the Challenger Plateau (Tasman Sea) and Campbell Plateau (Southern Ocean), New Zealand. *Abhandlungen der Senckenbergischen Naturforschenden Gesellschaft*. **558**, pp. 329.
- JELLINEK T., SWANSON K. and MAZZINI I. (2006) Is the cosmopolitan model still valid for deep-sea podocopid ostracods? *Senckenbergiana maritima* **36**(1).
- JONES T. R. (1849) A Monograph of the Entomostraca of the Cretaceous formation of England. *Paleaeontographical Society of London Monograph*, pp. 14.
- KAWAGATA S. (2001) Tasman Front shifts and associated paleoceanographic changes during the last 250,000 years: foraminiferal evidence from the Lord Howe Rise. *Marine Micropaleontology* **41**, 167-191.
- KAWAGATA S., HAYWARD B. W., GRENFELL H. R. and SABAA A. (2005) Mid-Pleistocene extinction of deep-sea foraminifera in the North Atlantic Gateway (ODP sites 980 and 982). *Palaeogeography Palaeoclimatology Palaeoecology* **221**(3-4), 267-291.
- KAWAGATA S., HAYWARD B. W. and GUPTA A. K. (2006) Benthic foraminiferal extinctions linked to late Pliocene-Pleistocene deep-sea circulation changes in the northern Indian Ocean (ODP Sites 722 and 758). *Marine Micropaleontology* **58**(3), 219-242.
- KEEN M. (1990) Ostracoda, sea-level changes and the Eocene-Oligocene boundary. In *Ostracoda and Global Events* (eds. R. C. WHATLEY AND C. MAYBURY), pp. 153-160. Chapman and Hall, Cambridge.
- KEMPF E. K. (1986) Index and bibliography of Marine Ostracoda 1. Index A. *Geologisches Institut der Universitat zu Koln, Sonderveroffentlichungen* **50**, pp. 762.
- KESLING R. V. (1969) Copulatory Adaptations in Ostracods Part III. Adaptations in Some Extinct Ostracods. *Contributions from the Museum of Paleontology* **22**(21), 273-312.
- KONTOVITZ M. (1975) A study of the differential transportation of ostracodes. *Journal of Paleontology* **49**(5), 937-941.
- LAIRD M. G. (1993) Cretaceous Continental Rifts: New Zealand Region. In *South Pacific Sedimentary Basins* (ed. P. F. BALANCE), 37-49.
- LUTZE G. F. (1979) Benthic foraminifers at Site 397: fluctuations and ranges in the Quaternary. In *Initial Reports of the Deep Sea Drilling Project* (eds. U. RAD AND W. B. F. RYAN *et al.*), 419-431. US Government Printing Office, Washington DC.

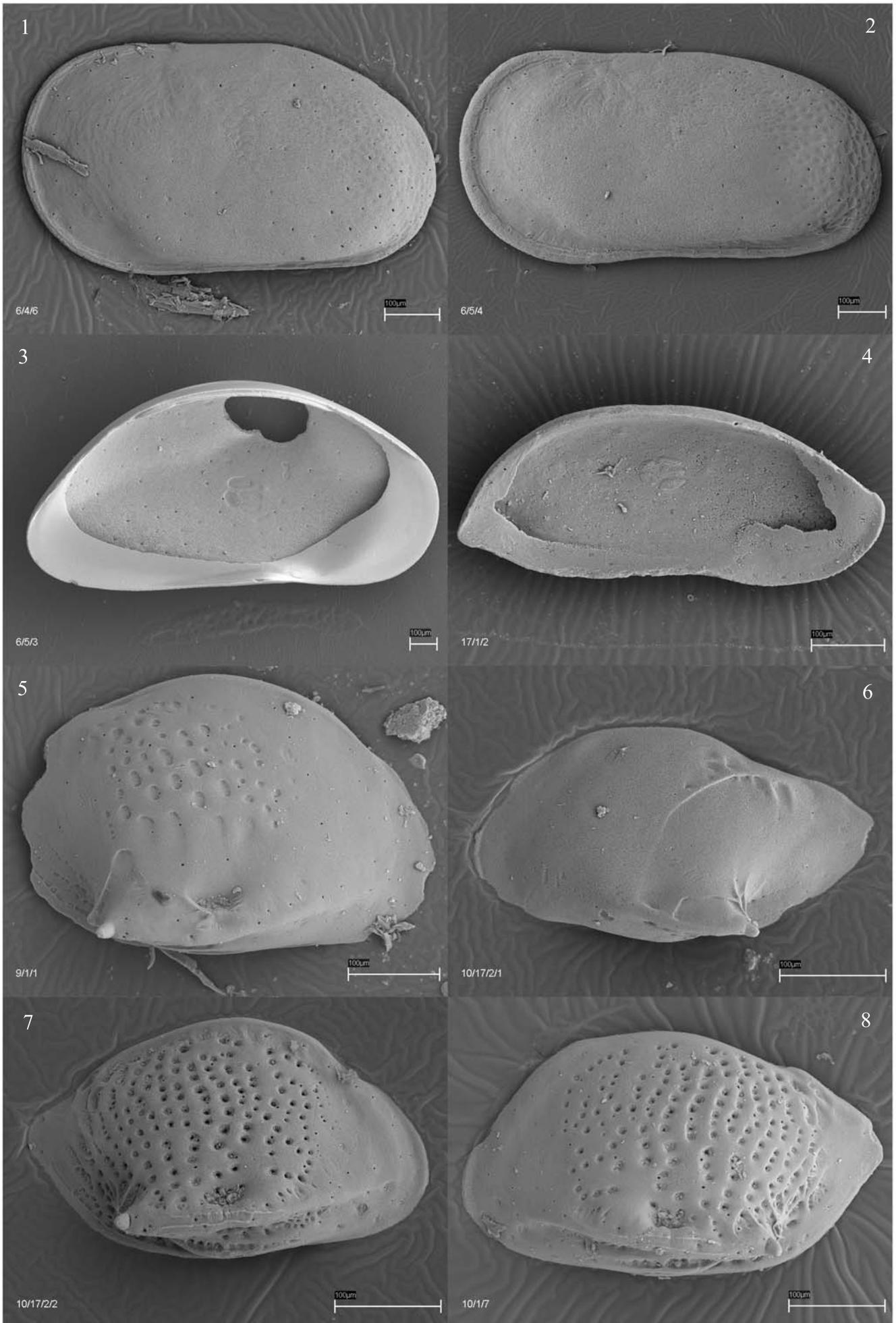
- LUYENDYK B. P. (1995) Hypothesis for Cretaceous rifting of east Gondwana caused by subducted slab capture. *Geology* **23**, 373-376.
- MARJORAN S. and DINGLE R. V. (2001) Palaeoceanographical changes recorded by Cenozoic deep-sea ostracod assemblages from the South Atlantic and the Southern Ocean (ODP Sites 1087 and 1088). *Lethaia* **34**, 63-83.
- MASLIN M. A. and RIDGWELL A. J. (2005) Mid-Pleistocene revolution and the "eccentricity myth". *Geological Society Special Publications* **247**, 19-34.
- MAZZINI I. (2005) Taxonomy, biogeography and ecology of Quaternary benthic Ostracoda (Crustacea) from circumpolar deep water of the Emerald Basin (Southern Ocean) and the S Tasman Rise (Tasman Sea). *Senckenbergiana maritima* **35**(1), 1-119.
- MCGREGOR D. L. and KESLING R. V. (1969) Copulatory Adaptations in Ostracods Part I. Hemipenes of *Candona*. *Contributions from the Museum of Paleontology* **22**(13), 169-191.
- NORCLIFFE G. B. (1977) *Inferential Statistics for Geographers*. Hutchinson & Co, London.
- NORRIS R. M. (1964) Sediments of Chatham Rise. *New Zealand Department of Scientific and Industrial Research Bulletin* **59**, pp. 40.
- PASSLOW V., PINXIAN W. and CHIVAS A. R. (1997) Late Quaternary palaeoceanography near Tasmania, southern Australia. *Palaeogeography Palaeoclimatology Palaeoecology* **131**, 433-463.
- PHILANDER S. G. (1998) *Is the Temperature Rising? The Uncertain Science of Global Warming*. Princeton University Press, Princeton, NJ. pp. 255.
- SABAA A. (2000) Pliocene foraminiferal biostratigraphy and paleoceanography of ODP Site 1125, eastern New Zealand. Unpublished MSc thesis of the University of Auckland, New Zealand.
- SCHAEFER G., RODGER J. S., HAYWARD B. W., KENNETT J. P., SABAA A. and SCOTT G. H. (2005) Planktic foraminiferal and sea surface temperature record during the last 1 Myr across the Subtropical Front, Southwest Pacific. *Marine Micropaleontology* **54**, 191-212.
- SCHONFELD J. (1995) Biostratigraphy and assemblage composition of benthic foraminifera from the Manihiki Plateau, southwestern Pacific. *Micropaleontology* **14**, 165-175.
- SHAVER R. H. (1953) Ontogeny and Sexual Dimorphism in *Cytherella bullata*. *Journal of Paleontology* **27**(3), 471-480.
- SMITH A. J. and HORNE D. J. (2002) Ecology of Marine, Marginal Marine and Nonmarine Ostracodes. In *The Ostracoda Applications in Quaternary Research* (eds. J. A. HOLMES & A. R. CHIVAS), 37-63. American Geophysical Union, Washington DC.

- SMITH P. D. (1983) Quaternary deep-sea Ostracoda from the Southwest Pacific. Unpublished MSc Thesis of the University of Aberystwyth, pp. 245. Aberystwyth
- SWANSON K. M. (1979) The Marine Fauna of New Zealand: ostracods of the Otago Shelf. *New Zealand Oceanographic Institute Memoir* **78**, pp. 56.
- SWANSON K. M. (1994) Podocopid ostracod dissolution - description of a new paleoenvironmental tool, with examples from the eastern Tasman Sea. In *Evolution of the Tasman Sea* (eds. G. J. v. d. Lingen, K. M. Swanson and R. J. Muir), pp. 245-260. A. A. Balkema, Brookfield, Vt.
- SWANSON K. M. (1995) Strategies for, and evolutionary implications of, carapace conservation in some living, benthic, marine Ostracoda. *Senckenbergiana lethaea* **75**(1/2), 193-213.
- SWANSON K. and AYRESS M. (1999) *Cytheropteron testudo* and related species from the SW Pacific with analyses of their soft anatomies, relationships and distribution. *Senckenbergiana biologica* **79**(2), 151-193.
- SWANSON K. M., JELLINEK T. and MALZ H. (2005) The platycopine condition: new observations on reproduction, respiration and feeding in living, deep-sea Platycopina (Crustacea, Ostracoda). *Senckenbergiana maritima* **35**(2), 157-187.
- SWANSON K. M. and VAN DER LINGEN G. J. (1997) Late Quaternary ostracod and planktonic foraminiferal dissolution signals from the eastern Tasman Sea - palaeoenvironmental implications. *Palaeogeography Palaeoclimatology Palaeoecology* **131**, 303-314.
- SYLVESTER-BRADLEY P. C. (1969) Comparative and Functional Sex in Ostracods and Cephalopods. *International Union of Geological Sciences* **A**(1), 242-250.
- VAN HARTEN D. (1990) Modern abyssal ostracod faunas of the eastern Mid-Atlantic Ridge area in the North Atlantic and a comparison with the Mediterranean. In *Ostracoda and Global Events* (eds. R. C. WHATLEY AND C. MAYBURY), 321-328. Chapman and Hall, Cambridge.
- VAN MORKHOVEN F. P. C. M. (1979) Notes on Post-Paleozoic Ostracoda. In *Second Short Course in Micropaleontology* (ed. P. R. KRUTAK), 1-38. The University of Nebraska, Lincoln, Nebraska.
- WALCOTT R. I. (1998) Modes of oblique compression: late Cenozoic tectonics of the South Island, New Zealand. *Reviews of Geophysics* **36**, 1-26.
- WEAVER P. P. E., NEIL H. and CARTER L. (1998) Response of surface water masses and circulation to late Quaternary climate change east of New Zealand. *Paleoceanography* **13**, 70-83.
- WEINHOLZ P. and LUTZE G. F. (1989) The *Stilostomella* extinction. In *Proceedings of the Ocean Drilling Program, Scientific Results* **108** (eds. W. F. RUDDIMAN AND M. SARNTHEIN), 113-117, College Station, Texas.

- WHATLEY R. C. (1996) The Bonds Unloosed: The contribution of Ostracoda to our understanding of deep sea events and processes. In *Microfossils and Oceanic Environments* (eds. R. C. WHATLEY AND A. MOGUILEVSKY), 3-25. University of Wales, Aberystwyth-Press, Aberystwyth.
- WHATLEY R. C., AYRESS M. and DOWNING S. (1986) Two unusual new species of the ostracod genus *Cytheropteron* from the Late Cainozoic of the deep sea. *Journal of Micropalaeontology* **5**(1), 31-36.
- WHATLEY R. C. and COLES G. P. (1987) The late Miocene to Quaternary Ostracoda of Leg 94, Deep Sea Drilling Project. *Revista Espanola de Micropaleontologia* **19**, 33-97.
- WHATLEY R. C. and DOWNING S. E. (1983) Middle Miocene Ostracoda from Victoria, Australia. *Revista Espanola de Micropaleontologia* **15**(3), 347-407.
- WHATLEY R. C., DOWNING S. E., KESLER K. J. and HARLOW C. J. (1984) New species of the ostracod genus *Bradleya* from the Tertiary and Quaternary of D.S.D.P. sites in the Southwest Pacific. *Revista Espanola de Micropaleontologia* **16**, 265-298.
- WHATLEY R. C., HARLOW C. J., DOWNING S. E. and KESLER K. J. (1983) Observations on the origin, evolution, dispersion and ecology of the genera *Poseidonamicus* Benson and *Bradleya* Hornibrook. In *Applications of Ostracoda - Proceedings of the 8th International Symposium on Ostracoda* (ed. R. F. MADDOCKS), 492-509, Houston, TX.
- WHATLEY R. C., MILLSON K. and AYRESS M. (1992) *Philoneptunus*, a new ostracod genus from the Cainozoic of Australasia. *Revista Espanola de Micropaleontologia* **24**(3), 43-62.
- WHATLEY R. C., MILLSON K. and AYRESS M. (1993) *Philoneptunus*, a new Ostracod Genus from the Cainozoic of Australasia - Errata Corrige. *Revista Espanola de Micropaleontologia* **15**(2), 372-378.
- WHATLEY R. C., PYNE R. S. and WILKINSON I. P. (2003) Ostracoda and palaeo-oxygen levels, with particular reference to the Upper Cretaceous of East Anglia. *Palaeogeography Palaeoclimatology Palaeoecology* **194**, 355-386.
- WHATLEY R. C., TRIER K. and DINGWALL P. M. (1982) Some preliminary observations on certain mechanical and biophysical properties of the ostracod carapace. *Fossil and Recent Ostracods*.
- WOOD R. A., ANDREWS P. B., HERZER R. H. *et al.* (1989) Cretaceous and Cenozoic geology of the Chatham Rise Region, South Island, New Zealand. *New Zealand Geological Survey basin studies* **3**.
- WOOD R. A. and HERZER R. H. (1993) The Chatham Rise, New Zealand. In *South Pacific Sedimentary Basins* (ed. P. F. BALANCE), 329-349.

**Plate 1**  
(all scale bars are 100  $\mu$ m)

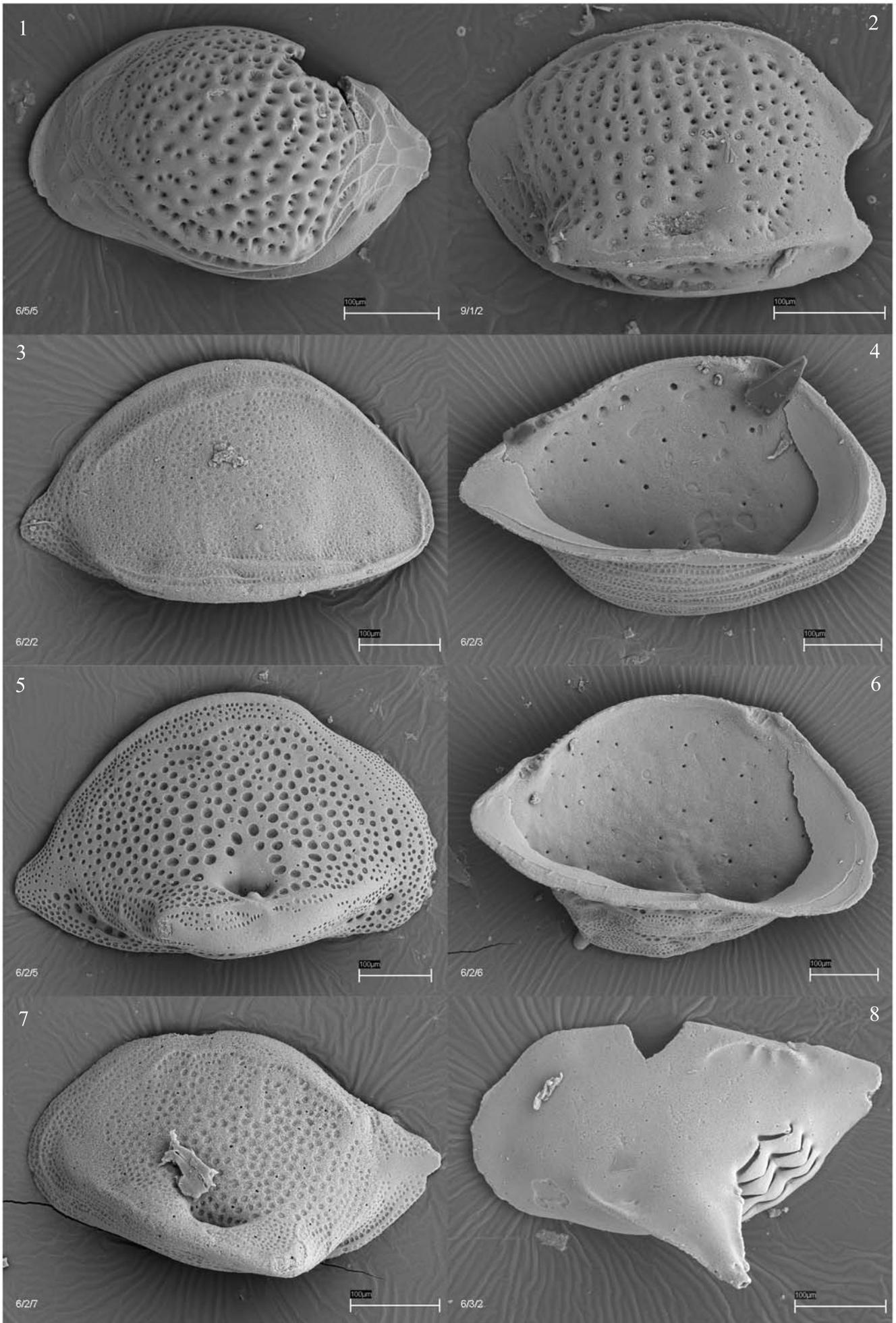
- Fig 1. *Cytherella* sp. a  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ALV, external view, specimen UCF 1416
- Fig 2. *Cytherella* sp. b  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ALV, external view, specimen UCF 1417
- Fig 3. *Bythocypris* sp.  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ALV, internal view, specimen UCF 1418
- Fig 4. *Argilloecia* sp.  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-6, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ALV, (carapace corroded) internal view, specimen UCF 1419
- Fig 5. *Cytheropteron* sp. aff. *dibolos*  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-5, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, (posterior broken) external view, specimen UCF 1420
- Fig 6. *Cytheropteron garganicum*  
Pleistocene sample, ODP Site 1125 sample 1125B-2H-4, Chatham Rise, East of South Island, New Zealand, 42°32.979'S 178°9.988'W, 1359 m  
ALV, external view, specimen UCF 1421
- Fig 7. *Cytheropteron* sp. aff. *quadrata*  
Pleistocene sample, ODP Site 1125 sample 1125B-2H-4, Chatham Rise, East of South Island, New Zealand, 42°32.979'S 178°9.988'W, 1359 m  
ALV, external view, specimen UCF 1422
- Fig 8. *Cytheropteron* sp. aff. *quadrata*  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-6, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, external view, specimen UCF 1423



## Plate 2

(all scale bars are 100  $\mu$ m)

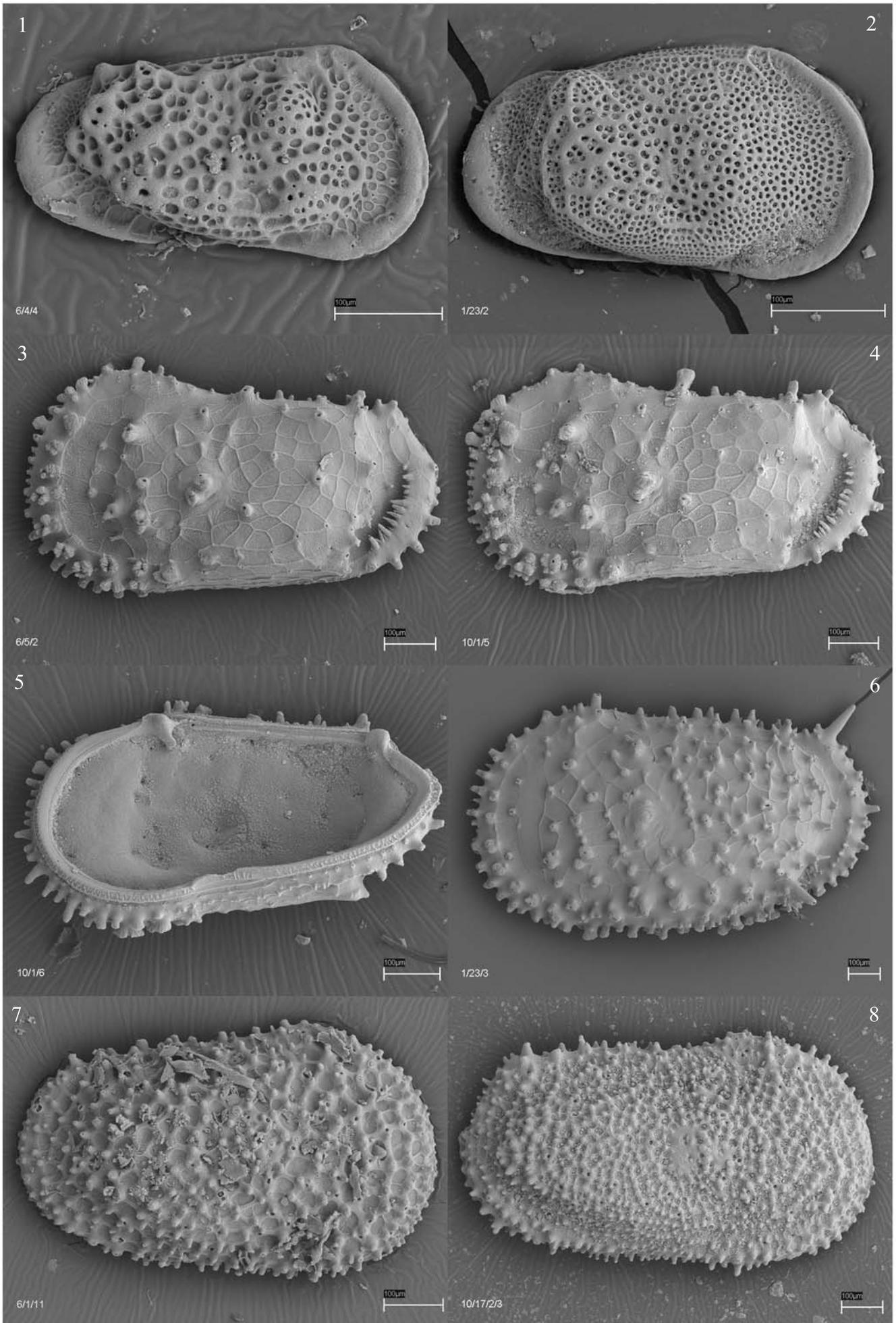
- Fig 1. *Cytheropteron posteroreticulata*  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ALV, (posterior broken), external view, specimen UCF 1424
- Fig 2. *Cytheropteron sianea*  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-5, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, (anterior broken) external view, specimen UCF 1425
- Fig 3. *Cytheropteron testudo*  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, external view, specimen UCF 1426
- Fig 4. *Cytheropteron testudo*  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ALV, external view, specimen UCF 1427
- Fig 5. *Cytheropteron* sp. aff. sp. 1 Ayress  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, external view, specimen UCF 1428
- Fig 6. *Cytheropteron* sp. aff. sp. 1 Ayress  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ALV, external view, specimen UCF 1429
- Fig 7. *Cytheropteron* sp. b  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ALV, external view, specimen UCF 1430
- Fig 8. *Cytheropteron* n. sp. a  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ALV, external view, specimen UCF 1431



### Plate 3

(all scale bars are 100  $\mu$ m)

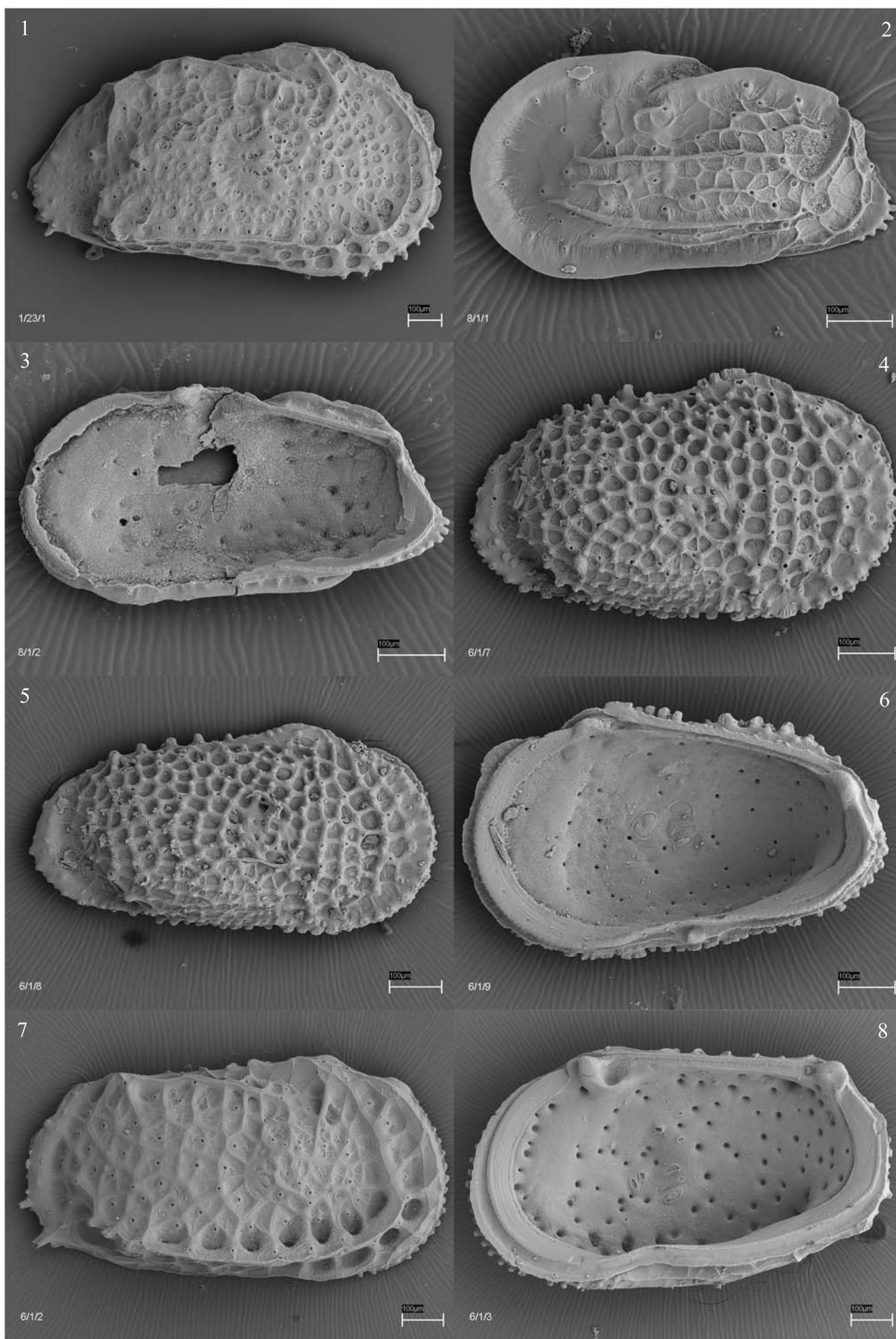
- Fig 1. *Cluthia* sp. a  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, external view, specimen UCF 1432
- Fig 2. *Cluthia* sp. b  
Pleistocene sample, ODP Site 1125 sample 1125A-1H-1, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, external view, specimen UCF 1433
- Fig 3. *Taracythere* n. sp. a  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ALV, (central node on hinge broken), external view, specimen UCF 1434
- Fig 4. *Taracythere* n. sp. a  
Pleistocene sample, ODP Site 1125 sample 1125B-2H-4, Chatham Rise, East of South Island, New Zealand, 42°32.979'S 178°9.988'W, 1359 m  
ALV, external view, specimen UCF 1435
- Fig 5. *Taracythere* n. sp. a  
Pleistocene sample, ODP Site 1125 sample 1125B-2H-4, Chatham Rise, East of South Island, New Zealand, 42°32.979'S 178°9.988'W, 1359 m  
ARV, internal view, specimen UCF 1436
- Fig 6. *Legitimocythere* sp.  
Pleistocene sample, ODP Site 1125 sample 1125A-1H-2, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, external view, specimen UCF 1437
- Fig 7. *Apatihowella* sp.  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, external view, specimen UCF 1438
- Fig 8. *Fallacihowella* sp. aff. *F.* sp. a MAZZINI  
Pleistocene sample, ODP Site 1125 sample 1125B-2H-4, Chatham Rise, East of South Island, New Zealand, 42°32.979'S 178°9.988'W, 1359 m  
ALV, external view, specimen UCF 1439



## Plate 4

(all scale bars are 100 µm)

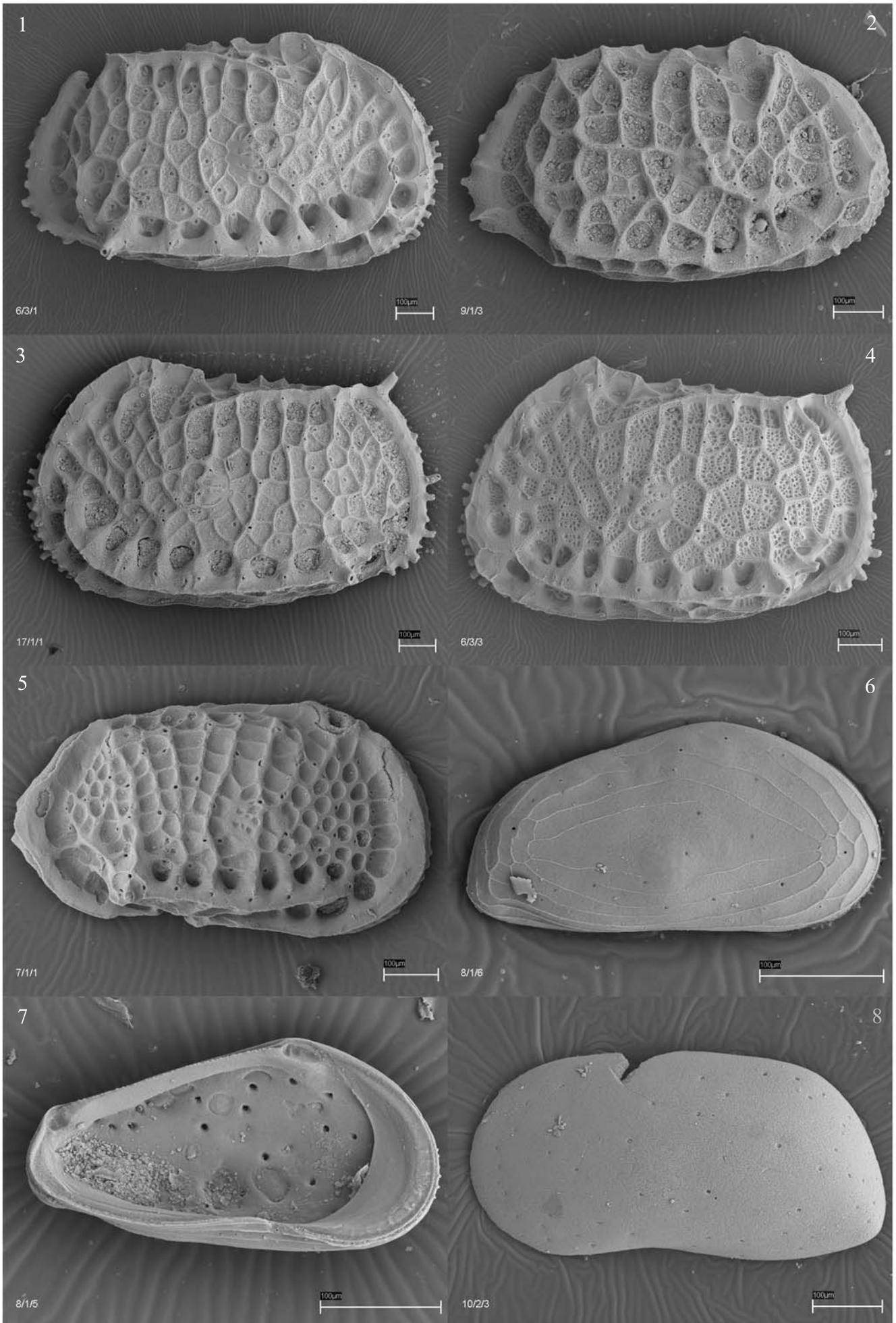
- Fig 1. *Philoneptunus provocator*  
Pleistocene sample, ODP Site 1125 sample 1125A-1H-1, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, external view, specimen UCF 1440
- Fig 2. *Ambocythere* sp. aff. *recta*  
Pleistocene sample, ODP Site 1125 sample 1125B-1H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.979'S 178°9.988'W, 1359 m  
ALV, external view, specimen UCF 1441
- Fig 3. *Ambocythere* sp. aff. *recta*  
Pleistocene sample, ODP Site 1125 sample 1125B-1H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.979'S 178°9.988'W, 1359 m  
ALV, (carapace perforated and broken), internal view, specimen UCF 1442
- Fig 4. *Rugocythereis horrida*  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, external view, specimen UCF 1443
- Fig 5. *Rugocythereis horrida*  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, external view, specimen UCF 1444
- Fig 6. *Rugocythereis horrida*  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, external view, specimen UCF 1445
- Fig 7. *Bradleya pelagica*  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, external view, specimen UCF 1447
- Fig 8. *Bradleya pelagica*  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, external view, specimen UCF 1448



## Plate 5

(all scale bars are 100  $\mu$ m)

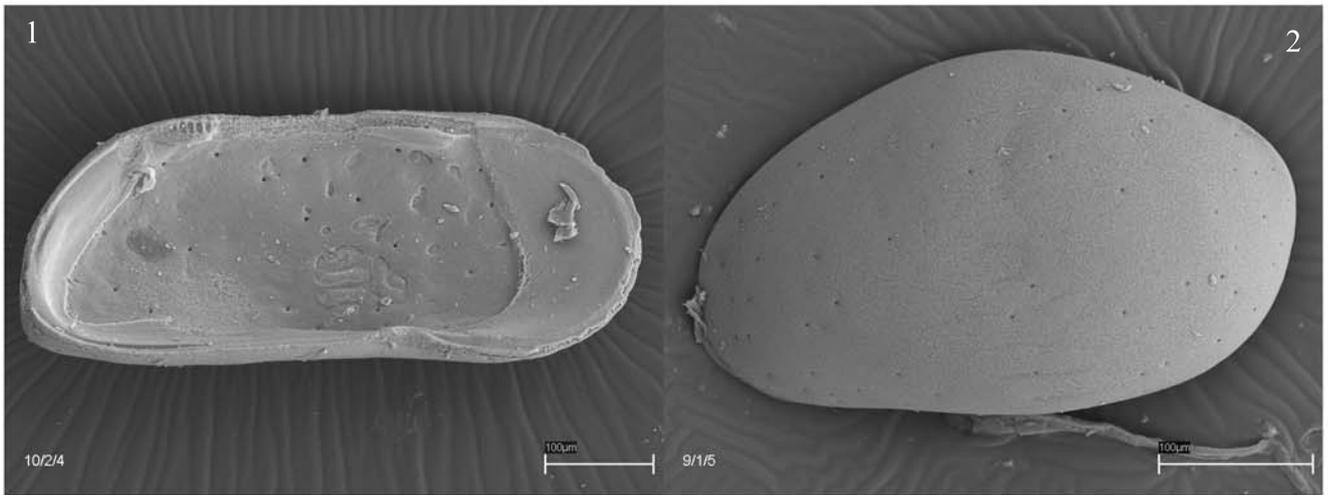
- Fig 1. *Bradleya perforata*  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, external view, specimen UCF 1449
- Fig 2. *Bradleya pygmaea*  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-5, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, external view, specimen UCF 1450
- Fig 3. *Bradleya* sp. aff. *silentium*  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-6, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ALV, external view, specimen UCF 1451
- Fig 4. *Bradleya* n. sp. a  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ALV, external view, specimen UCF 1452
- Fig 5. *Poseidonamicus major*  
Pleistocene sample, ODP Site 1125 sample 1125B-1H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.979'S 178°9.988'W, 1359 m  
ARV, external view, specimen UCF 1453
- Fig 6. *Pseudeucythere* n. sp.  
Pleistocene sample, ODP Site 1125 sample 1125B-1H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.979'S 178°9.988'W, 1359 m  
ARV, external view, specimen UCF 1454
- Fig 7. *Pseudeucythere* n. sp.  
Pleistocene sample, ODP Site 1125 sample 1125B-1H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.979'S 178°9.988'W, 1359 m  
ALV, external view, specimen UCF 1455
- Fig 8. *Parakrithe* sp.  
Pleistocene sample, ODP Site 1125 sample 1125B-2H-4, Chatham Rise, East of South Island, New Zealand, 42°32.979'S 178°9.988'W, 1359 m  
ALV, (carapace broken), external view, specimen UCF 1468



**Plate 6**

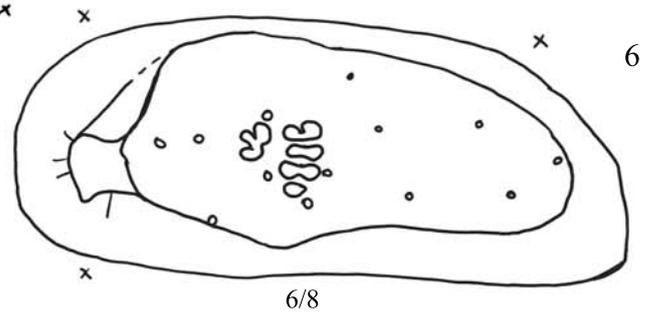
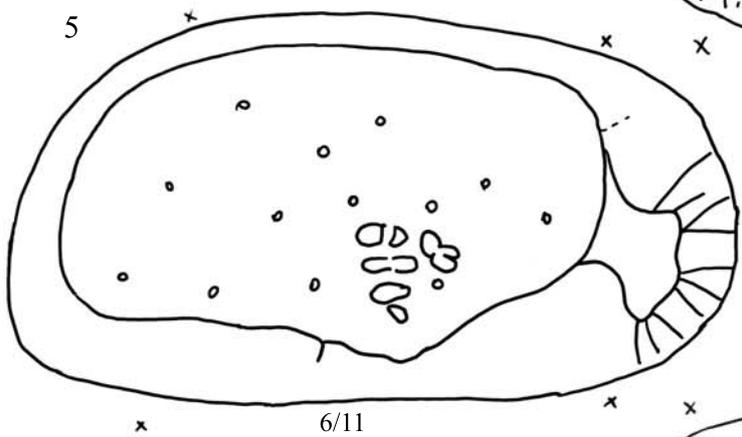
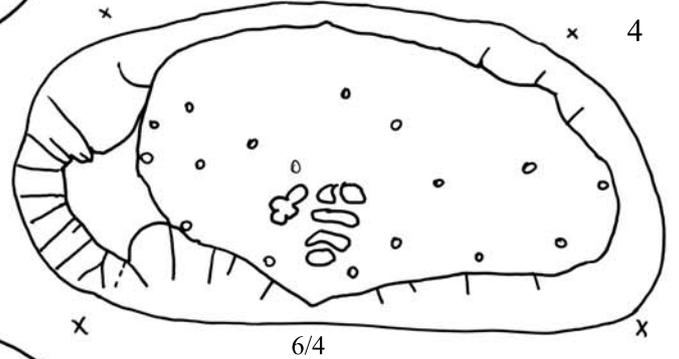
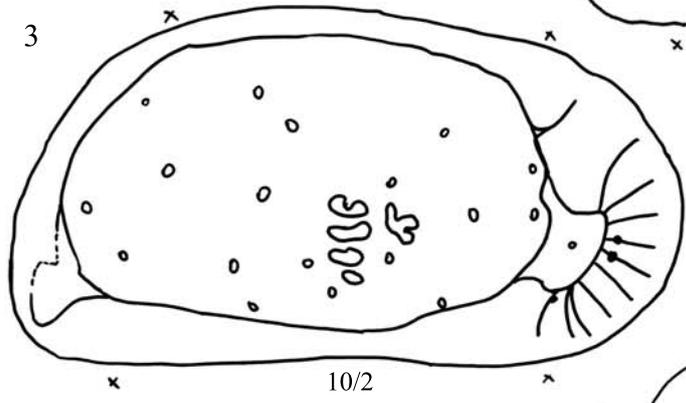
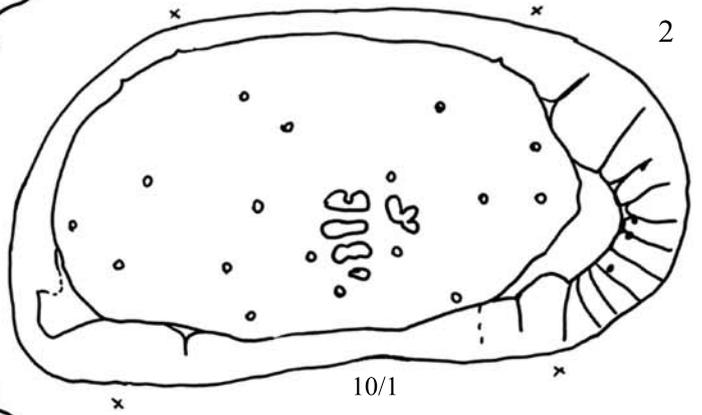
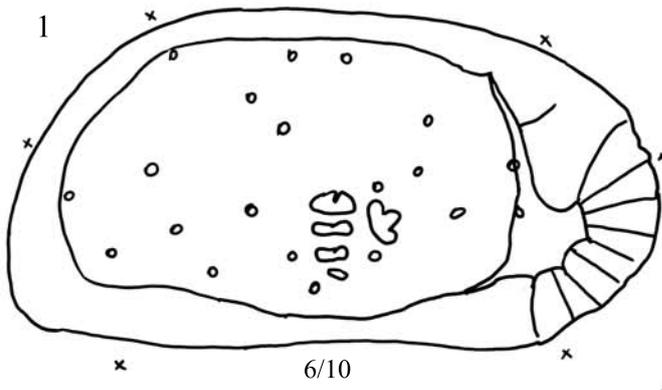
(all scale bars are 100  $\mu\text{m}$ )

- Fig 1. *Parakrithe* sp.  
Pleistocene sample, ODP Site 1125 sample 1125B-2H-4, Chatham Rise, East of South Island, New Zealand, 42°32.979'S 178°9.988'W, 1359 m  
ALV, internal view, specimen UCF 1469
- Fig 2. *Xestoleberis* sp.  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-5, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, external view, specimen UCF 1470



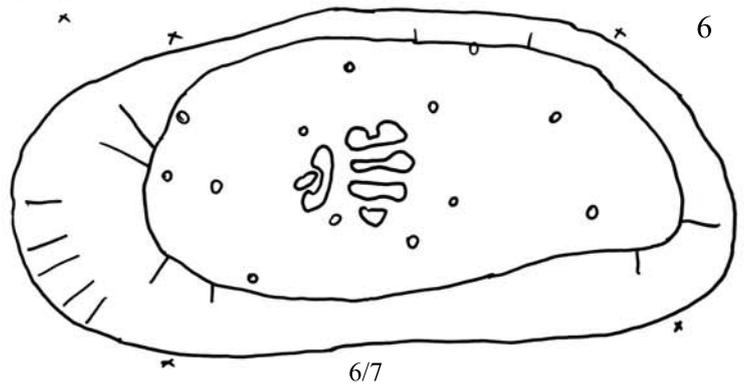
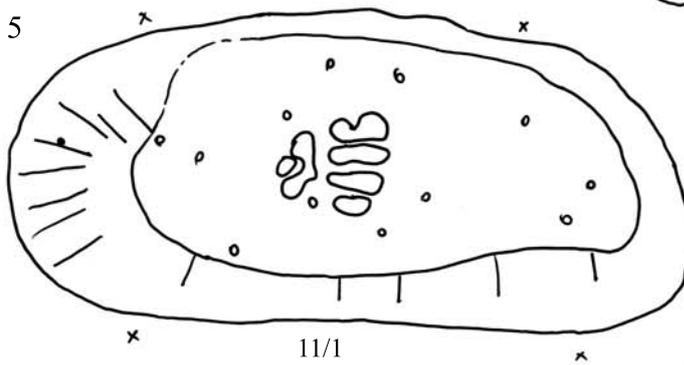
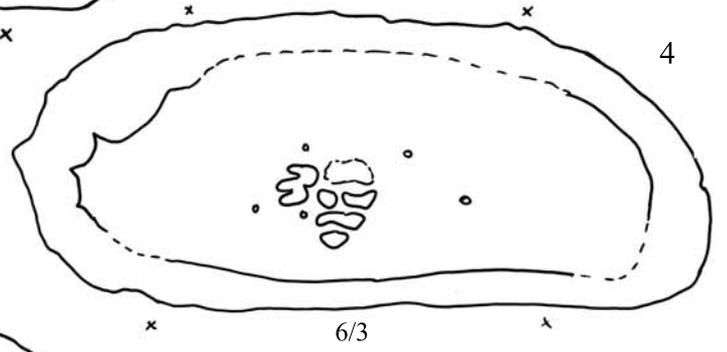
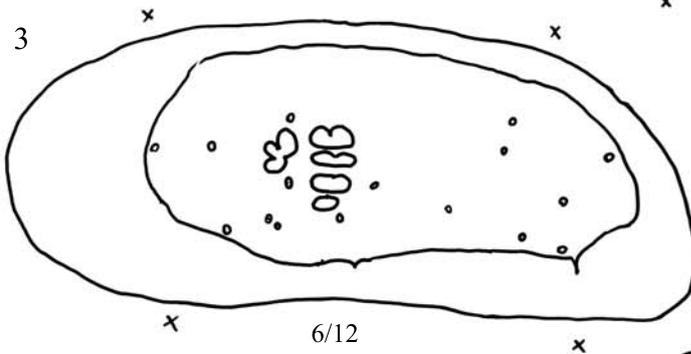
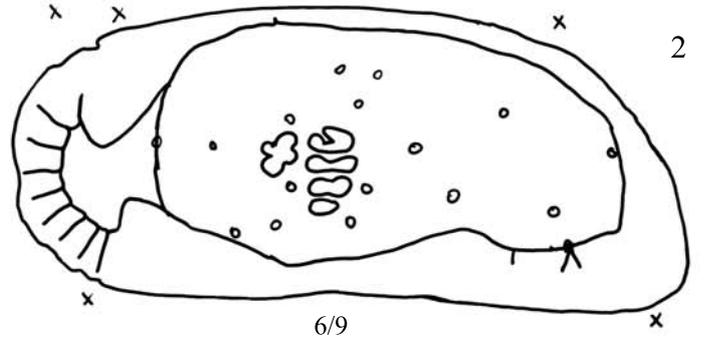
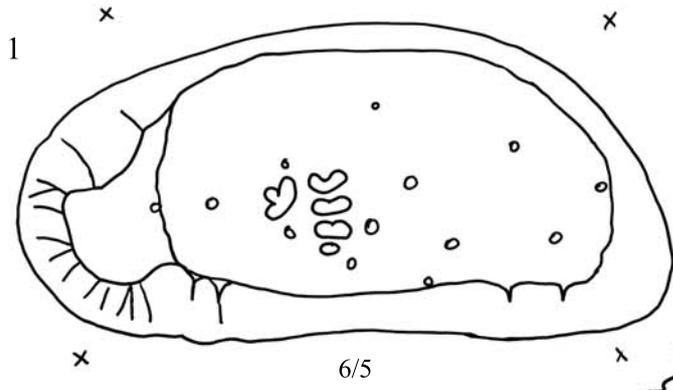
## Plate 7

- Fig 1. *Krithe* sp. a  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ALV, internal view (pore map); ×106, specimen UCF 1456
- Fig 2. *Krithe* sp. a  
Pleistocene sample, ODP Site 1125 sample 1125B-2H-4, Chatham Rise, East of South Island, New Zealand, 42°32.979'S 178°9.988'W, 1359 m  
ALV, internal view (pore map); ×95, specimen UCF 1457
- Fig 3. *Krithe* sp. a  
Pleistocene sample, ODP Site 1125 sample 1125B-2H-4, Chatham Rise, East of South Island, New Zealand, 42°32.979'S 178°9.988'W, 1359 m  
ALV, internal view (pore map); ×95, specimen UCF 1458
- Fig 4. *Krithe* sp. b  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, internal view (pore map); ×85, specimen UCF 1459
- Fig 5. *Krithe* sp. b  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ALV, internal view (pore map); ×95, specimen UCF 1460
- Fig 6. *Krithe* sp. c  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, internal view (pore map); ×110, specimen UCF 1461



## Plate 8

- Fig 1. *Krithe* sp. c  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, internal view (pore map); ×92, specimen UCF 1462
- Fig 2. *Krithe* sp. c  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, internal view (pore map); ×106, specimen UCF 1463
- Fig 3. *Krithe* sp. c  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, internal view (pore map); ×90, specimen UCF 1464
- Fig 4. *Krithe* sp. c  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, internal view (pore map); ×85, specimen UCF 1465
- Fig 5. *Krithe* sp. d  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, internal view (pore map); ×180, specimen UCF 1466
- Fig 6. *Krithe* sp. d  
Pleistocene sample, ODP Site 1125 sample 1125A-2H-CC, Chatham Rise, East of South Island, New Zealand, 42°32.996'S 178°9.989'W, 1359 m  
ARV, internal view (pore map); ×190, specimen UCF 1467



## APPENDIX 1 - INTRODUCTION

### 1.1 Macroscopic tephra for ODP Site 1125A and 1125B (from Carter et al., 1999)

Hole	Core, section	Depth of tephra at base of section		Thickness of tephra (cm)	Comments
		(cm)	(mbsf)		
1125A	1H-1	74	0.74	11	Color: 5Y 5/1
1125A	1H-1	93	0.93	5	Blebs only
1125B	1H-3	143	4.43	9	Color: 5B 6/1
1125A	2H-4	19.5	8.995	14	
1125B	2H-4	4	12.84	17	Color: 5B 6/1
1125A	3H-4	67	18.97	13	
1125A	3H-5	127	21.07	14	
1125A	3H-6	60	21.9	10	
1125A	3H-6	108	22.38	8	
1125B	3H-3	32	21.12	13	Color: 5B 7/1
1125B	3H-5	90	24.7	5	Tephra burrow
1125A	4H-3	34	26.64	7	
1125A	4H-3	75	27.05	2	
1125A	4H-4	117.5	28.975	13	Color: 5YR 6/1 (base), 5YR 7/1 (top)
1125B	4H-2	13	28.93	3	Color: 5Y 6/1
1125A	5H-6	39	40.69	11.5	Color: 5YR 7/1 (base), 5YR 8/1 (top)
1125A	5H-6	68	40.98	14	Color: 5YR 7/1 (base), 5YR 8/1 (top)
1125A	5H-6	108	41.38	2	Color: 5YR 7/1 (base and top), 5YR 6/1 (middle)
1125B	5H-2	138.5	39.685	5.5	Color: 5YR 6/1 (base), 5YR 6/1 (top)
1125B	5H-3	20.5	40.005	5	Color: 5YR 6/1 (base), 5YR 6/1 (top)
1125B	5H-3	123	41.03	14	Color: 5YR 6/1 (bottom 2/3), 5YR 8/1 (top)
1125B	5H-4	65.5	41.955	7	Color: 5YR 4/1 (base), 5YR 5/1 (top)
1125A	6H-5	73.5	49.035	5.5	Color: 5YR 8/1
1125B	6H-1	150	47.8	8.5	Color: 5YR 6/1 (basal 9/10ths), 5YR 8/1 (top)
1125B	6H-5	135	53.65	5.5	Color: 5YR 8/1
1125A	7H-2	138	54.68	0.5	
1125A	9H-5	30	77.1	10	Color: 5GY 5/1, dispersed
1125A	9H-5	66	77.46	11	Color: 5GY 5/1, dispersed
1125A	9H-5	93	77.73	4	Color: 5GY 5/1, dispersed
1125B	11H-4	69	98.99	9	
1125B	15H-3	112	135.92	6	
1125B	19X-4	50	174.8	10	
1125A	20H-3	32	178.42	1	
1125A	20H-2	150	178.1	1	Bioturbated tephra
1125A	20H-3	5	178.15	1	Bioturbated tephra
1125B	24X-4	75	221.65	5	
1125B	24X-4	86	221.76	7	
1125B	24X-4	133	222.23	7	
1125B	28X-5	41.5	261.215	1	
1125B	34X-1	137.5	313.975	2	Nannofossil tephra
1125B	34X-6	42	320.52	2.5	
1125B	36X-CC	45	332.57	1	
1125B	39X-3	138	364.78	8	
1125B	40X-2	1	371.61	9	

Continued over

1125B 40X-3	133	374.43	8
1125B 41X-5	26	385.96	10
1125B 43X-2	122	401.72	10
1125B 46X-3	75	431.65	3
1125B 47X-1	26	437.76	4
1125B 47X-4	62	442.62	3
1125B 48X-2	22	448.52	5
1125B 49X-3	95	460.35	5
1125B 49X-5	14	462.54	2
1125B 49X-6	20	464.1	3
1125B 50X-3	16	469.16	3
1125B 50X-4	72	471.22	4
1125B 52X-3	87	488.77	2
1125B 52X-5	120	492.1	6
1125B 53X-4	17	499.17	5
1125B 54X-1	81	504.91	1
1125B 57X-5	149	540.49	2

---

## 1.2 Nannofossil datum levels identified and age estimates used at ODP Site 1125 (from Carter et al., 1999)

Depth (mbsf)	Bioevent	Age (Ma)	Reference
2.05	LO <i>Helicosphaera inversa</i>	0.16	Sato and Kameo, 1996
4.53	LO <i>Pseudoemiliana lacunosa</i>	0.42	Sato and Kameo, 1996
23.6	LO <i>Reticulofenestra asanoi</i>	0.85	Sato and Kameo, 1996
23.6	FO <i>Gephyrocapsa parallela</i>	0.95	Sato and Kameo, 1996
28.22	LO <i>Helicosphaera sellii</i>	1.26	Sato and Kameo, 1996
35.8	FO <i>Gephyrocapsa (medium)</i>	1.67	Raffi and Flores, 1995
42	LO <i>Discoaster brouweri</i>	1.96	Raffi and Flores, 1995
47.08	LO <i>Discoaster tamalis</i>	2.76	Raffi and Flores, 1995
80.76	<i>Acme Gephyrocapsa (small)</i>	3.88	Rio, 1982
94.87	FO <i>Pseudoemiliana lacunosa</i>	4	Gartner, 1990
285.25	LO <i>Discoaster quinqueramus</i>	5.56	Raffi and Flores, 1995
374.5	LO <i>Minylitha convallis</i>	7.73	Shackleton et al., 1995
432.4	FO <i>Minylitha convallis</i>	9.34	Raffi and Flores, 1995
516.85	FO <i>Discoaster bellus</i>	10.5	Gartner, 1990

---

Note: The depth of each datum level is placed at the midpoint between samples

### 1.3 Significant foraminiferal and bolboformid datums at ODP Site 1125 (from Carter *et al.*, (1999))

Foraminiferal and bolboformid events	Epoch	NZ stage	Age (Ma)	Core, section, interval (cm)	Depth (mbsf)
LO <i>Globorotalia puncticuloides</i>	Pleistocene	Wc	~0.6	1125A-1H-CC	4.2
LO <i>Stilostomella</i> spp.	Pleistocene	Wc	0.6-0.8	1125A-2H-CC	13.4
LO <i>Plectofrondicularia advena</i>	Pleistocene	Wc	0.6-0.8	1125A-2H-CC	13.4
FO <i>Globorotalia truncatulinoides</i>	Pleistocene	Wn	~0.8*	1125A-3H-CC	23.6
LO <i>Globorotalia inflata triangula</i>	late Pliocene	Wn	~2	1125A-5H-CC	42.6
FO <i>Globorotalia crassula</i>	late Pliocene	Wm/Wn	2.6	1125A-5H-CC	42.6
LO <i>Globorotalia crassaformis</i> (dextral)	late Pliocene	Wn	2.1	1125A-6H-2,130-135	45.1
FO <i>Globorotalia crassaformis</i> (dextral)	early Pliocene	Wp/Wm	3	1125A-7H-CC	61.8
LO <i>Globorotalia crassaconica</i>	early Pliocene	Wp/Wm	3	1125A-8H-CC	74.4
FO <i>Globorotalia puncticuloides</i>	early Pliocene	Wp	3.6	1125A-11H-CC	99.8
FO <i>Globorotalia inflata</i>	early Pliocene	Wo/Wp	3.7	1125A-11H-CC	99.8
FO <i>Globorotalia inflata triangula</i>	early Pliocene	Wo/Wp	3.6	1125A-11H-CC	99.8
LCO <i>Globorotalia pliozea</i>	early Pliocene	Wo/Wp	3.6	1125A-13H-CC	118.8
LO <i>Globorotalia puncticulata</i>	early Pliocene	Wo/Wp	3.7	1125A-13H-CC	118.8
FO <i>Globorotalia crassaconica</i>	early Pliocene	Wo	4.7	1125A-17H-CC	156.7
LO <i>Globorotalia mons</i>	early Pliocene	Wo	4.8	1125A-17H-CC	156.7
FO <i>Globorotalia puncticulata</i>	Miocene/Pliocene	Tk/Wo	5.2	1125B-25X-CC	234.7
FO <i>Globorotalia crassaformis</i>	Miocene/Pliocene	Tk/Wo	5.2	1125B-25X-CC	234.7
LO <i>Globorotalia sphericomiozea</i>	Miocene/Pliocene	Tk/Wo	5.2	1125B-25X-CC	234.7
LO <i>Globorotalia juanai</i>	Miocene/Pliocene	Tk/Wo	5.2	1125B-26X-CC	245.2
LO <i>Globorotalia miotumida</i>	late Miocene	Tk	5.6	1125B-26X-CC	245.2
FO <i>Globorotalia pliozea</i>	late Miocene	Tk	5.4	1125B-26X-CC	244.2
FO <i>Globorotalia mons</i>	late Miocene	Tk	5.5	1125B-27X-CC	253.9
FO <i>Globorotalia sphericomiozea</i>	late Miocene	Tk	5.6	1125B-29X-CC	274
FO <i>Globorotalia juanai</i>	late Miocene	Tt	6.6	1125B-45X-CC	427.8
LO <i>Bolboforma</i> aff. <i>metzmacheri</i>	late Miocene	Tt	8.5	1125B-45X-CC	427.8
FCO <i>Neogloboquadrina pachyderma</i>	late Miocene	Tt	9.2	1125B-45X-CC	427.8
LO <i>Globoquadrina dehiscens</i>	late Miocene	eTt	9.9	1125B-48X-CC	450.8
LO <i>Globorotalia panda</i>	late Miocene	eTt	10.3	1125B-57X-CC	542.2
LO <i>Globorotalia miotumida</i> (dextral)	late Miocene	eTt	10.7	1125B-58X-CC	548.2
FO <i>Globorotalia miotumida</i> (dextral)	late Miocene	eTt	10.9	1125B-58X-CC	548.2

Note: Wc = Castlecliffian, Wn = Nukumaruan, Wm = Mangapanian, Wp = Waipipian, Wo = Opoitian, Tk = Kapitean, Tt = Tongaporutuan. \* = in subantarctic

## APPENDIX 2 - METHODS

### 2.1 Details from ODP Site 1125 samples used in this study

Sample number, this study	ODP Sample Number	Depth (mcd)	Age (ka)	Post-picked sample weight	Total number of valves
21	1125A-1H-1, 0-2 cm	0.01	3	2.6	2
1	1125A-1H-1, 38-40 cm	0.39	22	0.7	77
23	1125A-1H-2, 31-35 cm	1.83	124	2.7	67
20	1125B-1H-1, 134-136 cm	2.89	179	2.0	26
7	1125A-1H-CC	4.10	208	5.5	34
22	1125B-1H-4, 106-108 cm	7.11	374	2.4	21
8	1125B-1H-CC	9.75	515	5.2	74
14	1125A-2H-4, 133-135 cm	11.71	612	1.6	49
9	1125A-2H-5, 63-67 cm	12.52	647	3.2	58
17	1125A-2H-6, 10-14 cm	13.49	695	1.1	107
13	1125A-2H-6, 50-52 cm	13.89	731	2.5	14
6,25	1125A-2H-CC	14.90	785	9.0	346
11	1125B-2H-3, 85-87 cm	15.21	808	1.8	23
15	1125A-3H-2, 130-132 cm	16.49	839	2.3	36
10	1125B-2H-4, 134-136 cm	17.21	858	4.0	161
18	1125A-3H-4, 27-30 cm	18.47	890	1.6	95
16	1125A-3H-4, 120-122 cm	19.40	916	3.1	25
29	1125B-2H-CC	20.90	962	1.8	20
26	1125A-3H-CC	23.40	1200	1.0	2
24	1125A-4H-2, 10-12 cm	28.00	1600	1.7	23
12	1125A-4H-3, 60-64 cm	30.05	1700	0.6	3
2,3,4	1125B-3H-CC	31.30	1750	8.6	13
19	1125A-4H-5, 45-50 cm	32.87	1800	1.0	3
27	1125A-4H-CC	35.90	2000	1.4	4
5	1125B-4H-CC	41.10	2200	4.1	6
28	1125A-5H-CC	47.60	2500	0.9	19

## 2.2 Database of all picked specimens.

Sample no	sample weight	Depth	Total no. valves	Total no. species	% juveniles	<i>Cytherella</i> sp A	<i>Bythocypris</i> sp.	<i>Argilloecia</i> sp.	<i>Cytheropteron</i> sp.	<i>Cytheropteron</i> sp. aff. <i>dibolos</i>	<i>Cytheropteron</i> sp. aff. <i>garganicum</i>	<i>Cytheropteron</i> sp. aff. <i>quadrata</i>	<i>Cytheropteron posteroreticulata</i>	<i>Cytheropteron sianae</i>	<i>Cytheropteron testudo</i>	<i>Cytheropteron 'confusum'</i>	<i>Cytheropteron</i> sp. a	<i>Cytheropteron</i> sp. b	<i>Cytheropteron</i> n. sp.	<i>Cluthia</i> sp.a	<i>Cluthia</i> sp.b	<i>Taracythere</i> n. sp.	<i>Legitimocythere</i> sp.	<i>Apatihowella</i> sp.	<i>Fallacihowella</i> sp. aff. <i>F. sp. a Mazzini</i>	<i>Philoneptunus provocator</i>	<i>Ambocythere</i> sp. aff. <i>recta</i>	<i>Rugocythereis horrida</i>	<i>Bradleya</i> sp.	<i>Bradleya opima</i>	<i>Bradleya pelagica</i>	<i>Bradleya perforata</i>	<i>Bradleya pygmaea</i>	<i>Bradleya</i> sp. aff. <i>silentium</i>	<i>Bradleya</i> sp. a	<i>Bradleya</i> sp. b	<i>Poseidonamicus major</i>	<i>Pseudeocythere</i> n. sp.	<i>Krithe</i> sp. a	<i>Parakrithe</i>	<i>Xestoleberis</i> sp.		
1	2.6	0	74	10	86			3	5								1			1			8		9				37										10				
21	0.7	0	2	1	0																																				2		
23	2.7	2	67	13	78		2	3							4	1						1	1	2	1		5	12					3						28	1	3		
20	2.0	3	26	7	65																	1	1	1	1		1					6							14	1			
7	5.5	4	38	7	55				1													2	2	2			1				6	4				3			17				
22	2.4	7	21	5	62										1												3			1	1								1	14			
8	5.2	10	72	9	57			2	1											2							2	4	18										4	38	1		
14	1.6	12	53	9	89		2	13							8													2	4	18			7						6	14	2	1	
9	3.2	13	57	13	74			2	5	1		1		1									1	12			3							21					9		1		
13	1.1	13	14	5	57																			2		2	1	4												5			
17	2.5	14	104	13	79	1	4	16							5		1					2				7				5		14	1					2	43	2	1		
11	1.8	15	23	4	70																			8			4	2												9			
6	8.7	15	346	21	61	2	19	29	11				1		3		3	1	1		1	15		12	8	4	9	2		50	12	6		1	3			7	146				
25	0.3	15	35	11	86																																						
15	2.3	16	36	7	64		4	1																4									17							1	6	3	
10	4.0	17	156	19	74	2	11	10	5							2						8	2	6	1		5	17					3						6	75	3		
16	1.6	18	25	6	76			4																4		2	2	3													10		
18	3.1	19	80	6	41	3																	5				4	5	3				4								56		
29	1.8	21	24	5	38	1		1				1										1				1		2				2									15		
26	1.0	23	2	3	0		1																																				
24	1.7	28	24	9	67	1		1				1										2	3	2		3		2				7								2			
12	0.6	30	3	1	0										1																		1										1
2	8.3	31	13	4	77																			4	2					2			3							2			
3	0.2	31	0	0	0																																						
4	0.1	31	0	0	0																																						
19	1.0	33	3	2	33																	2																			1		
27	1.4	36	4	3	75																						1								1						2		
5	4.1	41	6	3	17																			1								1	2								1	1	
28	0.9	48	9	2	56																	1	2							1											5		

Note: highlighted squares indicate those samples from which SEM images were taken

### 2.3 Database of juveniles picked from each sample

Sample no	Depth	Total no. juveniles	<i>Cytherella</i>	<i>Bythocypris</i>	<i>Argilloecia</i>	<i>Cytheropteron</i>	<i>Cluthia</i>	<i>Taracythere</i>	<i>Legitimocythere</i>	<i>Apathowella</i>	<i>Fallacihowella</i>	<i>Philoneptunus</i>	<i>Ambocythere</i>	<i>Rugocythereis</i>	<i>Bradleyinid</i>	<i>Poseidonamicus</i>	<i>Pseudeuocythere</i>	<i>Krithe</i>	<i>Parakrithe</i>	<i>Xestoleberis</i>
1	0	65			3	3		1	8		8			33			9			
21	0	2															2			
23	2	54		1	2	3		1	1	1	1	4	13				25		3	
20	3	19							1	1		1	4				11			
7	4	25				1		2	2	2				6	2		10			
22	7	15											3	1			11			
8	10	44			1		1						2	17		1	22			
14	12	48		2	13	6								7		4	13	2	1	
9	13	45			2	4			1	11			3	20			4			
13	13	8								1		2		2			3			
17	14	82	1	4	11	3		1				6		16		2	37		1	
11	15	19								6			3	2			8			
6	15	226		14	23	10		9		9		8	3	6			5	139		
25	15	30		1	4	1			1	1			2	7		1	10	2		
15	16	23			1					4				15		1	2			
10	17	121	1	10	7	2		4	1	5		1	2	17		4	67			
16	18	20			4					4			2	1	3		6			
18	19	38							4					3	8		23			
29	21	13	1		1	1		1					1	1	1		6			
26	23	1		1																
24	28	19	1		2	1			2	1		3		2	6		1			
12	30	3				1									1				1	
2	31	10								4					5		1			
3	31	0																		
4	31	0																		
19	33	1																1		
27	36	3											1		1			1		
5	41	1																1		
28	48	7							2						1			4		

**2.4 Graphical comparisons of a range of variables**  
 (raw data held in database collection of Kerry Swanson, University of Canterbury)

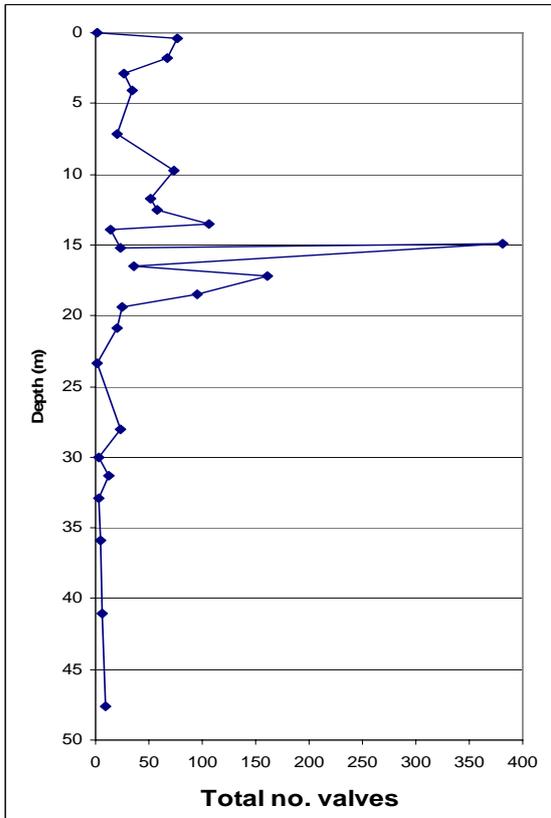


Figure 1 Total valves, raw data

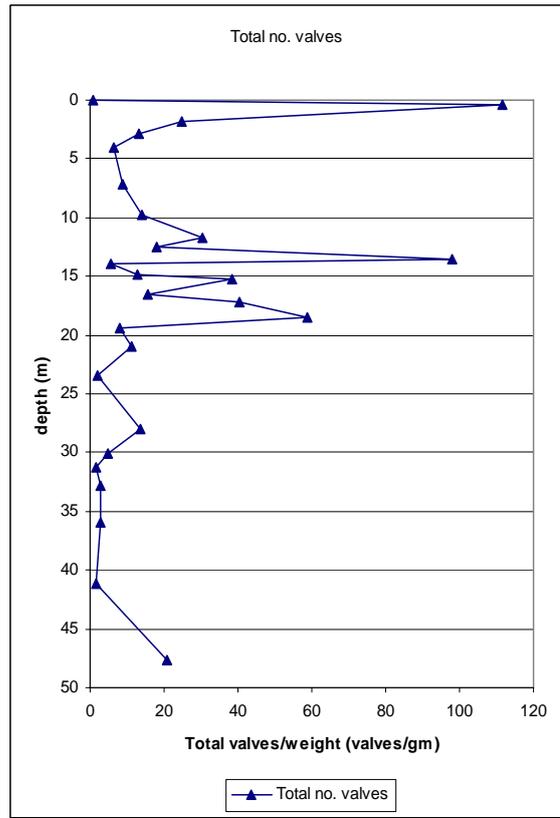


Figure 3. Total valves, normalised data.

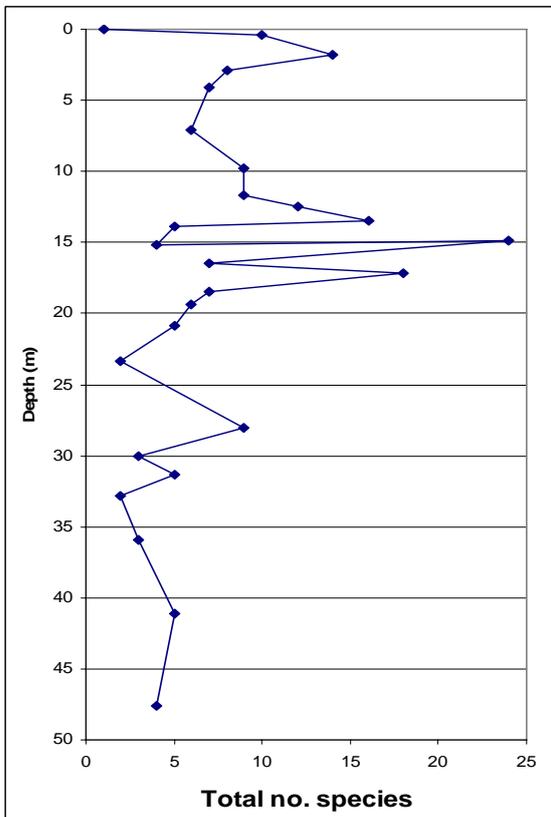


Figure 2. Total number of species, raw data

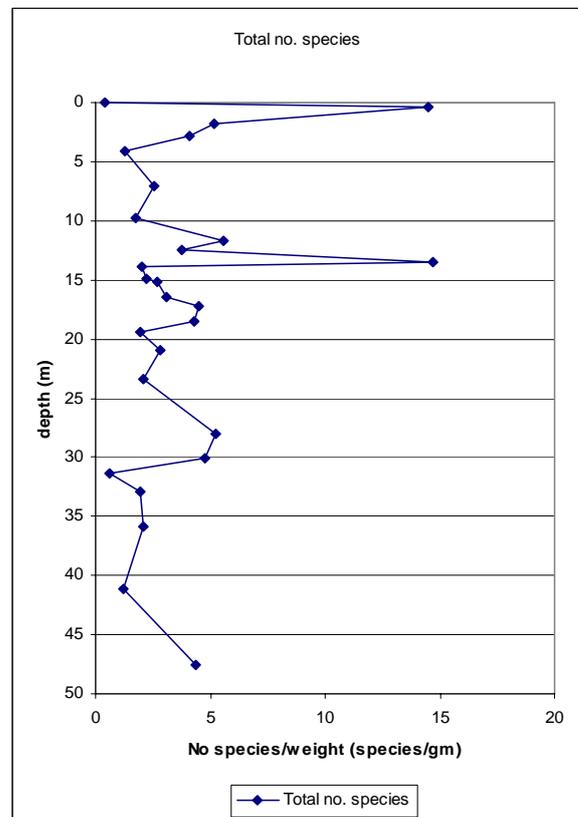
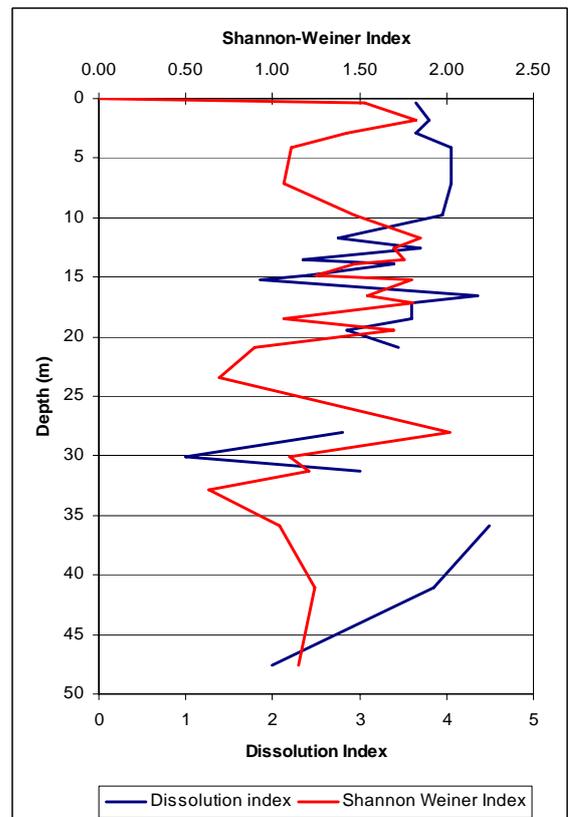
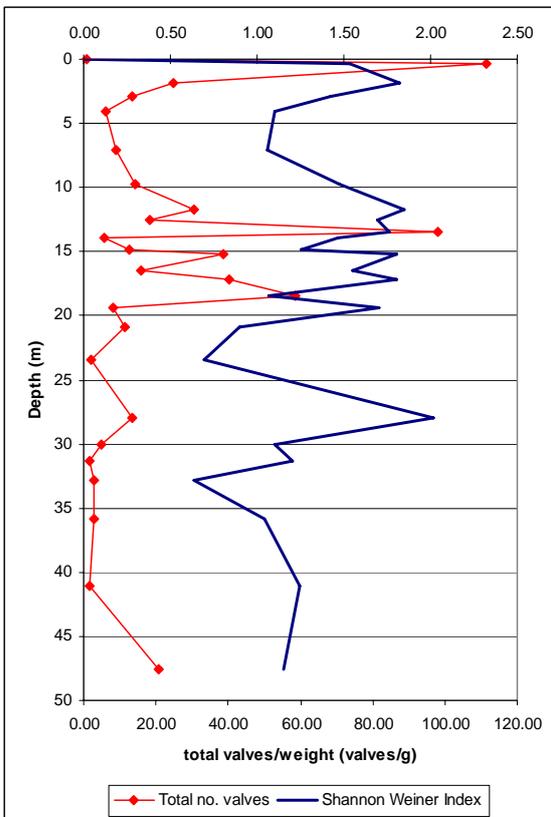
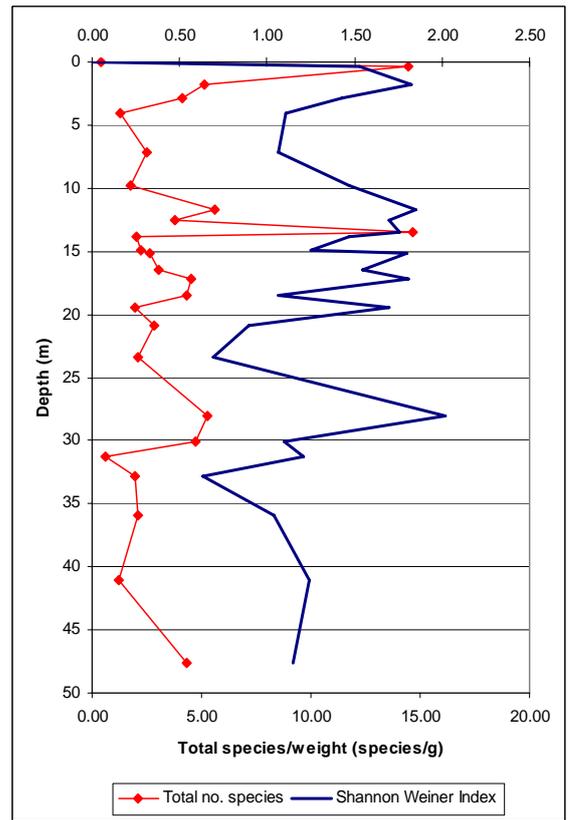
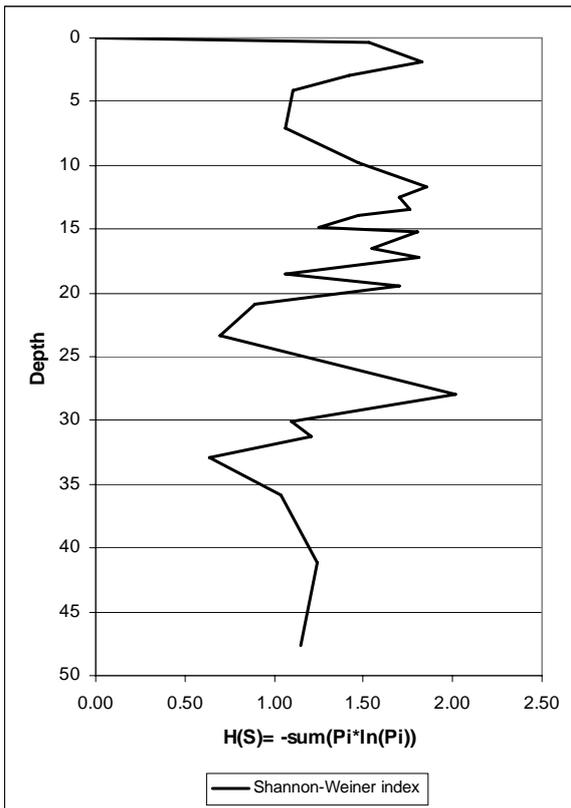


Figure 4. Total no of species, normalised data



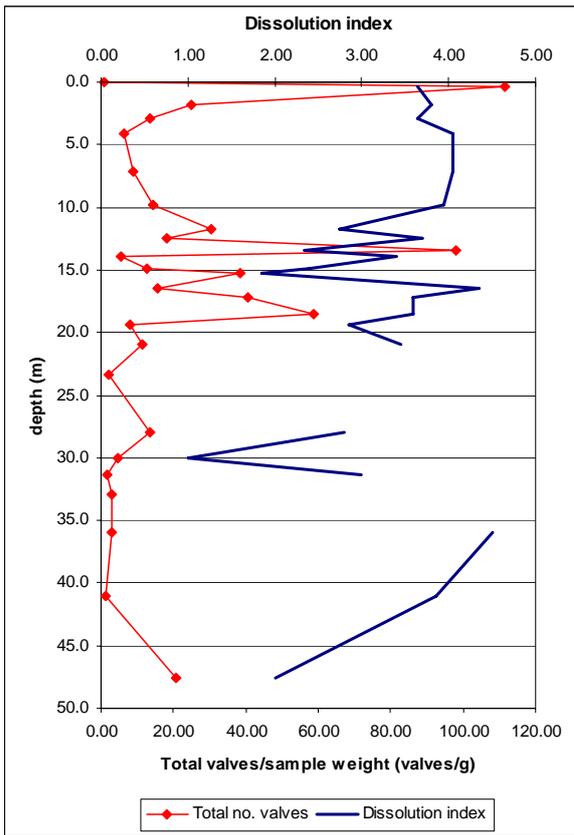


Figure 9. Dissolution and total no valves

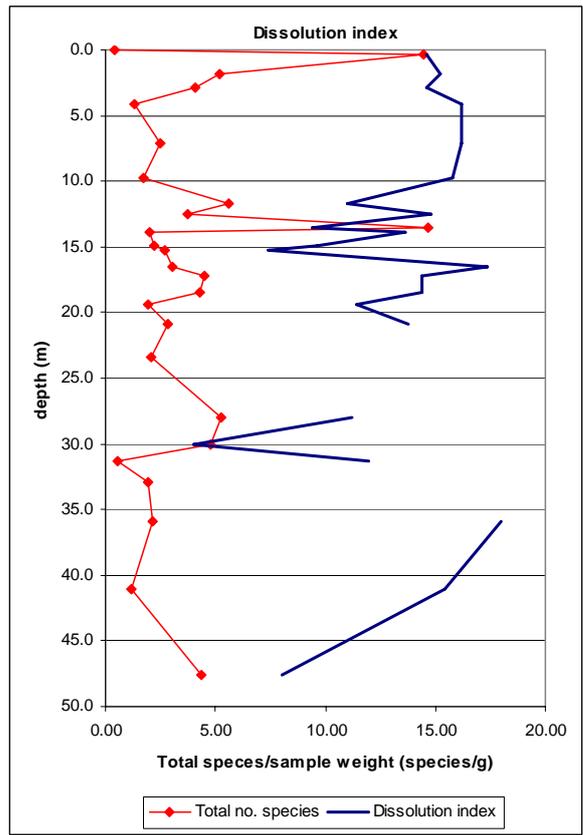


Figure 11. Dissolution vs total no. species

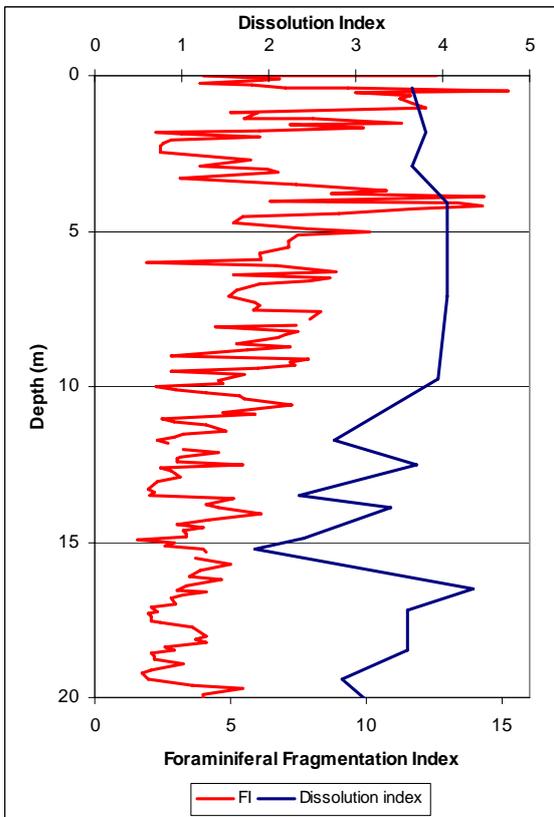


Figure 10. Dissolution vs Foraminiferal Fragmentation Index

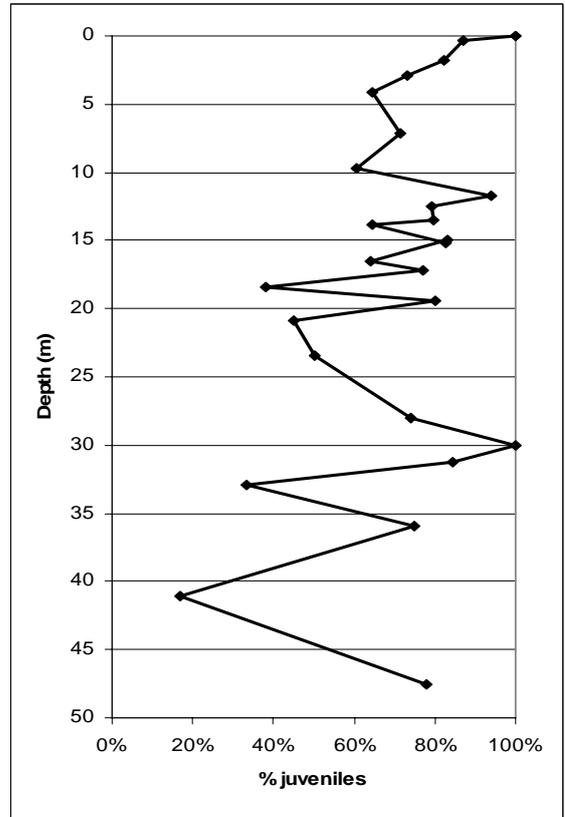


Figure 12. Percentage of juveniles downhole

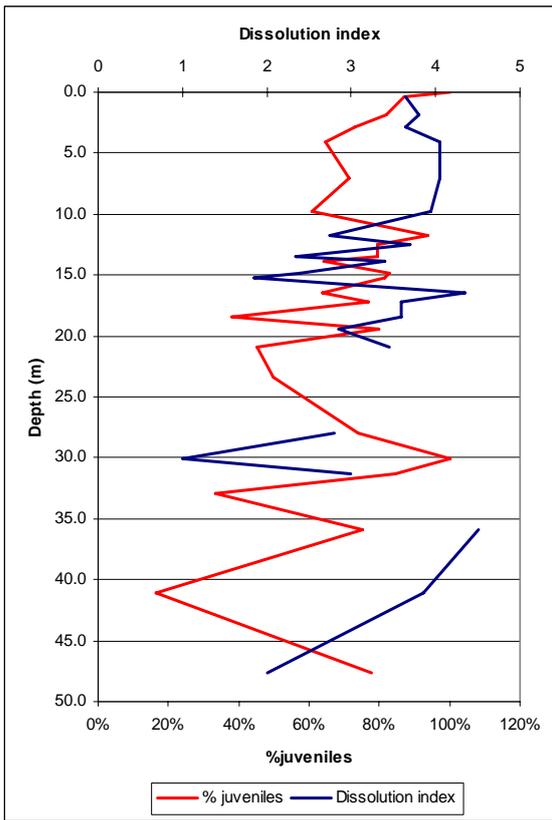


Figure 13. Dissolution and percentage of juveniles for all samples

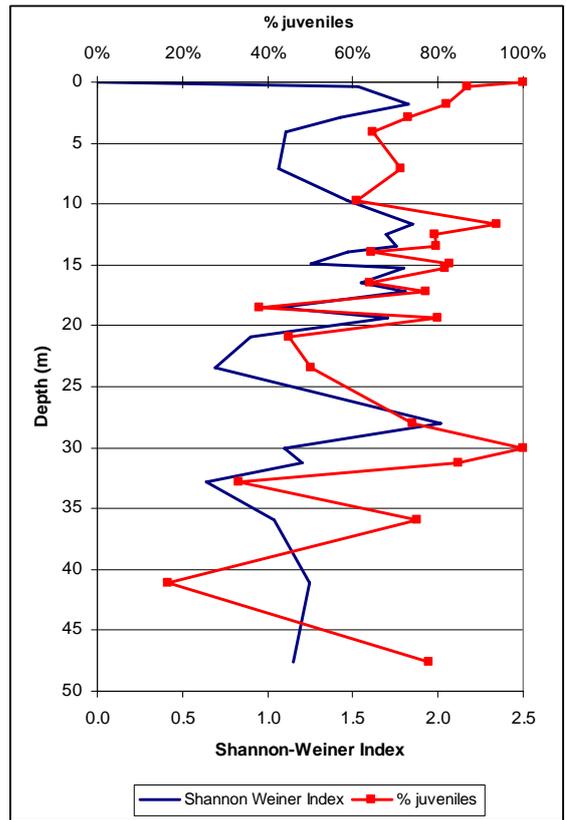


Figure 15. Shannon-Weiner Index and percentage of juveniles of juveniles

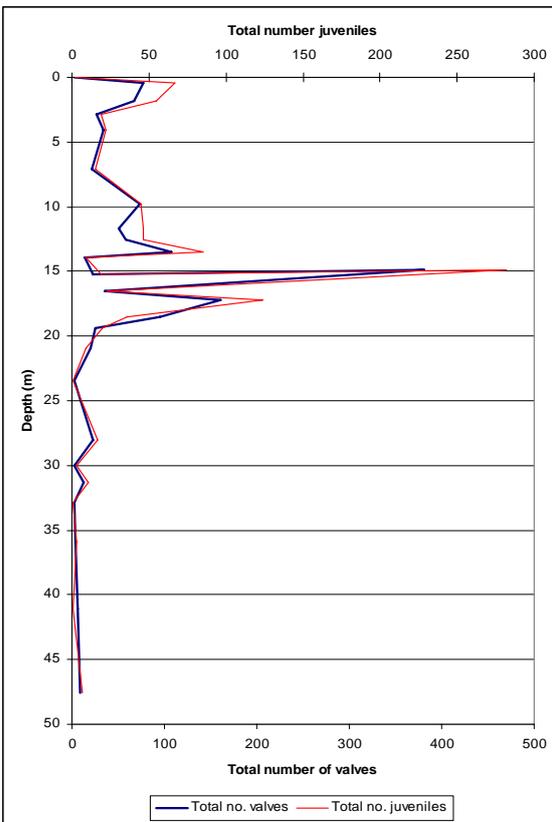


Figure 14. Total number of valves and total number of juveniles

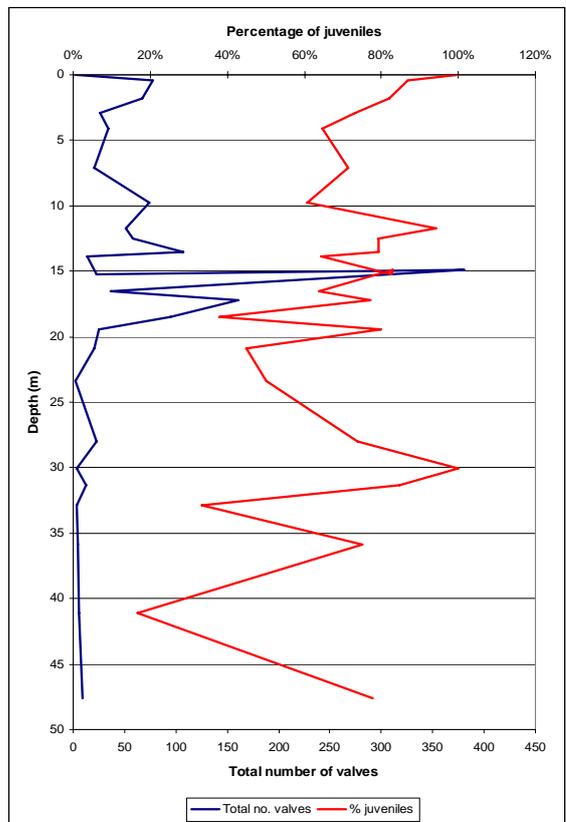


Figure 16. Total number of valves and percentage of juveniles

## 2.5 University of Canterbury Microfossil (UCF) Catalogue listing of all taxa referred to in this text

### a) Figured specimens

Specimen	UCF number
<i>Cytherella</i> sp. a	1416
<i>Cytherella</i> sp. b	1417
<i>Bythocypris</i> sp.	1418
<i>Argilloecia</i> sp.	1419
<i>Cytheropteron</i> sp. aff. <i>dibolos</i>	1420
<i>Cytheropteron</i> sp. aff. <i>garganicum</i>	1421
<i>Cytheropteron</i> sp. aff. <i>quadrata</i> (specimen 1)	1422
<i>Cytheropteron</i> sp. aff. <i>quadrata</i> (specimen 2)	1423
<i>Cytheropteron posteroreticulata</i>	1424
<i>Cytheropteron sianae</i>	1425
<i>Cytheropteron testudo</i> Sars 1869 (specimen 1)	1426
<i>Cytheropteron testudo</i> Sars 1869 (specimen 2)	1427
<i>Cytheropteron</i> sp. aff. sp. 1 Ayress 1996 (specimen 1)	1428
<i>Cytheropteron</i> sp. aff. sp. 1 Ayress 1996 (specimen 2)	1429
<i>Cytheropteron</i> sp. a	1430
<i>Cytheropteron</i> n. sp.	1431
<i>Cluthia</i> sp. a	1432
<i>Cluthia</i> sp. b	1433
<i>Taracythere</i> n.sp. (specime 1)	1434
<i>Taracythere</i> n.sp. (specimen 2)	1435
<i>Taracythere</i> n.sp. (specimen 3)	1436
<i>Legitimocythere</i> sp.	1437
<i>Apatihowella</i> sp.	1438
<i>Fallacihowella</i> sp. aff. <i>F.</i> sp. a Mazzini	1439
<i>Philoneptunus provocator</i>	1440
<i>Ambocythere</i> sp. aff. <i>recta</i> (specimen 1)	1441
<i>Ambocythere</i> sp. aff. <i>recta</i> (specimen 2)	1442
<i>Rugocythereis horrida</i> (specimen 1)	1443
<i>Rugocythereis horrida</i> (specimen 2)	1444
<i>Rugocythereis horrida</i> (specimen 3)	1445
<i>Rugocythereis horrida</i> (specimen 4)	1446
<i>Bradleya pelasgica</i> (specimen 1)	1447
<i>Bradleya pelasgica</i> (specimen 2)	1448
<i>Bradleya perforata</i>	1449
<i>Bradleya pygmaea</i>	1450
<i>Bradleya</i> sp. aff. <i>silentium</i>	1451
<i>Bradleya</i> n. sp. a	1452
<i>Poseidonamicus major</i>	1453
<i>Pseudeucythere</i> n.sp. (specimen 1)	1454
<i>Pseudeucythere</i> n.sp. (specimen 2)	1455
<i>Krithe</i> sp. a (specimen 1)	1456
<i>Krithe</i> sp. a (specimen 2)	1457
<i>Krithe</i> sp. a (specimen 1)	1458
<i>Krithe</i> sp. b (specimen 1)	1459
<i>Krithe</i> sp. b (specimen 2)	1460

Continued over

<i>Krithe</i> sp. c (specimen 1)	1461
<i>Krithe</i> sp. c (specimen 2)	1462
<i>Krithe</i> sp. c (specimen 3)	1463
<i>Krithe</i> sp. c (specimen 4)	1464
<i>Krithe</i> sp. c (specimen 5)	1465
<i>Krithe</i> sp. d (specimen 1)	1466
<i>Krithe</i> sp. d (specimen 2)	1467
<i>Parakrithe</i> sp. (specimen 1)	1468
<i>Parakrithe</i> sp. (specimen 2)	1469
<i>Xestoleberis</i> sp.	1470

---

**b) assemblage slides**

<b>Slides</b>	<b>UCF number</b>
Sample 1	1471
Sample 2	1472
Sample 5	1473
Sample 6	1474
Sample 7	1475
Sample 8	1476
Sample 9	1477
Sample 10	1478
Sample 11	1479
Sample 12	1480
Sample 13	1481
Sample 14	1482
Sample 15	1483
Sample 16	1484
Sample 17	1485
Sample 18	1486
Sample 19	1487
Sample 20	1488
Sample 21	1489
Sample 22	1490
Sample 23	1491
Sample 24	1492
Sample 25	1493
Sample 26	1494
Sample 27	1495
Sample 28	1496
Sample 29	1497

---