Palaeo-Climatic and -Biogeographical Implications of Oligocene Ostracoda from CRP-2/2A and CRP-3 Drillholes, Victoria Land Basin, Antarctica

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Abstract - A total of eighteen species of marine ostracods, in at least twelve genera, have been recovered from Early and Late Oligocene glacio-marine sediments from boreholes CRP-3 and CRP-2/2A in the Victoria Land Basin, Ross Sea, Antarctica. Faunas are sparse and generally moderately-well preserved. Previously, three species or closely related species have been recorded only from glacial settings (*Kuiperiana meridionalis*lain (Müller), *Australicythere polylyca* (Müller), *Hemicytheridea* aff. *H. kinggeorgeensis* Blaszyk), but palaeotemperatures somewhat higher than at present in the Ross Sea are suggested by the presence of *Austrocythere reticulotuberculata* Hartmann, *Cluthia* aff. *C. antiqua* Ayress & Drapala and *Cytherella?* sp 4796. *Majungaella* sp. 4471 is an enigmatic component, representing a genus previously known only from warm Cretaceous and Eocene, and relatively warm interglacial Pliocene habitats in southern Gondwana and the Antarctic Peninsula. Palaeobiogeographical considerations indicate that during Early Oligocene times, the Ross Sea area had faunal links with both Antarctic Peninsula/South America and southern Australasia. Three species present in the Early Oligocene glacial environments at Cape Roberts have survived to the Recent in the cool-cold Antarctic/Sub-Antarctic region: *Austrocythere reticulotuberculata* Hartmann, *Australicythere polylyca* (Müller), and *Kuiperiana meridionalis* (Müller).
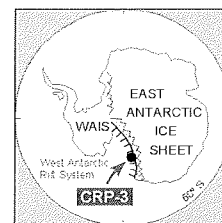
INTRODUCTION

Boreholes CRP-2/2A (77.006 °S, 163.719°E) and CRP-3 (77.0106°S, 163.6404°E) of the Cape Roberts Project penetrated approximately 1300m of Oligocene sediments in the Victoria Land Basin of the Ross Sea, East Antarctica (CRST, 2000a). The sequence ranges in age from Early Oligocene/Late Eocene to Late Oligocene, and is bounded by an upper erosion surface with overlying Early Miocene sediments, and rest unconformably upon Beacon Supergroup quartzose sandstones of Devonian age (~350 Ma) (CRST, 2000a) (Fig. 1). The possibility of a few metres of overlap between the two boreholes in Early Oligocene strata is unresolved (CRST, 2000a). The whole of the Oligocene succession is thought to have been deposited under glacial conditions, which become marine <50m above the base of the Late Eocene/Early Oligocene strata (CRST, 2000a) (Fig. 1).

Twenty-four ostracod-bearing samples were recovered from the Oligocene strata in boreholes CRP-2/2A (18 samples) and CRP-3 (6 samples) (Fig. 1). Specimens were kindly separated by Dr P. Strong, and the authors have not had access to unpicked residues. Faunas from five of the CRP-2/2A samples were described by Dingle (2000) (marked with a hash in Tab. 1), but extra CRP-2/2A material

has become available, which, together with the CRP-3 specimens, reveals important new faunal elements that have considerable biogeographical significance. On the basis of palaeontological and palaeomagnetic studies, the age of the ostracodiferous strata from CRP-3 has been determined as Early Oligocene (31-32 Ma) (CRST, 2000a), and from CRP-2 as Late Oligocene (23.7 - 24.1 Ma) (CRST, 1999a).

The oldest cold climate ostracod faunas with which comparison can be made, are from the Oligocene early glacial/interglacial sediments of the Polonez Cove Formation on King George Island (Blaszyk 1987) and the relatively warmer interglacial Pliocene sediments of Cockburn Island (Szczechura & Blaszyk 1996). Both these localities are in the Antarctic Peninsula, and have been dated at 30 Ma and 3-4.7 Ma, respectively (Dingle et al., 1997; Dingle & Lavelle, 1998; Jonkers & Kelley, 1998). Eocene pre-glacial ostracod faunas have been described from the Antarctic Peninsula (Szczechura, in press), and comparisons can be made with several studies of Late Eocene and Oligocene strata in Australia/New Zealand (McKenzie, 1974; McKenzie et al., 1991; 1993; Milhau, 1993; Majoran, 1995; 1996; Ayress, 1993; 1995; Ayress & Drapala, 1996), and southern South America (Kielbowicz, 1988; Echevarria, 1991a, b; 1995; 2000; Wood et al., 1999).
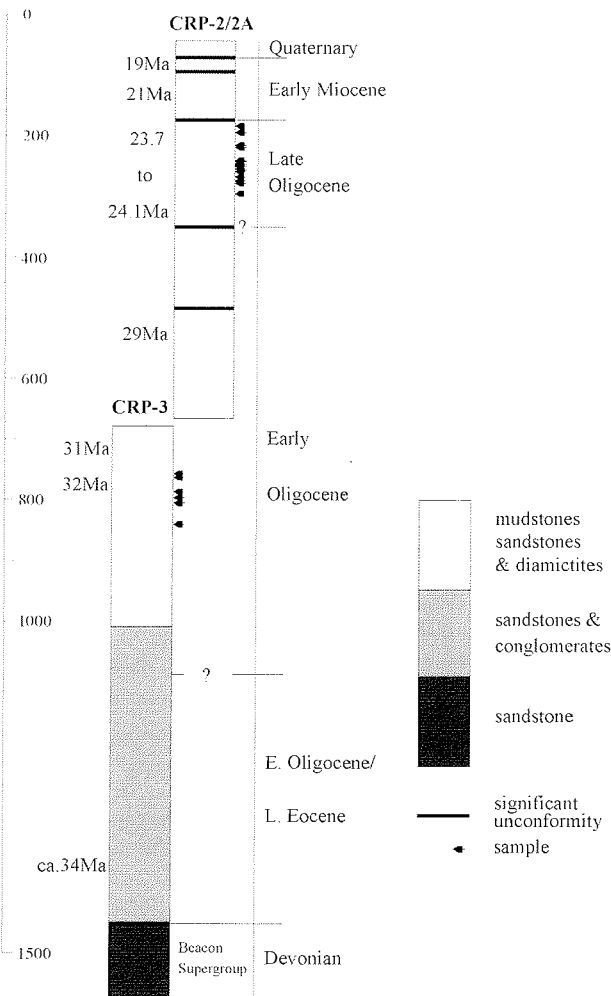
CRP-2/2A

Depth (m)	Age (Ma)	Stratigraphy
0	19Ma	Quaternary
	21Ma	Early Miocene
200	23.7 to 24.1Ma	Late Oligocene
400		
	29Ma	
600		

CRP-3

Depth (m)	Age (Ma)	Stratigraphy
	31Ma	Early Oligocene
800	32Ma	
1000		?
		E. Oligocene/ L. Eocene
ca.34Ma		
1500		Beacon Supergroup — Devonian

Lithology key: mudstones sandstones & diamictites; sandstones & conglomerates; sandstone; significant unconformity; sample

Fig. 1 - Distribution of ostracod-bearing samples in the Early and Late Oligocene strata of boreholes CRP-2/2A and CRP-3, Ross Sea, Antarctica. Depths are expressed in metres below the top of the Early Miocene strata in borehole CRP-1 (not shown). All post-Devonian sequences were deposited under glacial conditions. Details of lithology, stratigraphy and ages (left-hand side, Ma) are after CRST (1999a,b, 2000a,b). Diagram is modified from CRST (2000a, Fig. 7.9).

However, in these areas, deposition was never under glacial conditions, and the recognition of any "warm" to "cool/cold" faunal transition in continental shelf environments has been subjective. For further comparison, there have been a relatively large number of publications describing the Quaternary Antarctic and sub-Antarctic deep and shallow-water faunas, as well as faunas from southern Argentina (Brady, 1880; Müller, 1908; Chapman, 1916; 1919; Benson, 1964; Neale, 1967; Hartmann, 1988; 1989; 1997; Briggs, 1978; Whatley et al., 1988; 1996; 1997; 1998).

Here, we document the Oligocene ostracods from the Ross Sea area and discuss palaeo-climatic and biogeographical implications for southern high latitude faunas during the development of the Antarctic cryosphere.

OSTRACOD FAUNAS

A total of 18 ostracod species in at least 12 genera were isolated from the two Oligocene sequences of the Cape Roberts boreholes (Tab. 1). The faunas are sparse (maximum of 14 valves/sample, average 6/sample in CRP-2/2A, 5/sample in CRP-3) and generally only moderately well-preserved, although some specimens are well-preserved. Carapaces predominate in the upper part of the Late Oligocene of CRP-2/2A, and throughout the Early Oligocene of CRP-3. Because of the low numbers involved, statistical parameters must be treated with caution, and faunal characters will be assigned to large biostratigraphical units. All named and important species are illustrated in figures 2, 3 and 4. Reference should be made to the Taxonomic Notes section for details of individual taxa.

The Early Oligocene fauna (CRP-3) contains 11 species in 8 genera, and the Late Oligocene fauna (CRP-2/2A) contains 13 species in 9 genera. At the specific level, the Simpson coefficient of similarity is 33% between the two faunas, and 40% at the generic level. The Early Oligocene fauna is dominated by *Munseyella* sp. 4781 (31%) and *Hemicytheridea* aff. *H. kinggeorgeensis* Blaszyk (14%), while the Late Oligocene fauna is dominated by *Majungaella* sp.

Tab. 1 - Ostracod species in Oligocene sediments of CRP-2/2A and CRP-3. Depths are expressed in metres below sea-floor and refer to individual boreholes.

Species	Reference	depth, mbsf	137.57	157.16	171.04	175.2	197.69	198.54	199.10	202.59	203.98	207.05	209.72	212.18	215.60	215.87	223.46	230.25	232.39	253.21	No	%	82.89	87.15	106.08	114.23	121.41	160.37	No	%
	Reference	S			#									#		#					No	%							No	%
Ameghinocythere sp. 4607	(Echevarria 1991b), (Dingle 2000)	4607				1	2														3	7								
Australicythere polylyca	(Müller 1908)	4801															2			2	5								
Austrocythere reticulotuberculata	Hartmann 1989	4782			C															2	5	1					1	3	
Cluthia aff. C. antiqua	Ayress & Drapala 1996	4784					2j												2	5									
Copytus aff. C. maluniani	Echevarria 1987	4631											2					2	5									
Copytus ? sp. 4804		4804						2C		C	1								7	17									
Cytherella ? sp. 4796		4796																			C				2	7	
Hemicytheridea aff. H. kinggeorgeensis	Blaszyk 1987	4617												2					2	5				2C		4	14	
Kuiperiana meridionalis	(Müller 1908)	4809	1																1	2				1		1	3	
Majungaella sp. 4471		4771				1	2j	1			1	1j	Cj	2j	1j	11	26	C					C	2	7	
Microcythere? sp. 4626	(Dingle 2000)	4626																C				2	7	
Munseyella? sp. 4781		4781	jC							1					2	5	12	1,2C	2C				9	31	
Orionina ? cf. sp	Echevarria 1988	4632										1				1	2								
Indet		4791																C			2	7	
Indet		4792																C			2	7	
Indet		4790																C			2	7	
Indet pyritised cast						C													2	5								
Indet		4630			2													2	5								
Total valves			2	1	2	2	3	8	1	5	1	1	2	1	3	1	2	2	3	2	42		1	2	7	14	1	4	29	

Notes: C= carapace; j= juvenile, #= described in Dingle (2000); $= informal SEM/species number.

Tab. 2 - Percentages at specific/generic level of total ostracod faunas in Cape Roberts boreholes CRP-2/2A and CRP-3.

	E Miocene (Dingle 2000)	L Oligocene	E Oligocene
Majungaella sp. 4471	0	26	7
Copytus (3 spp)	27	22	7
Munseyella sp. 4781	0	12	31
Indet (5 spp)	0	10	21
Ameghinocythere sp 4607 (Dingle)	23	7	0
Cluthia aff. C. antiqua A&D	0	5	0
Hemicytheridea aff. H. kinggeorgeensis Blaszyk	0	5	14
Australicythere polylyca (Muller)	0	5	0
Austrocythere reticulotuberculata Hartmann	0	5	3
Kuiperiana meridionalis (Müller)	0	2	3
Orionina ? sp 4632	0	2	0
Microcythere? sp. 4626 (Dingle)	40	0	7
Cytherella ? sp 4791	0	0	7
Nodoconcha aff. N. minuta Hartmann	13	0	0

Notes: A&D= Ayress & Drapala 1996.

4471 (26%), Copytus spp (22%), and Munseyella sp. 4781 (12%) (Tab. 2). Both faunas contain Kuiperiana meridionalis (Müller). Ameghinocythere sp. 4607, Australicythere polylyca (Müller) and Orionina? sp. 4632 occur only in the Late Oligocene fauna, while Microcythere? sp. 4626, and Cytherella? sp. 4796 occur only in the Early Oligocene fauna. There are five single, poorly-preserved specimens which cannot be allocated to any taxonomic category, and these constitute 21% of the Early Oligocene fauna. Several of these occurrences require further comment.

A noteworthy aspect of the Cape Roberts Oligocene faunas is the presence of the progonocytherid ostracod Majungaella. Previously, all published records of this taxon have been either from warm water environments in the Maastrichtian of South America (see Ballent et al., 1998), and the Campanian of James Ross Island (Fauth & Luther, 1999) and pre-glacial Eocene of Seymour Island (Szczechura, in press), both in the Antarctic Peninsula, or the cooler, but still relatively warm inter-glacial Pliocene of Cockburn Island, also in the Antarctic Peninsula (recorded as ?Loxocythere sp. by Szczechura & Blaszyk, 1996). (These palaeoclimatic assessments are based on Dingle & Lavelle (1998, 2000) and Dingle et al. (1998)). The present record from the high Antarctic is, therefore, the first of this originally Tethyan taxon from a glacial environment, and greatly extends the spatial distribution and climatic preferences of the genus. The species found at Cape Roberts is similar to both M. australis Rossi de Garcia & Proserpio and M. antarctica Szczechura (in press), but shows some consistent differences in ornamentation (see Taxonomic Notes section).

A further potentially significant component in the Cape Roberts Oligocene fauna is the record of a species which we refer to Cluthia aff. C. antiqua Ayress & Drapala in the Late Oligocene at Cape Roberts. C. antiqua was originally described from the

Late Eocene of New Zealand (Ayress & Drapala 1996). Cluthia is generally regarded as a cool-cold water taxon in the Tertiary and Quaternary in both hemispheres (Neale, 1973; Ayress & Drapala, 1996). Neither Kielbowicz (1988) nor Echevarria (1991a, b, 1995) recorded the genus from the Palaeogene of southern South America, and it has so far not been detected in the Recent faunas of Antarctica (Hartmann, 1997). (The report by Whatley et al. 1998 comes from north of the Polar Front, in the Scotia Sea).

Copytus is one of the two dominant taxa in the Late Oligocene fauna, where two species occur (C. aff. C malumiani Echevarria and C. sp. 4804). The latter is also found in the Early Oligocene. Both species are close to C. malumiani, which ranges Late Oligocene-Early Miocene in southern Argentina, and are probably distinct from Blaszyk's (1987) species (C. ezcurraensis) from the Early Oligocene of the South Shetland Islands in the northern Antarctic Peninsula. These records indicate that the genus was represented by at least three species during the early development of the Antarctic cryosphere. Two species of Copytus are currently extant in the region (Hartmann, 1997).

Several species, which had previously been recorded from younger strata in Antarctica, now have their local stratigraphic ranges extended (Fig. 5). Austrocythere reticulotuberculata Hartmann, which was previously recorded only from the Quaternary (Hartmann, 1997), is now known to range Early Oligocene to Recent. Austrocythere is well-represented in the Miocene of New Zealand (M.A. Ayress 2001 pers. comm.), whence Milhau (1993) has recorded a species similar to A. reticulotuberculata, and we believe that the Oligocene taxon Cluthia novaezealandiae (Ayress & Drapala, 1996) also belongs in this genus. Similarly, Australileberis polylyca (Müller) extends its range from the Recent
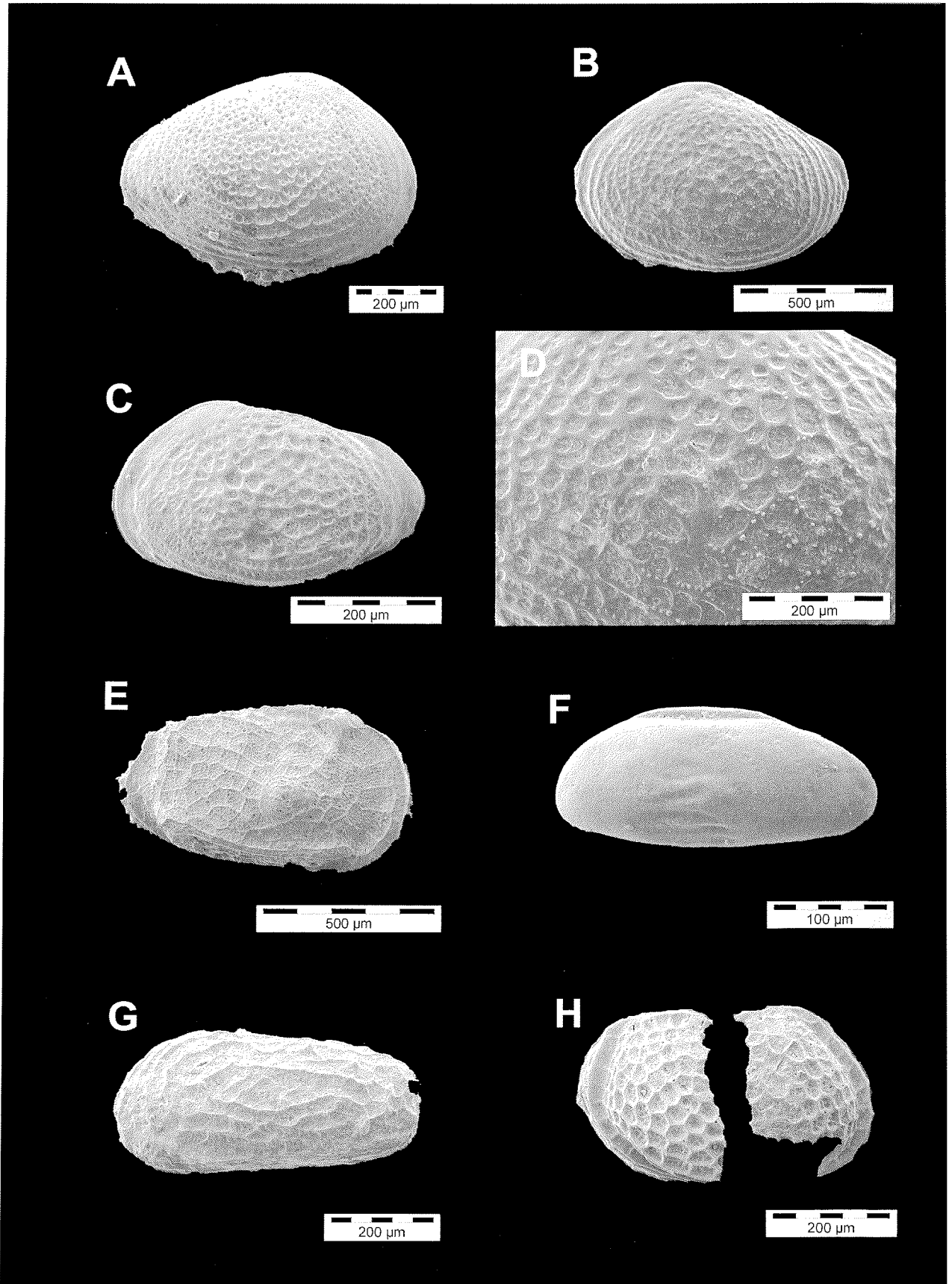
Fig. 2 - Early and Late Oligocene Ostracoda from boreholes CRP-2/2A and CRP-3, Ross Sea, Antarctica. RV = right valve, LV = left valve. **A**. *Majungaella* sp. 4471, RV, CRP-2/2A, Late Oligocene, 202.59m. **B, D**. *Majungaella* sp. 4471, LV, CRP-3, Early Oligocene, 160.37m. **C**. *Majungaella* sp. 4471, LV juvenile, CRP-2/2A, Late Oligocene, 199.1m. **E**. *Australicythere polylyca* (M₋ller 1908), RV, CRP-2/2A, Late Oligocene, 253.21m. **F**. *Microcythere?* sp. 4626 (Dingle 2000), RV, CRP-3, Early Oligocene, 87.15m. **G**. *Hemicytheridea* aff. *H. kinggeorgeensis* Blaszyk 1987, LV, CRP-3, Early Oligocene, 114.23m. **H**. *Kuiperiana meridionalis* (M₋ller 1908), RV, CRP-2/2A, Late Oligocene, 157.16m.
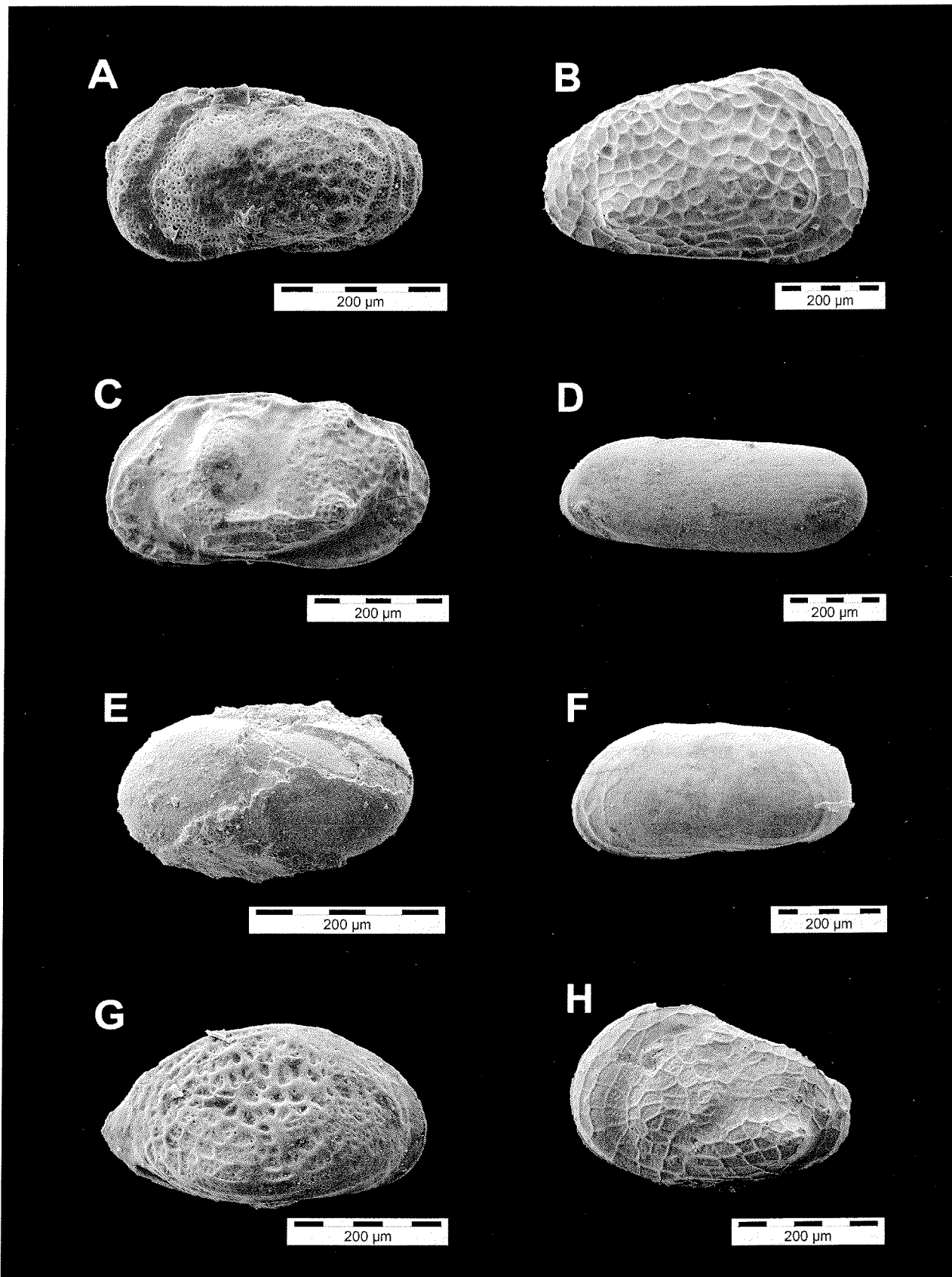
Fig. 3 - Early and Late Oligocene Ostracoda from boreholes CRP-2/2A and CRP-3, Ross Sea, Antarctica. RV = right valve, LV = left valve. **A**. *Cluthia* aff. *C. antiqua* Ayress & Drapala 1996, LV, CRP-2/2A, Late Oligocene, 198.54m. **B**. *Munseyella?* sp. 4781, RV, CRP-2/2A, Late Oligocene, 232.39m. **C**. *Austrocythere reticulotuberculata*lain Hartmann 1989, LV, CRP-2/2A, Late Oligocene, 197.69m. **D**. *Copytus?* sp. 4804, LV, CRP-2/2A, Late Oligocene, 203.98m. **E**. *Cytherella?* sp. 4796, RV, CRP-3, Early Oligocene, 106.08m. **F**. *Ameghinocythere* sp. 4607 (Dingle 2000) (= *Cushmanidea* sp. Echevarria 1991b), LV, CRP-2/2A, Late Oligocene, 197.69m. **G**. *Majungaella* sp. 4471, RV juvenile, CRP-2/2A, Late Oligocene, 202.59m. **H**. *Munseyella?* sp. 4781, LV juvenile, CRP-2/2A, Late Oligocene, 207.05m.
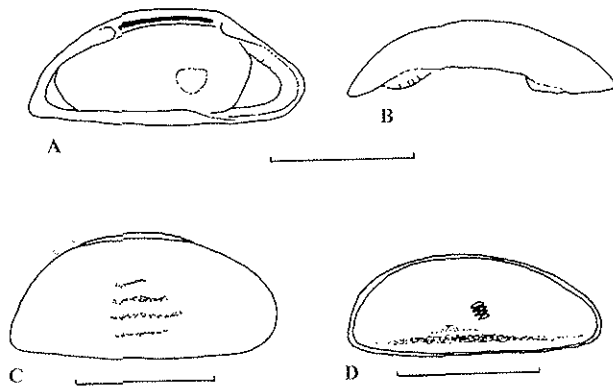
Fig. 4 - **A** & **B**. *Microcythere?* sp. 4626, LV, CRP2/2A, Early Miocene, 64.67m. Aain . Interior view, circular feature is muscle scar area. **B**. Same specimen, dorsal view. **C**. *Microcythere?* sp. 4626, carapace, CRP2A, Early Miocene, 71.13m. View of RV showing four feint longitudinal ridges and LV overlap along dorsal margin. **D**. *Microcythere frigida* Müller 1908, carapace, CRP1, Quaternary, 32.37m. View of RV showing LV overlap around entire margin, the impression of muscle scars on the exterior surface, and the sharp vento-lateral keel. Scale bars are 200 microns.

to the Late Oligocene. There have been numerous records of the species, both living and in Quaternary sediments, from around Antarctica (Müller, 1908; Chapman, 1916; 1919; Benson, 1964; Neale, 1967; Hartmann, 1997; Whatley et al., 1998; Dingle, 2000), but none north of 60°S. The present record indicates that *A. polylyca* has been present for most of the glacial history of the continent. *Microcythere?* sp. 4626 has a range Early Oligocene to Early Miocene at Cape Roberts. It is the dominant taxon in the Early Miocene of CRP-2/2A (Dingle, 2000), and its absence from the Late Oligocene is presumably a sampling artifact. *Hemicytheridea kinggeorgeensis* Blaszyk was originally reported from the Early Oligocene of the Antarctic Peninsula (Blaszyk, 1987), and our new data show that *Hemicytheridea* aff. *H. kinggeorgeensis* was extant in the Ross Sea area for at least most of Oligocene time. *Ameghinocythere* sp. 4607 was recorded from the Early Miocene of CRP-2/2A by Dingle (2000) (as *Munseyella* sp. 4607), and it has now been found at two levels in the Late Oligocene. The one species of *Kuiperiana* presently extant in Antarctica (*K. meridionalis* (Müller), has been reported from widely separated localities south of ~65°S (Gauss Station, Müller 1908 and Weddell Sea, Neale 1967), and from the southern tip of Chile (Whatley et al., 1996). Curiously, *K. meridionalis* (Müller) was not reported by Hartmann (1997) in his extensive surveys in the Antarctic Peninsula. We find two specimens of *K. meridionalis* (M,ller) in the Early and Late Oligocene at Cape Roberts, and a further species, which is possibly conspecific with the Cape Roberts material, has been illustrated by Echevarria (1991a) as *Palmoconcha?* sp. from the Late Oligocene of Argentina. Consequently, the genus, possibly represented by the same species, has a long

history in Antarctic and sub-Antarctic areas, since at least early glacial times.

Finally, there are several species which are represented by single specimens, whose identification is uncertain. *Cytherella* is an extant, cosmopolitan genus that has a long geological history. One carapace of *C?* sp. 4796 occurs in the Early Oligocene, and possibly represents the youngest record of the taxon on the continent. The genus is known from glaciated areas off southern Chile (Whatley et al., 1996), but although *Cytherella* was present as far south as the northern Antarctic Peninsula (James Ross Island) in late Campanian time (Fauth & Luther, 1999), it was found neither in the Early Oligocene of the South Shetland Islands (Blaszyk, 1987), nor in the Pliocene of the northern Antarctic Peninsula (Szczechura & Blaszyk, 1996). *Orionina?* sp 4672 was reported by Dingle (2000), and was compared to *Orionina?* sp of Echevarria (1988) from the Pliocene of Argentina at 41°S. No additional specimens have been recovered, and the status of neither specimen can be resolved. Five poorly preserved specimens are placed in an Indeterminate category: Indet. sp. 4790, Indet. sp. 4792, Indet. sp. 4796, Indet sp. 4630 and Indet sp.. Indet. sp. 4790 has the outline of a hemicytherurid, but no details of ornament or internal features can be observed.

DISCUSSION

OLIGOCENE-MIOCENE TRANSITION AT CAPE ROBERTS

Oceanic oxygen isotope data suggest that Antarctica remained glaciated during the Oligocene-Miocene transition (Zachos et al., 1997), and all the evidence from the Cape Roberts boreholes supports this (CRST 2000a). Ostracod specific and generic similarity coefficients are only 20% and 27%, respectively, between the 20 species and 11 genera recorded from the Early Miocene and Late Oligocene faunas in the CRP-2/2A borehole. At face value, these figures suggest a faunal discontinuity over the ~3 Ma interval between the ostracod-bearing levels, but the difference is likely to be more apparent than real given the paucity of the faunas. If we consider figure 5 and table 2, then it is clear that the three dominant taxa in the Early Miocene fauna (*Microcythere?* sp. 4626, *Copytus* spp, and *Ameghinocythere* sp. 4607) are either relatively well-represented in the Late Oligocene, or in the case of *Microcythere?* sp. 4626, present in the Early Oligocene, and probably missing from the Late Oligocene because of sampling factors. Similarly, *Australicythere polylyca* (Müller), *Majungaella* ssp, *Austrocythere reticulotuberculata* in Hartmann and *Kuiperiana meridionalis* (Müller), all of which occur in the Late Oligocene of CRP-3, are also known from strata in Antarctica younger than Early Miocene, their absence in the latter being
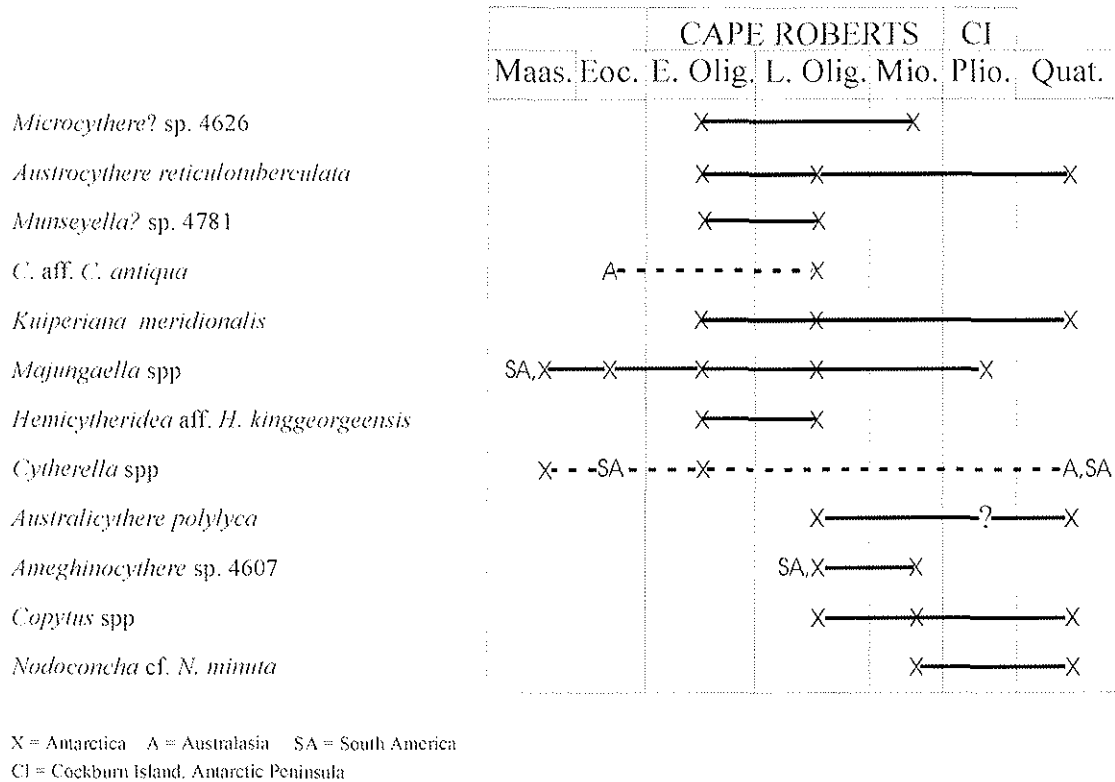
	CAPE ROBERTS CI						
	Maas.	Eoc.	E. Olig.	L. Olig.	Mio.	Plio.	Quat.
Microcythere? sp. 4626			X————————X				
Austrocythere reticulotuberculata			X————X————————X				
Munseyella? sp. 4781			X————X				
C. aff. *C. antiqua*		A- - - - - - - - - X					
Kuiperiana meridionalis			X————X————————X				
Majungaella spp	SA,X————X————————X————X————————X						
Hemicytheridea aff. *H. kinggeorgeensis*			X————X				
Cytherella spp	X- - -SA- - - -X- - - - - - - - - - - - - - - -A,SA						
Australicythere polylyca			X————?————X				
Ameghinocythere sp. 4607			SA,X————X				
Copytus spp			X————X————X				
Nodoconcha cf. *N. minuta*				X————X			

X = Antarctica   A = Australasia   SA = South America
CI = Cockburn Island, Antarctic Peninsula

Fig. 5 - Ranges of key ostracod taxa in Cretaceous to Quaternary strata in Cape Roberts boreholes and adjacent areas. Dashed lines are lineages outside Antarctica. Data from: Ayress & Drapala (1996), Ayress & Swanson (1991), Ballent et al (1998), Blaszyk (1987), Dingle (2000), Echevarria (1991b), Fauth & Luther (1999), Hartmann (1997), Neale (1967), Szczechura & Blaszyk (1996), Whatley et al (1996), Szczechura (in press).

probably also due to inadequate sampling and/or preservation.

Two faunal changes may be real. *Hemicytheridea* aff. *H. kinggeorgeensis* Blaszyk occurs in the Early and Late Oligocene, but not in the Early Miocene, or in any other younger Antarctic strata, and it may have become extinct close to the Oligocene-Miocene boundary. *Nodoconcha* makes its earliest appearance in the Early Miocene of CRP-2 (Dingle 2000). It is a distinctive endemic Antarctic taxon which occurs in the Quaternary of the Ross Sea, Antarctic Peninsula and Prydz Bay areas (Briggs, 1978; Hartmann, 1997; M.A. Ayress pers. comm. 2001). However, *Nodoconcha minuta* Hartmann 1989 has not been found living in the high Antarctic (south of ~75°S). Although its presence indicates cold, glacial conditions, all modern records from the Antarctic Peninsula and Prydz Bay (173m and 538m) (M. A. Ayress pers. comm. 2001) also suggest that it prefers outer shelf depths (see Dingle 2000), and its presence in the Early Miocene possibly indicates a relative deepening over the Oligocene-Miocene boundary.

The overall impression is, therefore, of no significant ostracod faunal changes across the Oligocene-Miocene boundary at the Cape Roberts site, which in turn suggests that there were no major palaeoenvironmental changes at this level. This accords with other data from Cape Roberts, which is

summarised as glaciomarine, open coast/shelf environments subject to cyclical glacial advances for the top of CRP-3 and CRP-2/2A (*i.e.* throughout the period ~32 - 19 Ma) (CRST, 2000a). The main palaeoenvironmental change across the Oligocene - Miocene boundary indicated by sedimentological evidence was a decrease in melt-water runoff (CRST, 1999a, p. 161).

PALAEOBIOGEOGRAPHICAL IMPLICATIONS OF THE CAPE ROBERTS OLIGOCENE OSTRACOD FAUNAS

Two taxa in particular from the Oligocene fauna at Cape Roberts have considerable biogeographical significance. The record of the progonocytherid genus *Majungaella* shows that during its evolution, it adapted from living in warm shallow water at low latitudes on the southern edge of the Tethyan sea, to high latitude glacial shelf habitats in Antarctica. It first appeared in the middle Jurassic of Madagascar/East Africa (Grekoff, 1963; Bate, 1972), and by late Jurassic-early Cretaceous time, became widely distributed across the seaways of the South Gondwana ostracod province in southern Argentina, South Africa, India and Australia (Dingle, 1988; Whatley & Ballent, 1996; Ballent & Whatley, 2000). During this period of its greatest geographical extent,

Tab. 3 - Percentages of important (>10%) ostracod families in Cenozoic southern high latitude faunas.

	S. AUSTRALIA					S. ARGENTINA				ANTARCTICA				
										A. PENINSULA			W.S.	C. ROBERTS
Palaeo-latitude	61	59	55	52	45	56	50	54	41	64	63	64	75	77
	L.Pal/E.Eoc	L.Eoc	E.Olig	L.Olig	M.Mio	M.Eoc	L.Olig	L.Ol/E.Mio	Plio	E.Eoc	E.Olig	Plio	Recent	E.+L.Olig
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Trachyleberididae	28	25	8	21	8	22	6	14	25	25	17	8	9	0
Pectocytheridae	22	2	2	1	3	3	1	13	3	15	0	0	0	28
Cytheruridae	14	8	11	3	15	0	1	0	21	0	36	13	7	0
Cytherellidae	10	23	9	13	16	4	3	4	8	0	0	0	0	3
Cytheridae	5	1	5	1	1	0	7	0	0	0	22	0	0	10
Pontocyprididae	2	15	2	1	18	0	0	0	0	15	0	0	0	0
Xestoleberidae	2	1	8	1	6	0	1	0	0	0	4	0	12	0
Bairdiidae	1	2	34	3	8	8	0	1	0	0	0	0	1	0
Thaerocytheridae	1	1	4	22	0	0	0	0	0	12	0	0	1	0
Leptocytheridae	1	1	0	0	0	0	0	2	4	0	0	6	0	8
Hemicytheridae	1	0	7	28	0	48	70	48	24	10	9	56	51	3
Neocytherideidae	1	0	0	0	0	0	1	4	1	0	5	2	1	18
Krithiidae	0	11	1	1	13	3	0	0	0	0	0	0	0	0
Loxoconchidae	0	1	4	2	1	0	1	0	13	7	3	10	9	5
Progonocytheridae	0	0	0	0	0	0	0	0	0	8	0	5	0	21
Total %	88	91	95	97	89	88	91	86	99	92	96	100	91	96
water temperatures	? warm	?cool ?warm	cool	cool	warm/ trop	temp/ warm	temp	temp/ cool	temp/ warm	warm	cool/ cold	cool	cold	cold

Notes: 1= Neil (1997); 2,3= Majoran (1996), 4= McKenzie et al (1991); 5= Whatley & Downing (1983); 6= Echevarria (1990); 7= Echevarria (1991b); 8= Keilbowicz (1988); 9= Echevarria (1998); 10= Szczechura (in press), 11= Blaszyk (1987); 12= Szczechura & Blaszyk (1996); 13= Neale (1967); 14= this paper; W.S.= Weddell Sea; Palaeolatitudes from Lawver et al (1992).

Majungaella probably inhabited generally warm-temperate waters (see Price, 1999). By Campanian-Maastrichtian time, the geographical distribution of *Majungaella* had shrunk to mid-southern Argentina (Ballent et al., 1998) and the northern tip of the Antarctic Peninsula (Fauth & Luther, 1999), between which there was still a shallow water connection (Lawver et al., 1992). Two species are known from this area (see Taxonomic Notes): *M. australis* (Bertels, 1975) and *M. australis* Rossi de Garcia & Proserpio (1980), where palaeoenvironmental data from the Antarctic Peninsula indicate a relatively warm, humid Campanian - early Maastrichtian climate (Dingle & Lavelle, 2000). In immediately pre-glacial time, Szczechura (in press) has recorded a further species (*M. antarctica* Szczechura) from the lower La Meseta Formation (Valle de Las Focas Member - see Dingle et al., 1998) of Seymour Island in the northern Antarctic Peninsula. Dingle & Lavelle (1998, 2000) and Dingle et al. (1998) have considered all available palaeontological and geochemical evidence from these strata, as well as obtaining Sr isotope dates from overlying strata, and show that the lower La Meseta sediments are >34 Ma and were deposited in warm shelf seas. Our new record of *Majungaella* sp. 4471 is, therefore, the earliest evidence that the genus had acclimatised to glacial conditions by Early Oligocene time, and had extended its distribution to high Antarctic latitudes in the Ross Sea area. The genus survived at least until the Pliocene interglacial period in the northern Antarctic Peninsula, where the Cockburn Island Formation (with *Majungaella* sp = ?*Loxocythere* sp Szczechura & Blaszyk, 1996) was

probably deposited in an ice-free environment in water temperatures no lower that those now occurring just north of the Antarctic Convergence at Cape Horn (~56°S, mean annual temperature range of ~4-7°C) (Jonkers, 1998). After Late Eocene time, the Antarctic populations of *Majungaella* would have been isolated from South America by relatively deep water in the Drake Passage (Lawver et al., 1992), but the genus survived for a further 30 Ma under glacial/interglacial conditions. *Majungaella* may be an example of a taxon for which high latitude cold climates became a *refugia*, but for which the Pleistocene climate of Antarctica was too severe.

Cluthia is a further genus upon whose biogeographical development the new records may throw light, with the occurrence of *Cluthia* aff. *C. antiqua* Ayress & Drapala in the Late Oligocene at Cape Roberts, and *Austrocythere*, which is clearly a closely related genus, in the Early Oligocene at Cape Roberts (*A. reticulotuberculata* Hartmann), and possibly in the Late Oligocene of New Zealand (as *A. novaezealandiae* (Ayress & Drapala). Ayress & Drapala (1996) questioned whether low temperature is the major control on *Cluthia*'s distribution because they believed that it was absent from Antarctica. Consequently, they suggested this might have been due to competition from well-established and better-adapted taxa. The earliest known species are of Late Eocene age from South Australia and Victoria (*Cluthia* sp. McKenzie et al., 1993), and from New Zealand (*C. antiqua* Ayress & Drapala, 1996). At this time, the Ross Sea area was linked at intermediate water depths (<2 km) to southern Australia via the

Tasman shelf and the South Tasman Ridge (Lawver et al. 1992). As observed by Ayress & Drapala (1996), the simultaneous occurrence of two Late Eocene species indicates that the origin of *Cluthia*ain pre-dates these records, and the Cape Roberts record opens the possibility that genus evolved in cool, pre-glacial, Middle Eocene environments of Antarctica. Later, rapid deterioration of the climate may have been a factor in the northward spread of certain demes across the Tasman connection to Australasia in early Late Eocene time.

OSTRACOD RECORD IN THE SOUTHERN HIGH LATITUDES AND EARLY DEVELOPMENT OF THE ANTARCTIC CRYOSPHERE

The ostracod records from Cape Roberts (Dingle 2000, this publication) and King George Island (Blaszyk, 1987) allow us to compare high and low Antarctic early cryogenic faunas, and to assess evolutionary development during the onset of glaciation by contrasting them with the warm water Eocene faunas from Seymour Island (Antarctic Peninsula) (Szczechura, in press). In addition, generalisations can be made by considering the composition of various ostracod shelf faunas at the family level from the adjacent parts of Australasia and South America (Tab. 3).

Through to Middle Miocene time, the southeastern part of Australia (Victoria/South Australia) drifted northward ~15°. During the earliest stage (at ~61°S), the climate was probably relatively warm during the global Palaeogene thermal maximum (Dingle et al. 1998), but had became cooler by Late Oligocene time (McKenzie, 1974), and with continued northward drift, the area lay at ~45°S, with a warm climate by the Middle Miocene (Whatley & Downing, 1983) (In fact, Whatley & Downing (1983) postulated a mid-outer shelf tropical-subtropical climate, but as M. A. Ayress has pointed out (pers. comm. 2001) the dominance of *Krithe* does not support this). The most obvious faunal change accompanying these climatic fluctuations was the increase, and subsequent decline, in the importance of the hemicytherids (Tab. 3). On this evidence, McKenzie et al., (1991, 1993) suggested that the Late Eocene ostracods are indicative of "warm water", while the Late Oligocene faunas reflected the establishment of cool circum-Antarctic currents. Ayress & Drapala (1996) questioned whether this was the case, however, and suggested that the non-ostracod faunal evidence, rather indicated cool-temperate conditions during the Late Eocene, which pre-dated the expansion of the hemicytherids. Majoran (1995) correlated the increase in hemicytherids over the Late Eocene - Early Oligocene transition in southern Australia with a 70m shallowing. By comparison, the latest Palaeocene/earliest Eocene ?warm fauna is dominated by trachyleberids and pectocytherids (Neil, 1997), and

the Middle Miocene warm water fauna has high cytherurid and low trachyleberid content, with no hemicytherids (Whatley & Downing, 1983) (Tab. 3).

During Middle Eocene through to Late Oligocene/Early Miocene time, South America moved away from Antarctica relatively slowly. All faunas cited in Table 3 come from palaeo-latitudes between 50° and 56°S, and are considered to have been deposited in water temperatures that decreased from warm/temperate to temperate/cool. Throughout this period, hemicytherids overwhelmingly dominated ostracod faunas in shelf seas. Only in a Pliocene warm/temperate fauna from a palaeo-latitude of ~41°S are they only jointly dominant (with trachyleberids), along with a greatly increased cytherurid component.

In summary, faunas from southeast Australia/southern Argentina show that the three most consistent faunal variables affected by fluctuating warm/cool water temperatures in the shelf faunas in the two areas during Eocene through Pliocene time, were an increase in the numbers of hemicytherids, and a decrease in trachyleberids and cytherurids, with falling temperatures, and *vice versa*.

Comparing these observations with data from Antarctica, we note that the warm-water Eocene fauna from the Antarctic Peninsula (Szczechura, in press) is dominated by trachyleberids (25%), with pontocyprids and thaerocytherids (15% and 12%, respectively), and has echoes in Australasian and South American faunas (see Tab. 3). The composition of this pre-glacial fauna, which was deposited during the waning phase of the Palaeogene climatic optimum (Dingle & Lavelle, 2000) sets it aside from the glacial and inter-glacial Antarctic faunas for which we have data. Extant, high Antarctic faunas (Neale, 1967), are dominated by hemicytherids, with subordinate trachyleberids, cytherurids, xestoleberids and loxoconchids. While these have a similar complexion to the Pliocene interglacial fauna from Cockburn Island (Szczechura & Blaszyk, 1996), the latter is distinguished by the presence of small numbers of leptocytherids, and the enigmatic progonocytherid n *Majungaella*. Both these faunas are overall more similar to the Eocene-Miocene southern Argentinean faunas (hemicytherid-dominant) than they are to the Early Oligocene cytherurid-dominated Polonez Cove fauna from the Antarctic Peninsula (Blaszyk, 1987). Reasons for this presumably are related to the high rate of endemism in the southern Argentina/northern Antarctic Peninsula region (Austral Basin) during Oligocene time (Wood et al., 1999). With the onset of glaciation in the Antarctic Peninsula in Early Oligocene time (~30 Ma, Dingle & Lavelle 1998), sharp environmental gradients may have prompted the development of endemic faunas, and as the oldest, and latitudinally-highest glaciated Antarctic site so far described, it is significant that the most abundant Oligocene taxon at Cape Roberts (*Munseyella*? sp 4781) is endemic to the Ross Sea area.

However, the Cape Roberts data show that the picture is regionally more complex. Although comparisons with the other faunas in table 3 must be made with caution because of the small number of specimens, the presence at Cape Roberts of two distinctive taxa, one each from the Early Oligocene, and Eocene and Pliocene of the Antarctica Peninsula (*Hemicytheridea* aff. *H. kinggeorgeensis* Blaszyk and *Majungaella* spp, respectively), shows that the southern Argentina-Antarctic Peninsula centre of endemism must have "leaked" species into the Ross Sea. The latter area was, however, simultaneously interchanging genera such as *Austrocythere* and possibly *Cluthia* with Australasia, presumably across the Tasman shelf shallows. An apparent enigma is the poor representation of hemicytherids at Cape Roberts: a similarity with the Seymour Island and Polonez Cove faunas. If real, this suggests that there was little interchange of hemicytherids with either Argentina or Australasia, and that the development of the majority of modern, Antarctic endemic hemicytherid species did not begin in earnest until after Oligocene time. In this sense, the evolution of the hemicytherids in Antarctica did not mirror the history in the adjacent regions.

Finally, all the sedimentological evidence from CRP-3 indicates deposition proximal to a glaciated hinterland (CRST, 2000a). The most southerly extant record of the genus *Cytherella* is in the sub-Antarctica at 53.8per oS in Chile (Whatley et al. 1996), while the most southerly known fossil occurrence in South America, after the initiation of the Antarctic cryosphere, is at 53.5°S in the Early Miocene of Tierra del Fuego, southern Argentina (Echevarria, 1982). Southern Chile is presently glaciated, but shallow-water temperatures are significantly warmer than in Antarctica (5-7.5°C mean annual) (Webb et al,. 1991), where very high glacial meltwater rates exceed those postulated for the Late Oligocene of CRP-2/2A (CRST, 1999a). This suggests that *Cytherella*? sp 4796 in the Early Oligocene at Cape Roberts may have existed in conditions somewhat colder that those presently obtaining in southern Chile, but less harsh than in the modern Ross Sea.

SUMMARY

Early Oligocene (CRP-3) and Late Oligocene (CRP-2/2A) ostracods are described from the Victoria Land Basin, Ross Sea. A total of 18 species in at least 12 genera occur in the Oligocene strata, with 13 species, 9 genera and 42 valves of Late Oligocene and 11 species, 8 genera and 29 valves of Early Oligocene age. All taxa are marine, and the faunas are sparse. Preservation is good to poor, and generally moderate. Some delicate specimens are preserved, but many are robust carapaces. The stratigraphical ranges of the ostracods are inadequately known, so that no specific conclusions can be reached on the ages of the faunas.

The new records extend the stratigraphic ranges of five taxa previously described from Antarctica: *Austrocythere reticulotuberculata* Hartmann (Early Oligocene - Recent); *Microcythere*? sp. 4626 (Dingle 2000) (Early Oligocene - Miocene); *Kuiperiana meridionalis* (Müller) (Early Oligocene - Recent); *Australicythere polylyca* (Müller) (Late Oligocene - Recent) and *Ameghinocythere* sp. 4607 (Dingle 2000) (Early - Late Oligocene). In addition, *Hemicytheridea* aff. *H. kinggeorgeensis* Blaszyk, which had already been found in the Late Oligocene at Cape Roberts (Dingle 2000), and a closely related form of which was known previously from the Early Oligocene of the Antarctic Peninsula (Blaszyk 1987), has now also been found in the Early Oligocene at Cape Roberts.

Species closely related to *C.* aff. *C. antiqua* Ayress & Drapala, *Majungaella* sp. 4471, and *Copytus* aff. *C. malumiani* Echevarria, have been previously recorded from New Zealand (Late Eocene), southern Argentina and northern Antarctic Peninsula (Campanian - Maastrichtian and Eocene), and southern Argentina (Late Oligocene - Early Miocene), respectively (Ayress & Drapala, 1996; Ballent et al., 1998; Fauth & Luther, 1999; Echevarria, 1987; Szczechura , in press). In addition, M.A. Ayress (pers. comm. 2001) informs us that *Austrocythere reticulotuberculata* Hartmann occurs in the Miocene of New Zealand. These records show that the Ross Sea area was faunally connected to the Austral Basin (southern Argentina - northern Antarctic Peninsula) via the proto-Drake Passage archipelago until at least Late Oligocene times, and to southeastern Australia (and thence New Zealand), presumably via the Tasman shelf/rise until Early Oligocene times. There is also the possibility, depending ultimately on the relationship between *Austrocythere* and *Cluthia*, that the latter may have evolved in Antarctica before spreading to Australasia and the Northern hemisphere.

Published palaeoclimatic preferences for the Cape Roberts Oligocene ostracods indicate that only three species or closely related-species are known solely associated with Antarctic glacial environments: *Kuiperiana meridionalis* (Müller) (Recent); *Australicythere polylyca* (Müller) (Recent) and *Hemicytheridea* aff. *H. kinggeorgeensis* Blaszyk (Oligocene). *Cytherella*? sp. 4796 occurs in the Recent sub-Antarctic of southern Chile, but *Majungaella* has been recorded previously only from warm Late Cretaceous and Eocene and relatively warm Pliocene inter-glacial Antarctic waters. *Cluthia* is generally regarded as a cool-cold water taxon, but has not previously been recorded in shallow water, pre-Quaternary Antarctic sediments (assuming *Cluthia* aff. *C antiqua* Ayress & Drapala is correctly identified). Given the glacial setting of the Cape Roberts Oligocene environment (CRST 2000a), our data suggest that unless the Oligocene *Cytherella* sp.

4796 was adapted to water considerably colder than extant forms, the Cape Roberts setting at that time was somewhat warmer than the present Ross Sea, but not necessarily as "warm" as modern southern Chile. This contention is further supported by the occurrence in the Oligocene of *Austrocythere reticulotuberculata* Hartmann, which today is found only north of 70°S (northern Antarctic Peninsula, South Georgia and Prydz Bay) (Hartmann, 1997; M.A. Ayress pers. comm. 2001). Despite the several faunal links that can be established with surrounding areas, it is significant to point out that the most abundant taxon in the Cape Roberts Oligocene fauna, *Munseyella*? sp. 4781, is endemic to the locality.

Finally, the record of *Majungaella* sp. 4471 at Cape Roberts (and *M.* sp in the Pliocene interglacial strata on Cockburn Island) opens up the intriguing possibility that this temporally and spatially long-ranging, originally Tethyan taxon, found its last *refugia* under glacial/inter-glacial conditions.

Taxonomic Notes

Ameghinocythere sp. 4607 (Dingle) (Fig. 3F). This species was ordinally recorded by Dingle (2000) as *Munseyella* sp 4607. Our new material (1 valve, 1 carapace) from CRP-2/2A (Late Oligocene) is slightly crushed, but the surface features suggest that we have the same species, although the relatively prominent surface reticulation of the Early Miocene material (CRP-2/2A Early Miocene) is only present in the anterior and posterior areas of the valve, with the central parts relatively smooth. Overall valve shape and surface relief is very close to Echevarria's (1991b) species *Cushmanidea* sp. from the Late Oligocene in the Austral Basin in southern Argentina.

Australicythere polylyca (Müller 1908) (Fig. 2E). Two valves were present in sample 253.2m CRP-2/2A of Late Oligocene age. They were clearly from a single carapace that had parted during preparation. The valves were well preserved, but the shell has a brown hue, is re-mineralised and clearly not of modern origin. There is some matrix internally. It was the only fossil in this sample. Comparing the specimen with Quaternary material from CRP-1 (Dingle 2000), the two are identical in all major features. The Oligocene specimen has a slightly less regular ridge joining the posterodorsal and posteroventral lateral surface nodes in

the RV, and there are minor differences in secondary ornament reticulation. There is every reason to believe that this species remained very stable morphologically during Late Oligocene to present time. Whatley et al. (1998) suggest that the species illustrated by Blaszyk (1987) as *Phalcocythere tokarskii* sp. nov. from the Early Oligocene of the Polonez Cove Formation in the Antarctic Peninsula is *A. polylyca*, but this seems unlikely given the differences in lateral outline and the former's lateroventral alate process. Similarly, they concur with the record of the species by Szczechura & Blaszyk (1996) from the Pliocene Cockburn Island Formation. The latter is close to *A. polylyca*, but there are sufficient differences in the lateral dorsal outline, and in dorsal and ventral views to suggest that the two are not conspecific.

Austrocythere reticulotuberculata Hartmann 1989 (Fig. 3C). Our specimens are very similar to those illustrated by Hartmann (1997), and are also probably conspecific with Briggs (1978) species (recorded as *?Cluthia* sp.) from the Pleistocene Taylor Formation in the Ross Sea area. Hartmann (1997) has recorded this species extant at three sites only (the islands of South Georgia, Lavoisier and Adelaide) between 54 and 67°S, and in water depths of 116-250m. M.A. Ayress (pers. comm. 2001) has also recorded the species at 402m and 1060m in Prydz Bay. This species is a further example (*e.g.* with *Australicythere polylyca* (Müller 1908)) of great morphological stability in a taxon that appeared early during the glacial history of Antarctica. M.A. Ayress (pers. comm. 2001) informs us that the genus is common, particularly in the Miocene, of New Zealand, whence he has recorded *A. reticulotuberculata*. Milhau, (1993) has described a species (as *Leptocythere*? sp. 11) similar to *A. reticulotuberculata* from the Miocene of New Zealand, which differs in being more reticulate and somewhat less nodose than the genotype. There appears to be a close relationship between the genotype of *Austrocythere* Hartmann 1989 and some species of *Cluthia* from New Zealand, one of which, *C. novaezealandiae* Ayress & Drapala, 1996, in our opinion, belongs in *Austrocythere*, and has a similar ornamentation to *A. reticulotuberculata*.

Cluthia Neale 1973 (Fig. 3A). Ayress & Drapala (1996) recorded six species of the genus from Australia and New Zealand in Late Eocene to Pleistocene strata . We have found one similar species: *Cluthia* aff. *C. antiqua* Ayress & Drapala, although, with no internal views available, it is not possible to make a more positive identification. Our species has a more prominent anterior marginal rim, but otherwise has similar exterior features. The New Zealand species was recorded from Late Eocene strata (Ayress & Drapala, 1996). Whatley et al. (1998) have also recorded a single, un-named species of the genus from deep-water in the South Scotia Sea, which has a relatively smooth external lateral surface, typical of deeper-water forms of the genus. McKenzie et al. (1993) recorded *Cluthia*? sp. from the Late Eocene of Victoria, and Majoran (1995) illustrated the same species from the Late Eocene of South Australia. Ayress & Drapala (1996) refer to this species as *Cluthia* sp.1, and comment that it lacks many of the nodose features found in other species from the region. M. A. Ayress (pers. comm. 2001) intimates that work is needed to resolve the relationship between the New Zealand and (by implication) Antarctic representatives of *Cluthia* and *Austrocythere*, and comparison of illustrations of the genotype (lain *C. cluthae* (Brady, Crosskey & Robertson)) given in Neale (1973) with those of Hartmann (1989, 1997) reinforce his point.

Copytus (Fig. 3D). Three species have been recovered from the CRP boreholes: *C.* aff *C. malumiani* Echevarria 1987 (Late Oligocene), *C.* sp. 4804 (Early-Late Oligocene) and *C.* sp. 4628 (Early Miocene). *C.* sp. 4804 and *C.* aff *C. malumiani* are very similar, but the latter has a more acuminate anteroventral outline, with a more pronounced ventral incision.

Cytherella? sp. 4796 (Fig. 3E). This is a partially crushed carapace, with a smooth exterior surface. In dorsal view the outline is elliptical, and in lateral view the anterior outline is typical for the genus. No indication of muscle scar patterns could be seen on the exterior surface.

Kuiperiana meridionalis (Müller) (Fig. 2H). Given that our material is not well-preserved, we feel that it is probably conspecific with *K. meridionalis* (Müller), which has been widely recorded from Antarctica and southern Argentina (Neale, 1967; Whatley et al., 1996; 1997). Blaszyk (1987) recorded a loxoconchid (*Loxoconcha rolnickii* Blaszyk) from the Early Oligocene at Polonez Cove, but the straight dorsal and asymmetric anterior margins distinguish it from *K. meridionalis*. Similar species such as *K. lindsayi* (McKenzie et al., 1991) and *K.* cf. *K. lindsayi* (McKenzie et al.,) (in Ayress 1995) from the Eocene of South Australia and New Zealand, respectively, can be distinguished from Müller's species by the latter's relatively coarse reticulation. *Kuiperiana* sp. Szczechura (in press) from the Eocene of Seymour Island seems very close to *K meridionalis* (Müller).

Majungaella sp. 4471 (Figs. 2A, B, C, D, 3 G). This species is very close to *Majungaella australis* Rossi de Garcia & Proserpio 1980, which is a subjective homonym of *M. australis* (Bertels 1975). Bertels originally placed the species in *Tumidoleberis* Deroo 1966, and recorded it from the middle Maastrichtian of Rio Negro Province (Neuquén Basin), Argentina. She stated that the hinge is antimerodont, but her illustration shows it to be entomodont, thus qualifying for inclusion within the emended diagnosis of the genus (Whatley & Ballent 1996). *Majungaella australis* Rossi de Garcia & Proserpio 1980 has been recorded from the Upper Campanian to Maastrichtian of the Austral Basin of Argentina (Ballent et al., 1998). Fauth & Luther (1999) recorded a closely comparable form to *M. australis* Rossi de Garcia & Proserpio 1980 from the Upper Campanian of James Ross Island in the Antarctic Peninsula. Our species is probably new, but is also similar to Rossi de Garcia & Proserpio's taxon. The two species consistently differ in the disposition of the pseudo-concentric rib patters, though both have the small papillae at the intersection of the primary reticula noted by Ballent et al. (1998) in the Argentinean *M. australis* Rossi de Garcia & Proserpio. *Majungaella* sp. 4471 is also very close to *M. antarctica* Szczechura (in press) from the Eocene of Seymour Island, Antarctic Peninsula. The two differ in details of the trajectory of the fine postero-dorsal and antero-marginal lateral surface rib patterns and the relatively coarser reticulation pattern of *M.* sp. 4471. *M.* sp (Szczechura & Blaszyk) from the Pliocene of Cockburn Island (Szczechura & Blaszyk, 1996) similarly has a coarser reticulation pattern than plain *M. antarctica* (even more so than *M.* sp. 4471), but is distinguished from *M.* sp. 4471 by a distinctly higher antero-dorsal outline in lateral view. Our faunas contain a relatively high proportion (19% of total valves) of fragile juvenile specimens, which have the characteristic, somewhat acuminate posterior outline. (For example by comparison with RVD's personal collection of *M. uitenhagensis* (Dingle) from the Valanginian of South Africa).

Microcythere? sp. 4626 (Fig. 2F, Fig. 4A, B, C) . This small species was originally recorded from the Early Miocene at Cape Roberts 2/2A (Dingle, 2000) as *Clinocythereis* cf. *C. australis* Ayress & Swanson 1991. M. A. Ayress advises us that the two are not conspecific. We now have one internal view (Fig. 4A), which shows a straight antimerodont hinge, a wide anterior vestibule, and a small posterior vestibule. Radial pores appear simple and straight, but along with the muscle scars, could not be seen clearly. Comparisons with *Microcythere frigida* Müller 1908, recorded by Dingle (2000) from CRP-1, show differences in carapace outline and degree of left valve overlap (Fig. 4C-D).The exterior of *M?* sp. 4626 is smooth, with the exception of four short, rounded, longitudinal ridges just posterior of mid-length. This is probably a new taxon, and is restricted to Cape Roberts, while *M. frigida* has been recorded from Gauss Station (Müller 1908), South Scotia Sea (Whatley et al., 1998), and the Ross Sea (Briggs, 1978, and Dingle, (2000).

Munseyella? sp. 4781. Although this is one of the most abundant species in the present study, no good internal views are available. It is a medium-sized, robust species with a broadly rounded anterior margin, a relatively straight ventral margin and a straight dorsal margin that slopes steeply posteriorly. The posterior margin is short and truncated. The lateral surface is nodose, with prominent postero-ventral and sub-central nodes, and covered in a prominent but finely sculptured reticulation. The anterior marginal rim is broad and rounded. This species bears a superficial resemblance to *M. undulata* Whatley et al. 1997, but differs in the shape of the ventral margin and ventro-lateral area and style of reticulate ornamentation.

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