A PALAEOENVIRONMENTAL ANALYSIS OF THE OSTRACOD FAUNA OF THE EARLY MIDDLE MIOCENE MORGAN LIMESTONE AND CADELL MARL, MURRAY BASIN, SOUTH AUSTRALIA.

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ABSTRACT

A stratigraphic section through the Early Middle Miocene (Batesfordian) Morgan Limestone and Cadell Marl was measured and sampled at regular intervals and these were picked for Ostracoda. Examination of familial variations through the section and a cluster analysis which discriminates 7 discernible ostracod assemblages has been used to reconstruct the depositional history of the sequence.

These ostracod assemblages appear to reflect a change from inner shelf onshore conditions to inner shelf offshore conditions through the lower Morgan Limestone, deepening to middle shelf depths low in the Cadell Marl. Conditions shallow from the middle of the marl to the top of this unit, this signal being overprinted by fluctuating nutrient conditions producing an alternation of *Maoricolpus* beds and marls. The upper limestone member was deposited on the inner shelf under oscillating nutrient levels.

Foraminiferal dating of the section places the deposition of the Morgan Limestone/Cadell Marl sequence during a time of rising and falling sealevel peaking at the highstand of cycle 2.3 in the Batesfordian stage. This appears to correlate well with the suggested highstand in the lower Cadell Marl (assemblage Cadell 1).

Milankovitch order fluctuations in sea level overprinting the third order Miocene oscillation and associated Batesfordian highstand have produced a cyclicity of lithology from meso-oligotrophic *Celleporaria* limestones to highly eutrophic *Maoricolpus* marls and limestones, with each of these depth/lithology/nutrient associations characterised by a distinctive ostracod assemblage.

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Well I finally got there and "killed it before it killed me" and there are many people who have had an interest in my progress along the way to whom I owe a large debt of thanks.

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1. INTRODUCTION

In recent times, the use of ostracods as palaeoenvironmental indicators has been gaining popularity amongst the micropalaeontological community. These microscopic crustaceans are admirably suited to this task as great deal of knowledge exists about the ecology of living ostracods and since their appearance in the Cambrian they have evolved to be abundant in most aquatic environments. Most species are benthonic and strongly substrate and latitude controlled in their distribution, whilst their small calcite carapaces are readily incorporated into sediments and subsequently fossilized. One powerful tool these animals have over other microfossils is that it is relatively easy to distinguish between autochthonous and allochthonous fractions of fossil ostracod faunas, thereby eliminating any doubts in a worker's mind on the validity of his environmental interpretations.

The history of Tertiary ostracod studies in Australia since the turn of the century is lamentably characterised by large intervals of inactivity, whereas foraminiferal research has been relatively prolific. Most early work was conducted by Chapman (1910, 1914) with a few later papers by Crespin (1943, 1945a, 1945b). Only in comparatively recent times has there been a large increase in the amount of published work on Tertiary ostracod faunas of southeastern Australia, mainly due to the solo or joint efforts of McKenzie, Warne, Neil & Majoran (see bibliography). A major shortfall of this recent research is that none has dealt with the Tertiary of the Murray Basin. The majority of the earlier of these works tended to be based on spot samples and concentrated on taxonomy whilst many of the later studies were directed towards palaeoenvironmental inferences. Several recent stratigraphic analyses of ostracod faunas from the St Vincent Basin of South Australia (Majoran, 1995, 1996, in press) and the South Island of New Zealand (Ayress, 1993) have closely examined faunal variation through a measured stratigraphic section with a view to establishing a palaeoenvironmental history for these sequences, a technique used for southeastern Australian sediments with great success by recent foraminiferal workers (McGowran & Li 1993, 1994, Li & McGowran 1993, 1994).

As no fossil ostracod studies have been specifically involved with the Murray Basin, it was decided by the author that the time was ripe for such a study. The identification and analysis of ostracod assemblages through a geological succession of the Early-Middle Miocene sequence at the type section of the Morgan Limestone/Cadell Marl (see Fig. 1, p.2, Plate 2, p.6) was conducted, with the intention of using this information to deduce the record of the environmental history of the sequence. This palaeoenvironmental history could then be used to correlate the sequence with sediments of similar ages in other southeastern Australian basins and with global sea level curves for the Miocene. The results of these studies are presented in this thesis.

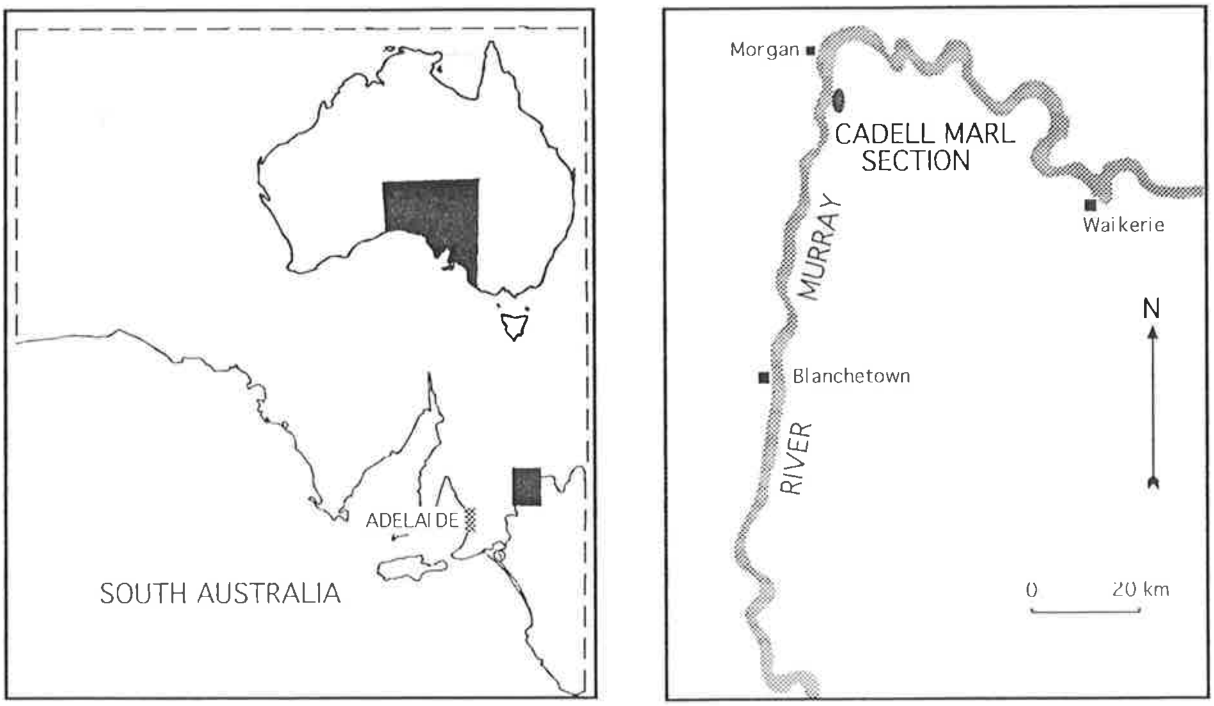


Figure 1. Location of Morgan Limestone/Cadell Marl section.

2. GEOLOGY

2.1 Regional Geology

The Murray Basin began to form during the Mesozoic as a shallow basin over a large area of the southeastern part of Australia (Ludbrook 1961) and its Palaeocene - Quaternary sedimentary sequence covers an area of some 300 000 km^2 in southeastern South Australia, southwestern New South Wales and northwestern Victoria (Drexel and Preiss, 1995) (see Fig. 2, p.4). These Cainozoic sediments unconformably overlie and onlap either Neoproterozoic to early Palaeozoic basement, Permian glacigene or Early Cretaceous marine strata.

In South Australia the basin is bounded in the north and west by folded Neoproterozoic sediments of the Adelaide System, Cambrian metasediments of the Kanmantoo Group and Cambro-Ordovician granites onto which the Tertiary sediments transgress (Ludbrook 1958). An area of structural highs composed of northwesterly trending Early Palaeozoic metasediments and granites known as the Padthaway Ridge parallels the southern margin of the basin roughly 50km inland from the present coastline. Sedimentation was initiated by uplift of the ancestral Mt Lofty Ranges along rejuvenated Delamerian fault trends probably during the early Paleocene. Sagging of the trailing margin of the northward moving Australian plate led to progressive marine transgression into southern Australian sedimentary basins from the middle Eocene onwards (Twidale et. al. 1978). Marine sedimentation was almost continuous over most of the Murray Basin during the middle of the Tertiary when a thick sequence of chiefly bryozoal limestones was deposited (Ludbrook 1969).

The maximum marine transgression in the basin occurred at the beginning of the Miocene and ended in the middle of this epoch probably due to the combined effects of a glacio-eustatic fall in sea level associated with the rapid growth of the Antarctic ice cap, and epierogenic uplift of the trailing continental margin (Twidale et. al. 1978).

Limestones and calcarenites of the Murray Group form a horizontal sheet of sediment which is locally disrupted by faulting. These sediments are on the whole concealed by Late

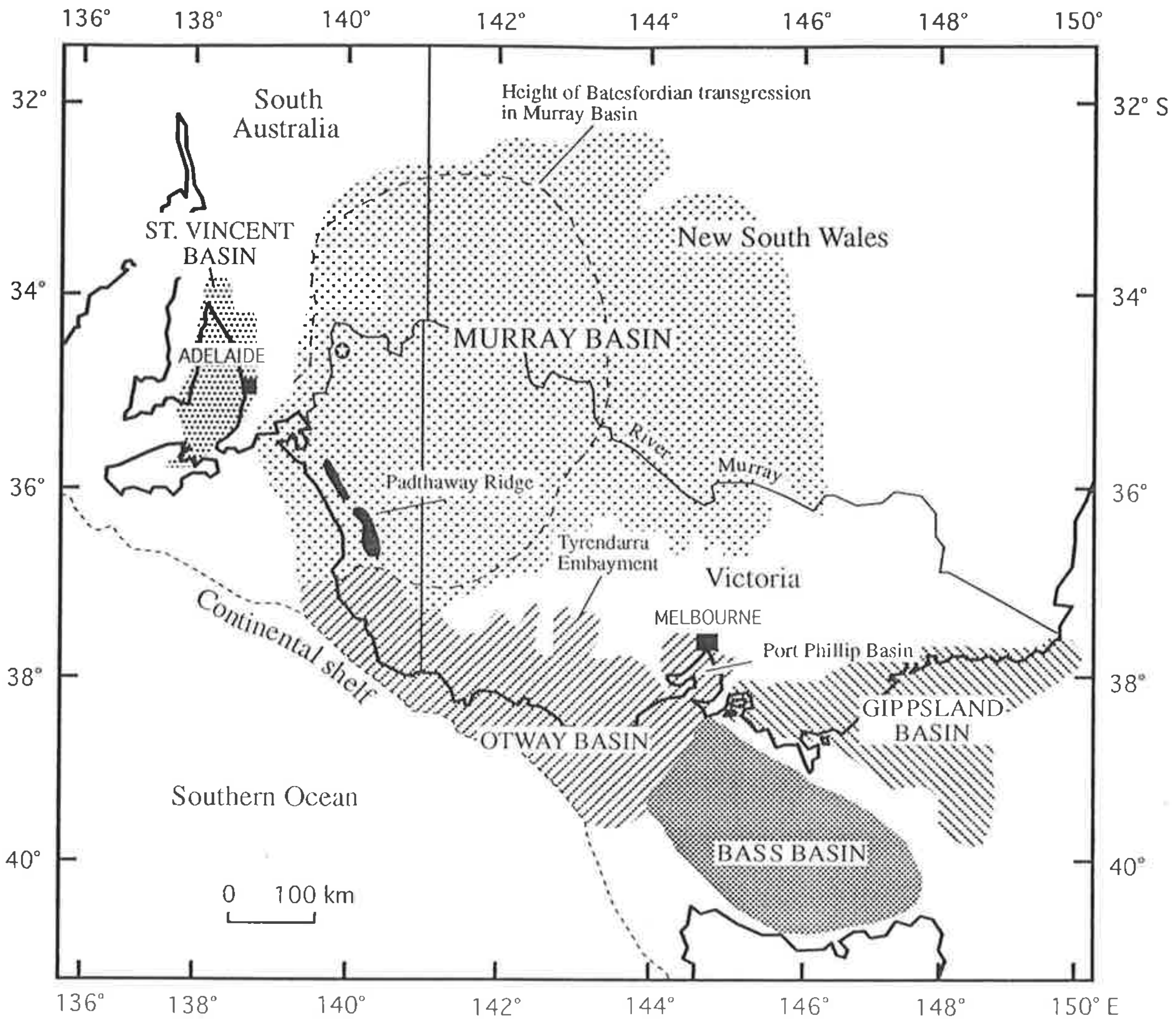


Figure 2. South East Australian Cenozoic sedimentary basins

Pleistocene to Holocene aeolian and fluviatile sediments but crop out at the western edge of the basin where the Mannum Formation locally onlaps basement Kanmantoo metasediments and is exposed in creek beds such as in the Marne Valley (Brown and Stephenson 1991). Murray Group sediments achieve their most extensive outcrops in the cliffs formed by the Murray River during the Pleistocene (Twidale et. al. 1978) (see Plate 1, p. 6).

Recent work by Rogers et. al. (1995) has included the Morgan Lst & Cadell Marl into the new massive Mannum Lst. This stratigraphic reorganisation is not recognised here. The former transgressive Mannum Formation and Morgan Limestone are separated by the regressive Finniss Clay and both are readily distinguishable by lithology in the field. The Mannum Formation, of mainly light cream to yellow skeletal calcarenites and calcareous sandstones, has been distinguished from other limestones of the Murray Group on

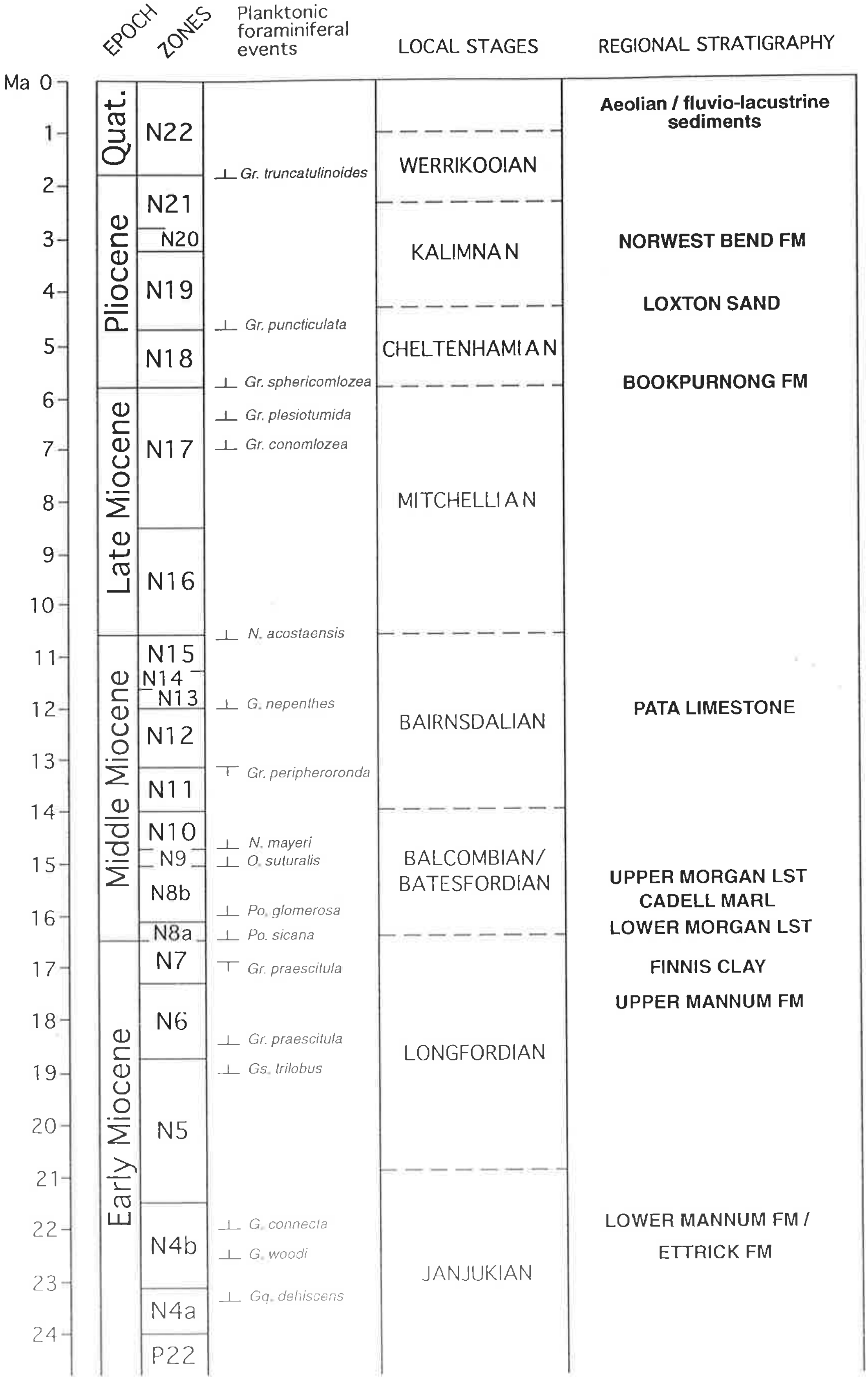


Figure 3. Regional stratigraphy of the Murray Basin.

Plate 1. The River Murray downstream from Morgan showing Tertiary sediments forming cliffs. Quaternary aeolinites overly Mio-Pliocene sequence above hard band at top.

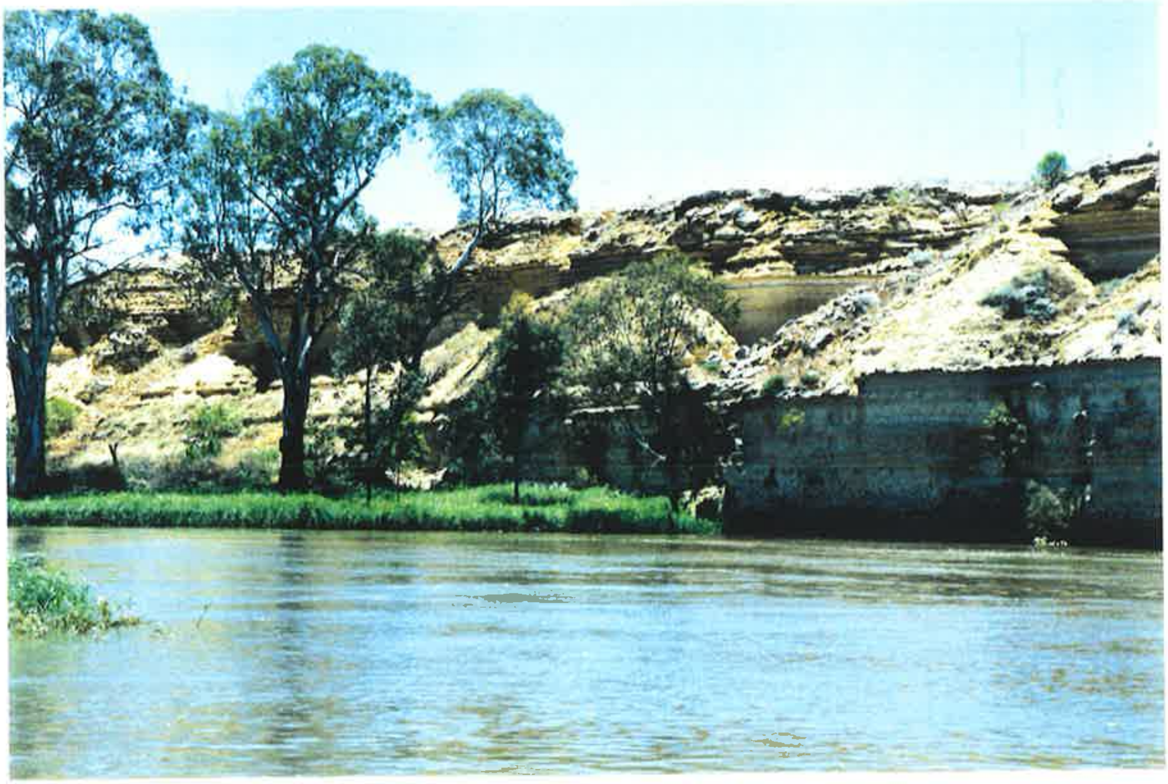


Plate 2. Type section of the Morgan Limestone/Cadell Marl, 6km downstream from Morgan.

palaeontological grounds (Ludbrook 1957, 1961), although it has proved difficult for some workers to recognise lithologically from the Morgan Limestone in bore logs (O'Driscoll 1960). In outcrop, however, the white bryozoal limestones and marls of the Morgan Limestone are quite distinct from the yellow, calcareous sands of the Mannum. On examination of the fossil faunas of these two units a major difference is also observed. The fauna of the Mannum Formation is dominated by infaunal forms such as burrowing spatangoid echinoids (*Lovenia forbesi* and *Eupatagus* spp.) whereas the Morgan Limestone is dominated by epifaunal organisms, reflecting a large scale change in trophic level from eutrophic to oligotrophic conditions (Li & McGowran, 1994).

The type section of the Morgan Limestone and Cadell Marl, designated by Ludbrook (1961), is exposed in the cliffs on the eastern side of the River Murray some 6km S of Morgan (see Fig. 1, p. 2, & Plate 2, p. 6). The sequence at the type section was deposited during a period of 3rd order fluctuations in sea level, overprinting a general 2nd order trend of transgressing seas from the Late Oligocene to the early Middle Miocene followed by a marked sea level fall to the Late Miocene (see Fig. 20, p. 72). This reversal of overall global climatic deterioration, peaking at the Batesfordian-Balcombian stages, has been termed the "Miocene Oscillation" (McGowran & Li 1994, 1996) and is also associated the warmest climate estimated for the last 25 million years (McGowran 1979, McGowran & Li 1993) - the "Miocene Climatic Optimum".

2.2 Morgan Limestone, lower member

The base of the cliffs of the River Murray gorge from above Overland Corner to just north of Blanchetown is composed of the cream coloured bryozoal Morgan limestone, typically exposed at its type locality (described by Tate in 1885) on the eastern bank of the River Murray some 6km south of the township of Morgan (see Plate 3, p. 8). The lower member is approximately 12m thick with the bottom 3m a soft and fairly even grained uniform white/cream bryozoal limestone. The top 9m of this lower unit is composed of harder

Plate 3. 50m downstream from type section. Showing resistant lower Morgan Limestone overlain by softer Cadell Marl. Above this, the recrystallised limestones of the upper Morgan Limestone are capped with Kalimnan Norwest Bend Formation.

Plate 4. Lower member of Morgan Limestone showing abundant *Celleporaria* colonies.

limestone characterised by the presence of abundant colonies of the bryozoan *Celleporaria* (see Plate 4, p. 8) with occasional softer marly beds (see stratigraphic column, pp. 15-16). The upper boundary of the lower Morgan Limestone member is marked by the presence of a grey, strongly cemented *Celleporaria* bed.

The large (sub)tropical foraminiferan *Lepidocyclina howchini* has been recorded from a thin zone about 3m above river level (Lindsay and Giles 1973, and personal observations) which is a useful stratigraphic and environmental marker both within the Murray Basin and between southeastern Australian sedimentary basins (McGowran 1979). The lower member of the Morgan Limestone bears the N8a marker species *Praeorbulina sicana* (Li *pers. comm.*) placing it within the Batesfordian stage.

2.3 Cadell Marl Lens

Sandwiched between the upper and lower members of the Morgan Limestone at the type locality is the Cadell Marl Lens. Here it stretches for over 90m and attains a thickness of 6.7m. In outcrop it varies from a grey to buff coloured silty sandy marl with alternating macroinvertebrate rich and absent layers (see Plate 3, p.8). Small pellets of accessory glauconite can be found. It also occurs subsurface north of Morgan and in cliff sections and boreholes in the Murray River valley (Lindsay and Barnett, 1989). This unit is the "gastropod bed" from which Tate (1885) obtained most of the molluscan species he collected from the River Murray cliffs (Ludbrook 1958). Early micropalaeontological analysis placed the marl as equivalent to the lower part of Planktonic Foraminiferal N9 zone (McGowran 1979).

The Cadell Marl commences with a bed similar to the boundary *Celleporaria* layer below, but the abundant bryozoan colonies have been replaced by moulds of the turritellid gastropod *Maoricolpus murrayana*. It then passes into a sequence of soft orange to buff marls with common bioturbation and occasional shelly beds dominated by *Maoricolpus*. This sequence is reversed above a mottled clay (Tate's 1885 "Blue Clay" - see Plate 5, p.10) till we once again see the indurated *Maoricolpus* bed followed by the grey cemented *Celleporaria* layer

Plate 5. Showing highly bioturbated marls and shell rich/absent beds in the middle of the Cadell Marl. Handle of hammer lies across Tate's "Blue Clay" (Sample C8 in this study).

Plate 6. Shell bed, sample C6. Note current concentration of shells along bedding plane.

which indicates the base of the upper member of the Morgan Limestone. The fossil macrofauna is both diverse and rich with 17 genera of bivalves, 11 of gastropods, 2 of scaphopods and 7 of shark teeth recorded in the literature (Brown and Stephenson 1991). The Cadell Marl has been previously interpreted on the basis of sedimentology as the result of deposition in a marginal marine environment during a minor regression (Brown and Stephenson 1991).

2.4 Morgan limestone, upper member

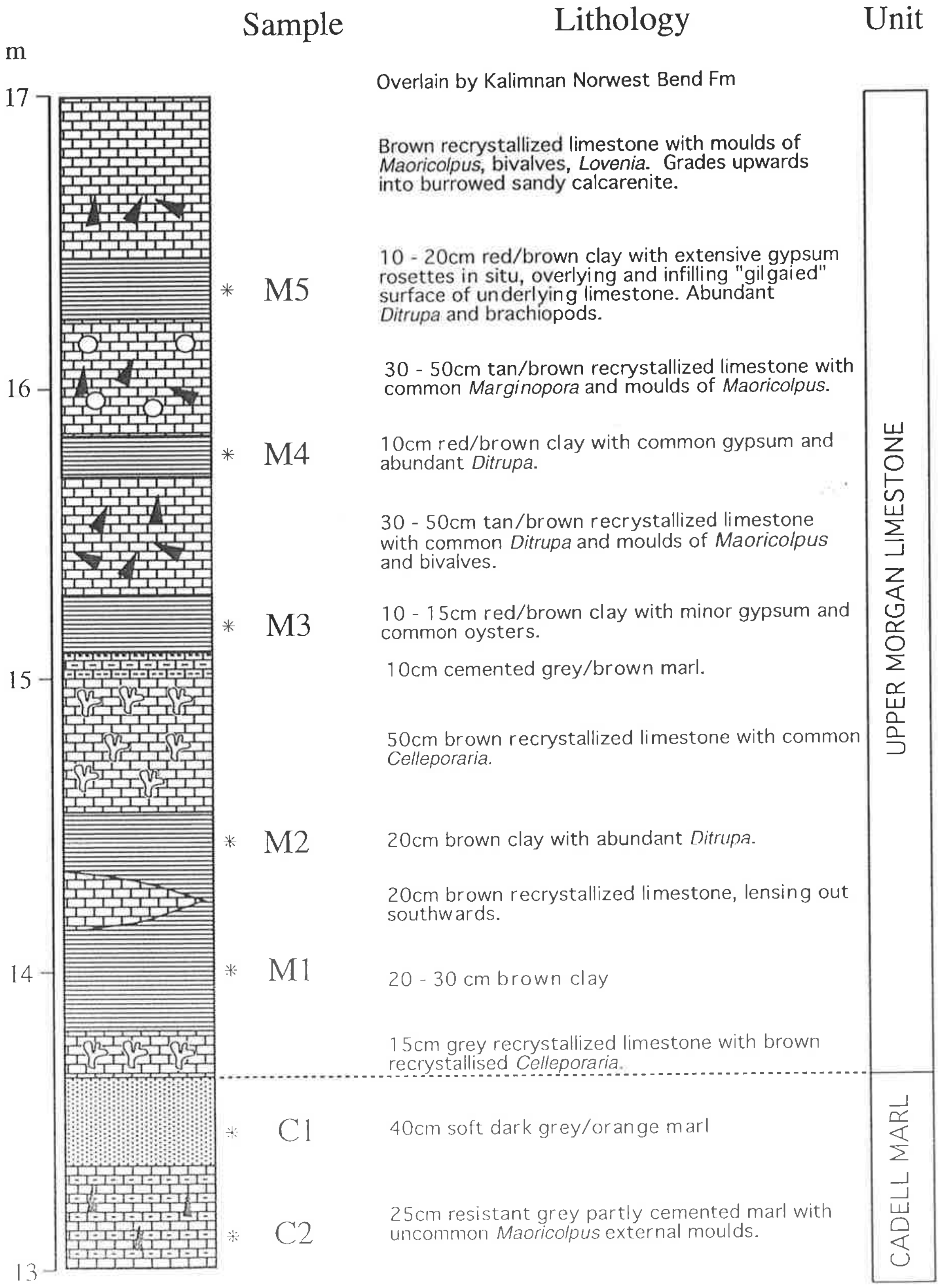
At the type locality, the upper member of the Morgan Limestone is quite distinct from the lower, and is composed of an alternation of six orange recrystallised limestones with red/brown gypsiferous clay interbeds (see Plate 7, p.12). This member overlies the Cadell Marl Lens and reaches a maximum thickness of 7m. The lower three hard limestone bands have abundant *Celleporaria* colonies but these change to *Maoricolpus* limestones above the third clay interbed. The upper three recrystallised beds also contain numerous remains of the serpulid worm, *Ditrupa* sp, bivalve moulds, fenestrate bryozoa and spatangoid echinoids, whilst the large extra tropical foraminiferan, *Marginopora vertebralis*, is common in the penultimate hard band. The clays interbeds which alternate with the hard beds contain abundant remains of *Ditrupa*, as well as locally common oysters (see Plate 8, p.12). The uppermost clay also is characterized by the presence of concentrations of small brachiopods infilling the convoluted surface of the underlying limestone. The top limestone bed of the measured section grades upwards into a heavily burrowed sandy calcarenite with no visible macrofauna. The top of the upper Morgan Limestone appears to exhibit a karst surface into which have percolated numerous brachiopods (*Victorithyris garibaldiana*). These have been attributed to the overlying Norwest Bend Formation (J Lukasik *pers. comm.*) but local stratigraphy and the species' known time range of Early to Late Miocene (Richardson 1980) appear to suggest infilling during the Middle to Late Miocene, with the overlying sediments associated with this period eroded prior to the deposition of the Kalimnan Norwest Bend Formation.

Plate 7. Alternating recrystallized limestones and clays of the upper member of the Morgan Limestone.

Plate 8. Sample M3. Note oysters above head of hammer.

3. STRATIGRAPHIC SECTION

Stratigraphic log at the Morgan Limestone/Cadell Marl type section.



Overlain by Kalimnan Norwest Bend Fm

Brown recrystallized limestone with moulds of *Maoricolpus*, bivalves, *Lovenia*. Grades upwards into burrowed sandy calcarenite.

10 - 20cm red/brown clay with extensive gypsum rosettes in situ, overlying and infilling "gilgaied" surface of underlying limestone. Abundant *Ditrupa* and brachiopods.

30 - 50cm tan/brown recrystallized limestone with common *Marginopora* and moulds of *Maoricolpus*.

10cm red/brown clay with common gypsum and abundant *Ditrupa*.

30 - 50cm tan/brown recrystallized limestone with common *Ditrupa* and moulds of *Maoricolpus* and bivalves.

10 - 15cm red/brown clay with minor gypsum and common oysters.

10cm cemented grey/brown marl.

50cm brown recrystallized limestone with common *Celleporaria*.

20cm brown clay with abundant *Ditrupa*.

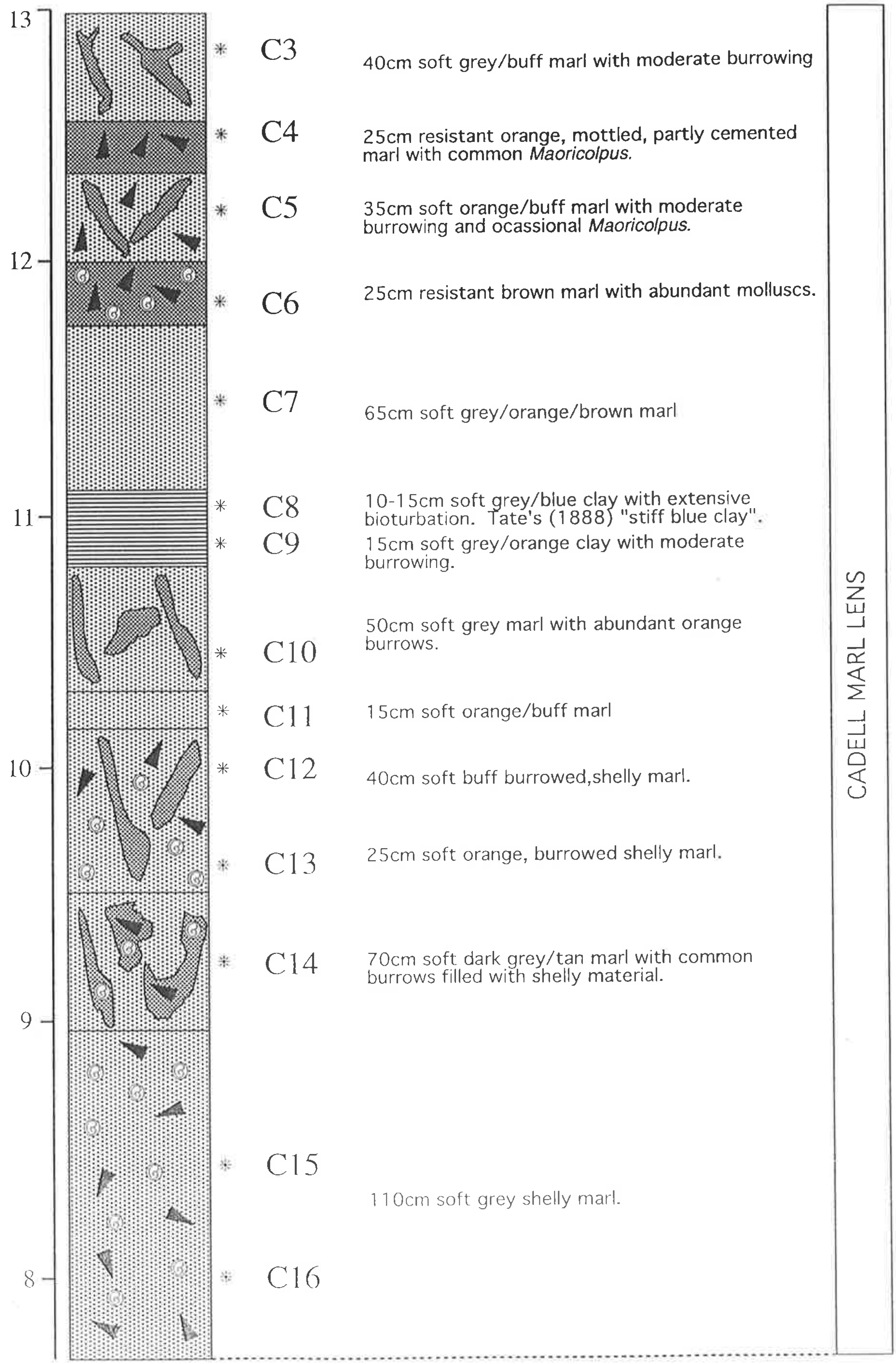
20cm brown recrystallized limestone, lensing out southwards.

20 - 30 cm brown clay

15cm grey recrystallized limestone with brown recrystallised *Celleporaria*.

40cm soft dark grey/orange marl

25cm resistant grey partly cemented marl with uncommon *Maoricolpus* external moulds.



40cm soft grey/buff marl with moderate burrowing

25cm resistant orange, mottled, partly cemented marl with common *Maoricolpus.*

35cm soft orange/buff marl with moderate burrowing and ocassional *Maoricolpus.*

25cm resistant brown marl with abundant molluscs.

65cm soft grey/orange/brown marl

10-15cm soft grey/blue clay with extensive bioturbation. Tate's (1888) "stiff blue clay".

15cm soft grey/orange clay with moderate burrowing.

50cm soft grey marl with abundant orange burrows.

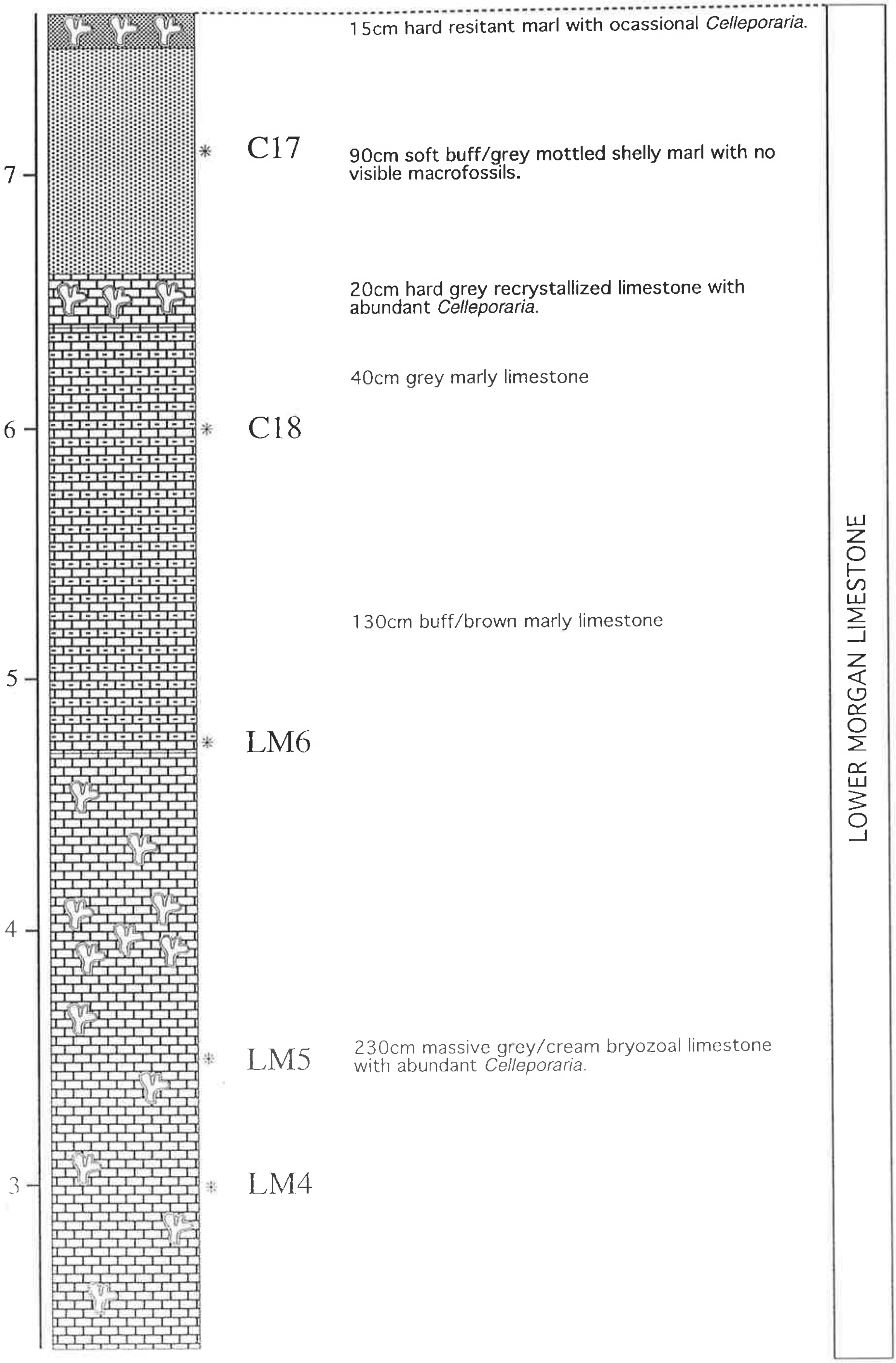
15cm soft orange/buff marl

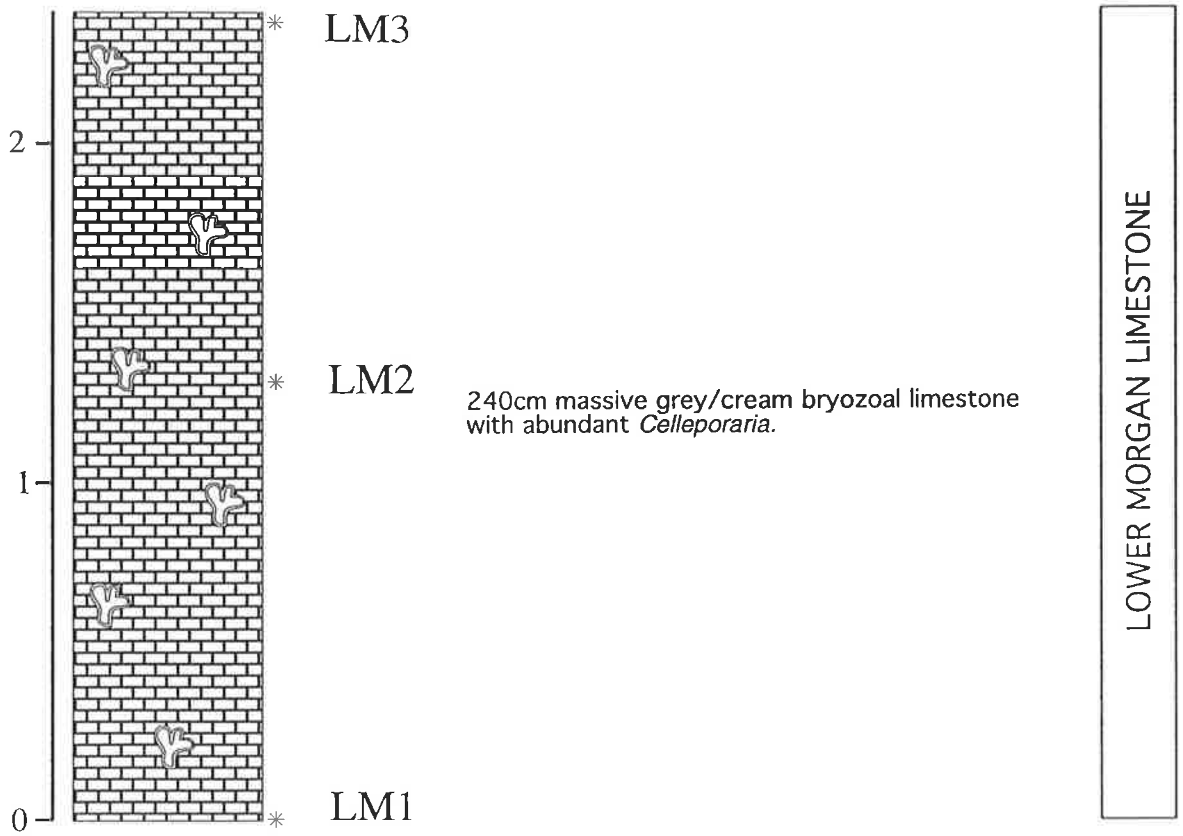
40cm soft buff burrowed,shelly marl.

25cm soft orange, burrowed shelly marl.

70cm soft dark grey/tan marl with common burrows filled with shelly material.

110cm soft grey shelly marl.


15cm hard resitant marl with ocassional *Celleporaria.*
C17
90cm soft buff/grey mottled shelly marl with no visible macrofossils.
7
20cm hard grey recrystallized limestone with abundant *Celleporaria.*
40cm grey marly limestone
6
C18
130cm buff/brown marly limestone
5
LM6
LOWER MORGAN LIMESTONE
4
LM5
230cm massive grey/cream bryozoal limestone with abundant *Celleporaria.*
3
LM4



240cm massive grey/cream bryozoal limestone with abundant *Celleporaria.*

Base of measured section

4. MATERIALS AND METHODS

The section was measured and approximately 1kg samples were taken at irregular intervals from the centre of lithologically distinct units (see pp.13 - 16). This resulted in 5 samples (M5 - M1) being collected from the brown clays which alternate with the recrystallized limestones of the 2.4m thick upper Morgan Limestone member. The appearance of *Celleporaria* dominated limestones was determined to mark the upper and lower boundaries of the Cadell Marl, from which 16 samples were collected. It was originally thought that the Marl extended down for a further 1.6m but later investigations at the site proved samples C17 and C18 lay below the uppermost *Celleporaria* bed of the lower limestone. As such, 8 samples were collected from the 7.6m of lower Morgan Limestone exposed at the site (LM1 - LM6, C18 & C17).

Samples were oven dried then disaggregated by extended soaking in water and wet sieved to remove the fine clays. Approximately 20g was taken for the author's examination, the remainder retained by Dr Quanyu Li of the Department of Geology & Geophysics, University of Adelaide for foraminiferal analysis. Each sample was picked for ostracods using an Olympus binocular microscope and specimens were mounted with water soluble glue on 40 square microfossil slides. Rather than picking the entire ostracod fauna from each sample, it was decided to pick the first 500 specimens as this number has been determined to be sufficient to guarantee identification of species that make up a minimum of 5% in a sample (Patterson and Fishbein, 1989). Specimens were then identified and species lists for each sample identifying the number of adults and juveniles for each were compiled (see Appendix, pp. 107-154). Identification of specimens was facilitated by whitening with NH_4Cl. Specimens were identified to specific level where possible with others left in open nomenclature if there were fewer than 20 specimens or diagnostic features were not detectable.

Species were mounted on stubs and photographed using the video print system on the Philips 20 Scanning Electron Microscope at the Centre for Electron Microscopy and Microstructure Analysis (CEMMSA) at the University of Adelaide.

5. TAXIC DISTRIBUTION

An examination of the population age structure of an ostracod species (the numbers of valves for each moult stage of the species) can help in the identification of the palaeoenergy level of the environment of deposition and consequently its depth. Studies on Quaternary and living ostracods have shown that certain types of population-age structure are indicative of biocoenoses or thanatocoenoses (Whatley 1988). This technique can be employed in the study of fossil faunas. Whatley's studies of recent faunas show that in low energy environments, faunas were typified by population age structure "A". This comprised adults of both sexes and a large number of juveniles of instar stages well back into the ontogeny of the species and was interpreted as the product of a low energy regime. Although Type A faunas can be found in the marine environment today and in the geological record, they are rare and confined to rather special conditions such as the bioclastic oozes of abyssal environments, or from marginal marine environments associated with low energy levels of deposition. Whatley suggested Type A populations were most likely to be found in lacustrine environments. In higher energy regimes, typically encountered in the marine littoral and shelf environments, where the current velocity is sufficient to remove all the younger dead valves, those of the adults and perhaps the largest instars remain. This results in the Type "B" population structure of the high energy biocoenosis. These faunas are common on the present day continental shelf associated with relatively coarse grained sediments. Type "C" population structures are typified by having no or very low numbers of adults and larger instars, and opposingly large numbers of juvenile instars. These populations would appear to be the downslope result of the high energy biocoenosis (Type B population structure) whose juveniles are dropped out of the water column as water current energy diminishes along an energy gradient to produce a low energy thanatocoenosis. Type C populations are common on continental shelves associated with finer grained sediments.

Variations in ostracod families and indicator genera/species were studied through the measured section for the purpose of palaeonvironmental interpretation. Identification of population structures for species was used to distinguish between allochthonous and autochthonous occurrences and Whatley's (1988) terminology is followed in the description of familial and specific abundances.

FAMILIAL ABUNDANCES.

BAIRDIIDAE

The Bairdiidae show a marked overall trend as one passes up through the measured section (Fig. 4, p.20). They achieve their greatest numbers at the base of the section in the Lower Morgan Limestone at around 16% of the total fauna and then gradually decline to absent at the top of the sequence. There are 2 major reversals of this overall trend - at C17, the top of the Lower Morgan Limestone, and C2, the recrystallized hard turritellid band just below the top of the Cadell Marl. These two samples however bracket a trend of decreasing numbers to the middle of the Marl (samples C8 and C9) after which this trend reverses and numbers gradually increase to peak again at C2. (C2 is an anomalous sample with very low specimen abundance - only 250 were collected - and an abnormal preservation with most specimens from this sample being either strongly recrystallized or occurring as internal moulds.) Bairdiids are virtually absent from the Upper Morgan Limestone member.

Neonesidea chapmani (Fig. 4, p.20 & Plate 9, p.86) dominates sample LM1 with 13% of the fauna and then gradually decreases in abundance to be absent at the top of the section. This trend is reversed briefly at the base of the upper limestone member. The population structure exhibited by this species begins with type B characteristic of the moderate energy biocoenosis at the base of the limestone, but approaches type C representing the low energy thanatocoenosis in the middle of the Cadell Marl, where no adults were picked from the samples. The large size of this species however would require a high energy current to effectively winnow out the smaller instars, thus

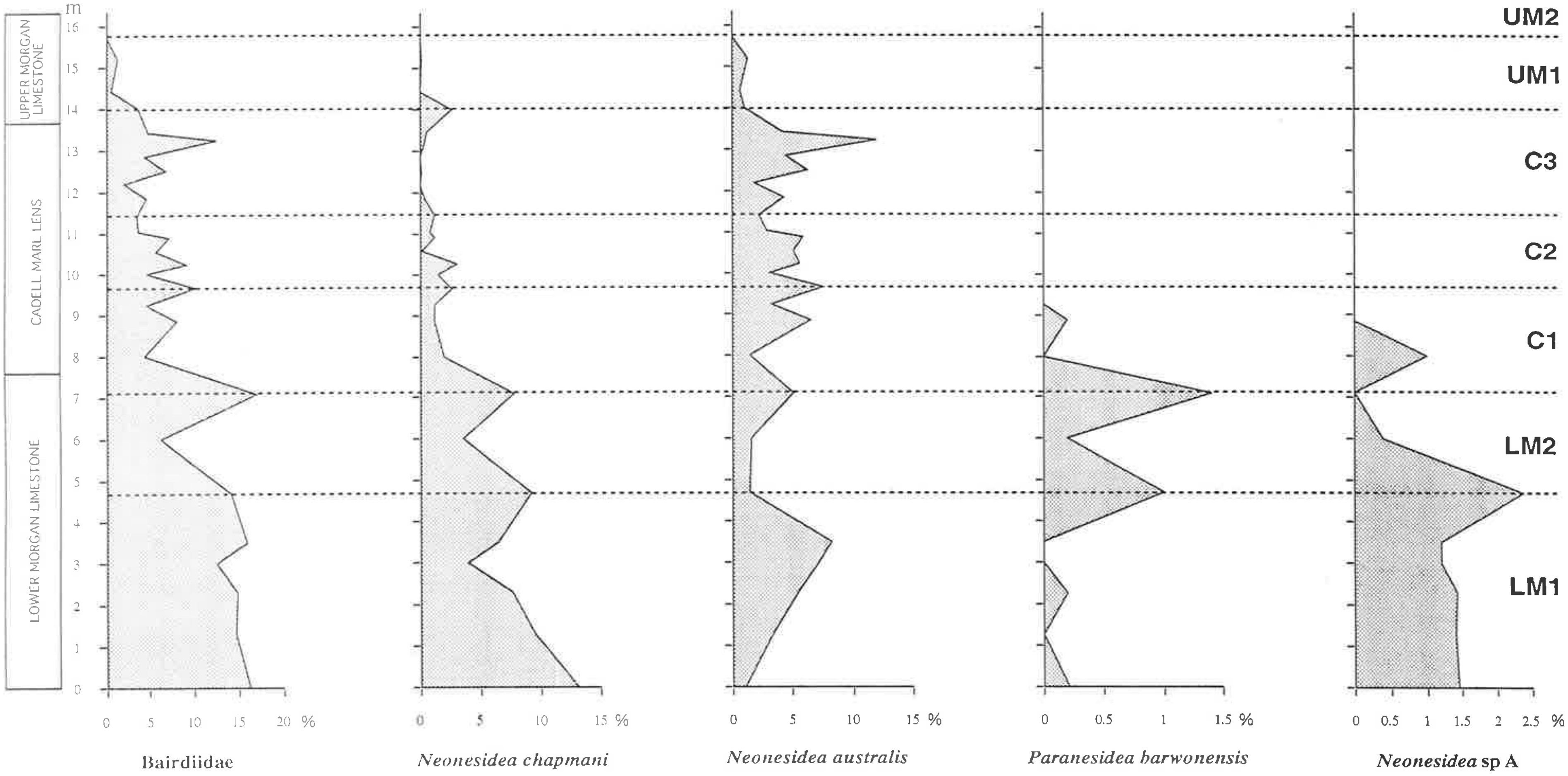


Fig. 4. Abundance variations of Bairdiidae, *Neonesidea chapmani*, *N. australis*, *Paranesidea barwonensis* & *Neonesidea* sp. A. Section has been divided into faunal assemblages LM1-UM2 (see Chap.6)

accounting for the large number of juveniles in the sample in the higher energy lower limestone. *N. australis* (Fig. 4, p.20 & Plate 9, p.86) appears to be fairly stable in abundance through the section fluctuating between 2 and 7%. As with *N. chapmani*, this species is characterized by a type B population structure in the lower limestone, with juveniles becoming more abundant towards the middle of the marl and then returning to the normal type B in the top of the marl and lower units of the upper limestone. Sample C3 presents an anomalous abundance with an Adult : Juvenile ratio of 6 : 1. *N. australis* peaks with 12% at C2 (accounting for the family's abundance at this sample). These populations are indicative of high energy biocoenoses characteristic of shallow environments. *N. chapmani* ranges from nearshore to the outer shelf/epibathyal realm whilst *N. australis* has a similar range but is less common in nearshore environments (Warne 1988).

Paranesidea barwonensis and *Neonesidea* sp. A are restricted to the lower Morgan Limestone member and the base of the Cadell Marl (Fig. 4, p.20 & Plate 9, p.86) whilst specimens referable to *N. fredericki* occur only at the base of the measured section (Fig. 5, p.22 & Plate 9, p.X). *N. fredericki* is reflective of inner shelf nearshore sediments (Warne 1988) whilst *P. barwonensis* ranges in the Batesfordian/Balcombian strata of the Port Phillip Basin from the shallow water Batesford Limestone into the mid shelf Fyansford Clay (Warne 1986).

BYTHOCYPRIDIDAE

The Bythocyprididae are rare in the section, reaching their greatest abundance at C14 with 1.2% of the sample (Fig. 5, p.22).

Bythocypris (*Bythocypris*) *subrectangula* (Plate 9, p.86) is represented solely by juveniles throughout the section, even at its peak abundance. Warne (1990) proposed that *Bythocypris* (*Bythocypris*) *subrectangula* is mainly a shallow water species although it is rare in near-shore facies whilst other representatives of the genus (Plate 9, p.86) are mainly deep water species. High numbers of bythocypridids have also been thought to signify deep conditions (Majoran 1996). No adult valves of *B.* (*B.*)

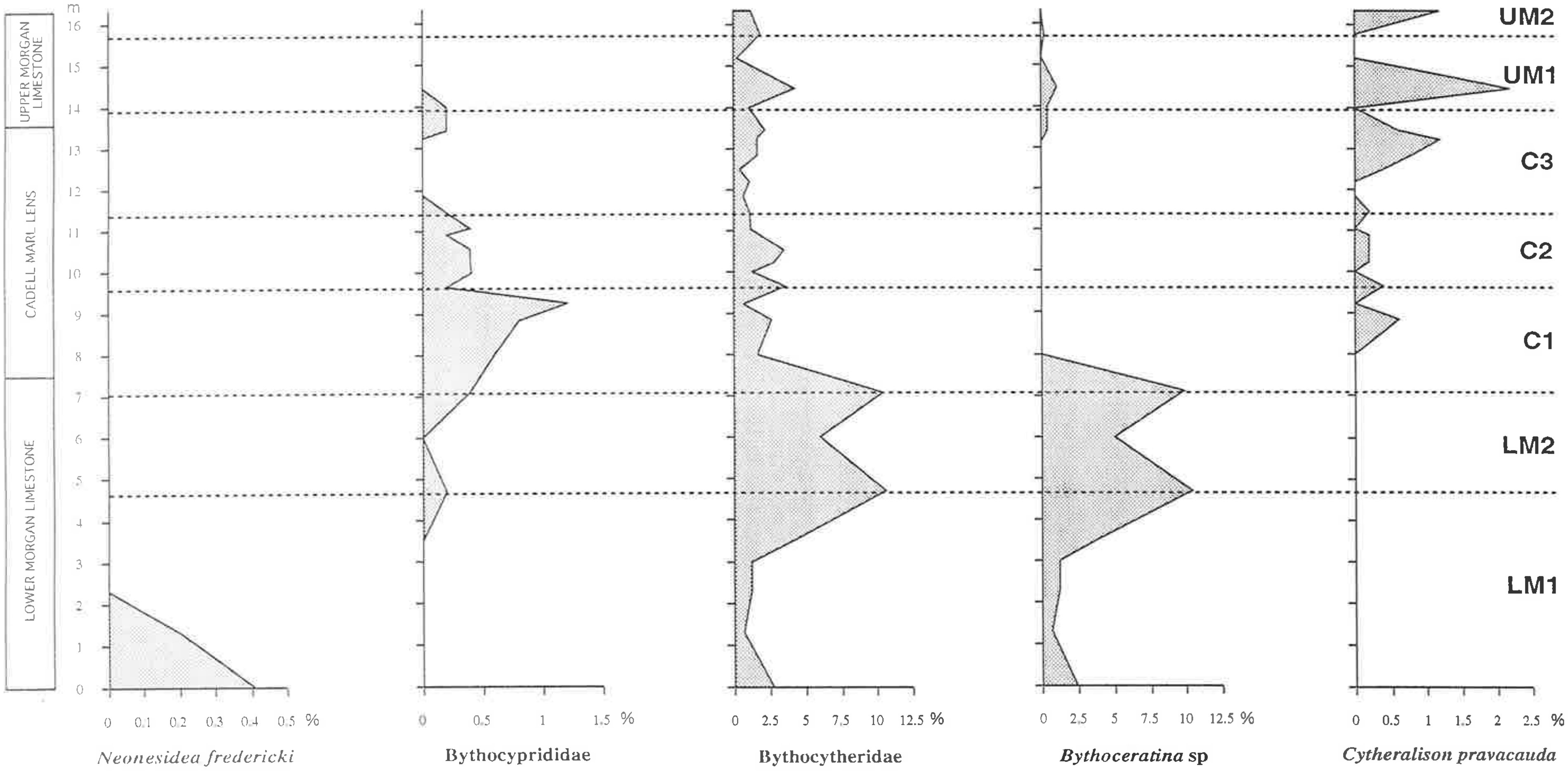


Fig. 5. Abundance variations of *Neonesidea fredericki*, Bythocyprididae, Bythocytheridae, *Bythoceratina* sp. & *Cytheralison pravacauda*. Section has been divided into faunal assemblages LM1-UM2 (see Chap.6)

subrectangula were picked in the samples and so it would appear that its presence here is the result of downslope deposition of allochthonous valves.

BYTHOCYTHERIDAE

The Bythocytheridae (Fig.5, p.22) occur in low numbers in the lowest 3m of the section but from then dramatically increase in abundance at 10% to the top of the lower Morgan Limestone. Numbers drop off at the base of the Cadell Marl to be fairly static around 2% of the fauna for the rest of the section with a light peak at M02.

One species is responsible for the large numbers of the family between 3 & 7m - *Bythoceratina* sp (Fig. 5, p.22 & Plate 12, p.92). It disappears at the base of the marl and does not reappear, albeit in small numbers, until the upper limestone member and so can be seen to be restricted to the Morgan Limestone. Population structures for this species in both limestone members reflect a high energy biocoenosis. McKenzie (1974) uses this genus as a shallow offshore environmental indicator in the Kalimnan-Cheltenhamian of South Eastern Australia. *Cytheralison pravacauda* is restricted to the Cadell Marl and the upper limestone member (Fig. 5, p.22 & Plate 9, p.86). Its numbers (generally between 1 & 3 valves/sample) are too low to establish whether its presence represents a bio- or thanatocoenosis, but it peaks at M02 (14.45m) with 2% of the fauna. It has been recorded as indicative of shallow offshore deposition (25-50m) by McKenzie (1974). *Cytheralison corrugata* has been identified in the upper Cadell Marl and this extends its known range from the Late Oligocene (Janjukian) of the Otway Basin (McKenzie *et al.* 1991). *Hanaiceratina arenacea* (Fig. 6, p.25 & Plate 10, p.88) appears at C16, the base of the Cadell Marl peaks at C13 (1%) and disappears at C7 and so is restricted to the lower half of the Marl. It is an acknowledged warm water and moderately deep water (75m) indicator (McKenzie 1974).

CYTHERELLIDAE

The Cytherellidae are not very abundant in the measured section, attaining their greatest abundance of around 4% at C16, C13 and C4, all of which are shell beds (Fig. 6, p.25).

It is notable that these peaks occur in strata dominated by the filter feeding gastropod *Maoricolpus murrayana*. The lowest abundance for the family occurs at C09 (10.9m). The solitary species of *Cytherella* identified in the samples is ornamented with fine pitting (Plate 10, p.88) and is the dominant species for the family. It occurs throughout the section at an average of 1% but peaks strongly (for this species!) at samples C2, C4 and C13 (shelly beds). The fossate *Platella parapunctata* (Plate 10, p.88) occurs rarely with its greatest numbers concentrated in the lower limestone. Species of *Cytherella* which are found in deeper environments tend to be smooth whereas shallow water forms are generally pitted. The species of *Cytherella* and *Platella* in the samples are punctate or fossate and appear to reflect shallow water conditions. *Cytherella* sp has a strong type B population structure in the lower limestone, shelly beds of the upper marl and the upper limestone member, all indicative of a moderate energy biocoenosis. Population structures in the lower and middle marl are type C, leading the author to suspect these are allochthonous occurrences. *P. parapunctata* also exhibits the same variation with type C populations between C14 and C5 bracketed by type B populations in the lower limestone member and upper marl/limestone. Several species of *Cytherelloidea*, a warm water indicator (Sohn 1962, 1964), have been identified in the section (Plate 10, p.88), adding weight to the case for sub tropical surface temperatures during the Batesfordian of Southern Australia (Gill, 1968). This genus averages less than 1% for the section but has a significant peak at samples C16, the grey shelly marl marking the base of the Cadell Marl. The characteristic surface punctation of *Platella* also indicates relatively warm ambient temperatures (McKenzie et al. 1991). The abundances for this family are too low for any strong environmental interpretations to be gleaned from them, although their relative rarity can be interpreted as reflecting generally well oxygenated conditions throughout the section. There does appear, however, to be a strong association between peak abundances and the *Maoricolpus* beds in the sequence.

CYTHERIDAE

The Cytheridae are not very abundant in the sequence but display an interesting pattern

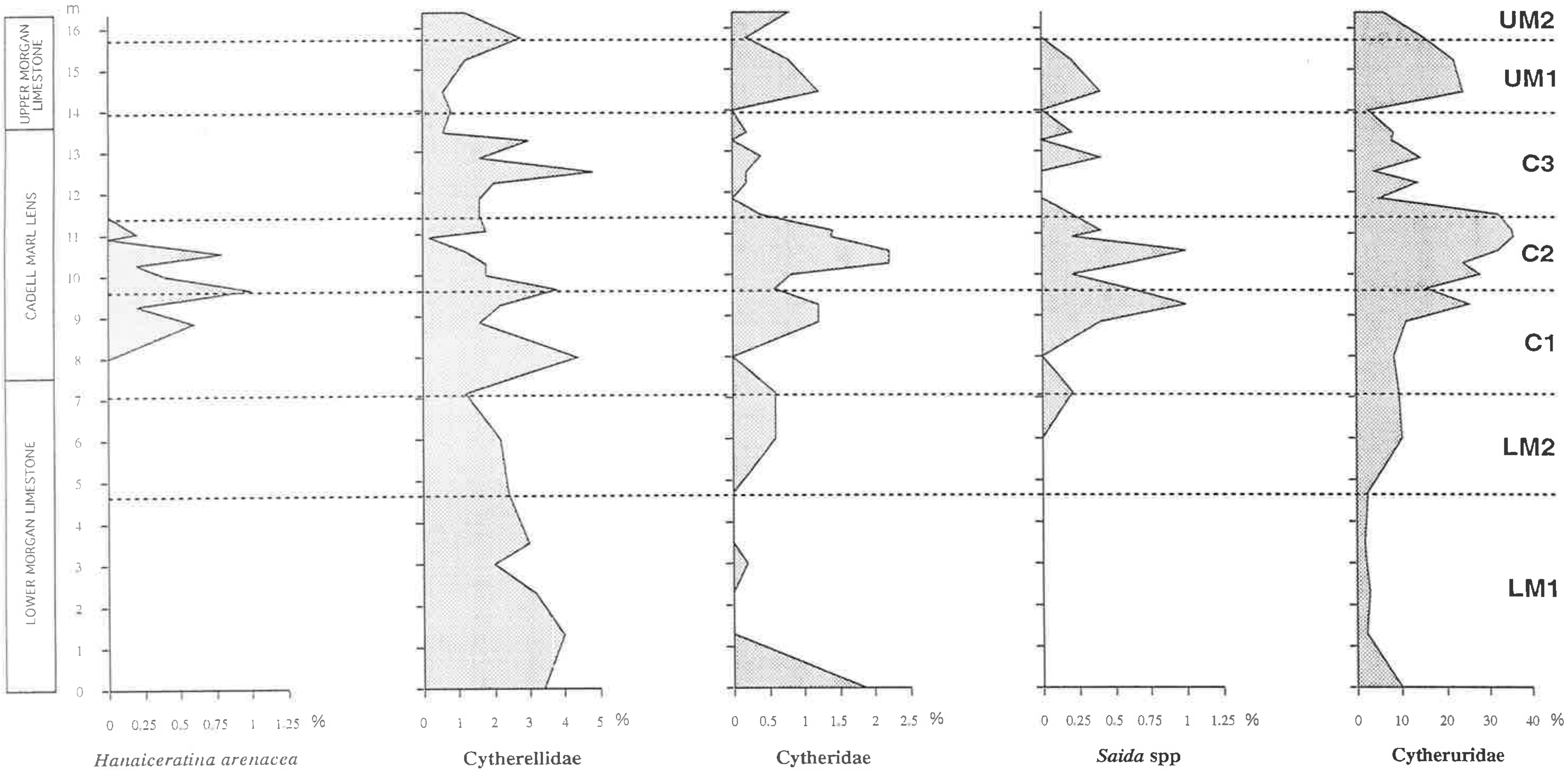


Fig. 6. Abundance variations of *Hanaiceratina arenacea*, Cytherellidae, Cytheridae, *Saida* spp. & Cytheruridae. Section has been divided into faunal assemblages LM1-UM2 (see Chap.6)

as one travels up the section (Fig. 6, p.25). They start at the base of the section with 1.85% from which they then effectively disappear until the Cadell Marl in which they peak at 2.20% in samples C11 and C10 (10.25 & 10.55m respectively). Numbers then drop off sharply to 0% at the top of the Cadell Marl, only to reappear in the Upper Morgan Limestone at around 1%. This pattern mirrors on a smaller scale that of the Cytheruridae.

There are 2 genera of the family present - *Loxocythere* and *Saida*. *Saida* (Fig. 6, p.25 & Plate 10, p.88) is a warm water indicator (McKenzie 1974) and its presence here accords with the subtropical surface temperatures prevalent during the early Middle Miocene in southern Australia (McKenzie 1974, Gill 1968, Whatley & Downing 1983, Warne 1990). McKenzie (1974) has also identified it as characteristic of shallow depths between 25 - 75m, whilst Yassini & Jones (1995) recorded it as ranging from rare on the inner shelf to common in Bass Strait. It is absent from the lower 6m of the section and reaches maximum numbers in the lower half of the marl. *Loxocythere* (Plate 10, p.88) is widely distributed in a variety of Recent environments off southeastern Australia and the 3 species identified in the samples occur in low numbers sporadically throughout the section.

CYTHERURIDAE

The members of the Cytheruridae constitute the most abundant family present in the measured section, a featured reflected by the close similarity between the abundance graph for the family and that for overall specimen abundance (Fig. 6, p.25 & Fig.17, p.49). The lower limestone member is characterised by fairly low numbers of this family between 2 - 10% but numbers increase fairly constantly from the base of the Cadell Marl to reach a peak of 36% at C8 & C9, the middle of the Marl. Numbers then decrease steadily to a minimum of around 3% at the top of the Marl, only to dramatically jump to over 20% in the upper limestone before tailing off at M5. This pattern of a decrease to a minimum at the top of the Marl being followed by a sudden large increase in the lower part of the upper limestone is also reflected in the abundances of the

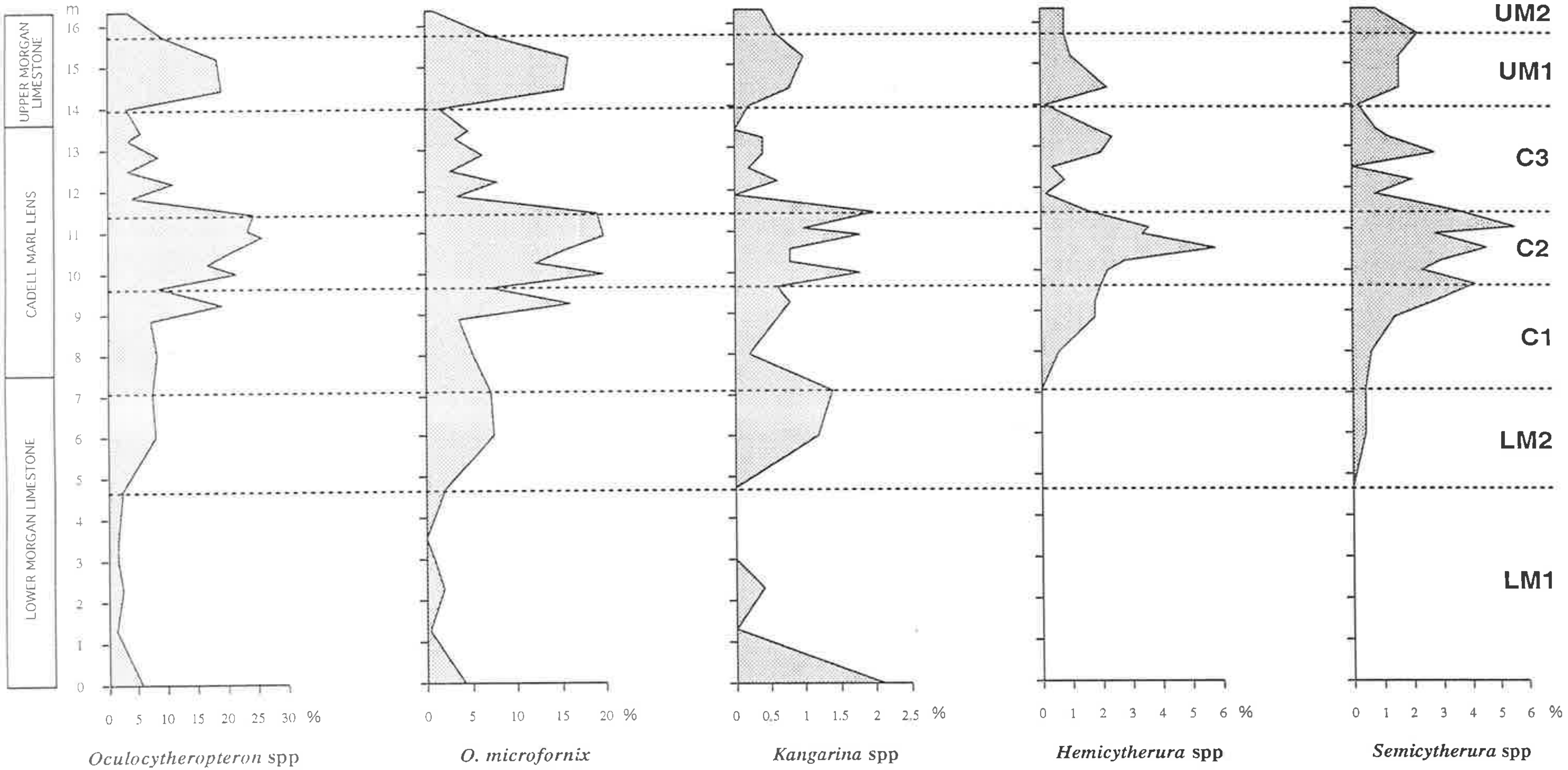


Fig. 7. Abundance variations of *Oculocytheropteron* spp., *O. microfornix*, *Kangarina* spp., *Hemicytherura* spp. & *Semicytherura* spp. Section has been divided into faunal assemblages LM1-UM2 (see Chap.6)

Cytheridae, Loxoconchidae and to some extent, the Pontocyprididae.

The 5 species of *Oculocytheropteron* and *Cytheropteron* (Fig. 7, p.27 & Plate 11, p.90) which have been identified in the section are uncommon in the lower limestone but they dominate the Cadell Marl Lens peaking with over 25% at Tate's (1885) "blue clay" (C8) then falling in abundance to around 5% at the top of the marl. In the upper limestone their numbers increase once again to almost 20% before dropping off to 5% at the top of the section. The dominant species by far is *O. microfornix*. (Fig. 7, p.27 & Plate 11, p.90), reaching abundances of almost 20% of the total ostracod fauna in samples from the lower and middle marl. Population structures for this species is type B in the lower limestone and lower marl, type C in the middle marl, type B in the upper marl and type C in the upper limestone member.

Kangarina spp are relatively uncommon with abundances fluctuating between 0 - 2% (Fig. 7, p.27 & Plate 11, p.90). Examination of a smoothed graph using a 3pt running average shows there to be a drop in abundance from the base of the section to LM4 and then a general rise to a peak at C8/9, from which numbers drop to the top of the marl, only to rise again in the upper limestone. This pattern is a small scale reflection of the abundance graph of the family as a whole. In the Tertiary of southern Australia *Kangarina* is generally associated with assemblages indicative of shallow (25 - 75m) warm to warm-temperate marine environments and open ocean conditions (McKenzie 1974). Yassini & Jones (1995) report it as uncommon across the inner and middle shelf off the NSW coast.

Hemicytherura spp are absent from the lower limestone member (Fig. 7, p.27 & Plate 11, p.90). Their numbers peak with 6% at C10 (10.55m) before gradually trailing away to 1% at the top of the section. Population structures are typical of a medium/low energy biocoenosis in the marl.

Semicytherura spp follow the abundance variations of the family (Fig. 7, p.27 & Plate 12, p.92), as with *Oculocytheropteron* and *Kangarina*. They are absent in the lower 5m of section and are rare in the lower limestone. They peak in the middle of the marl with 5% where they exhibit a good population structure characteristic of a low energy

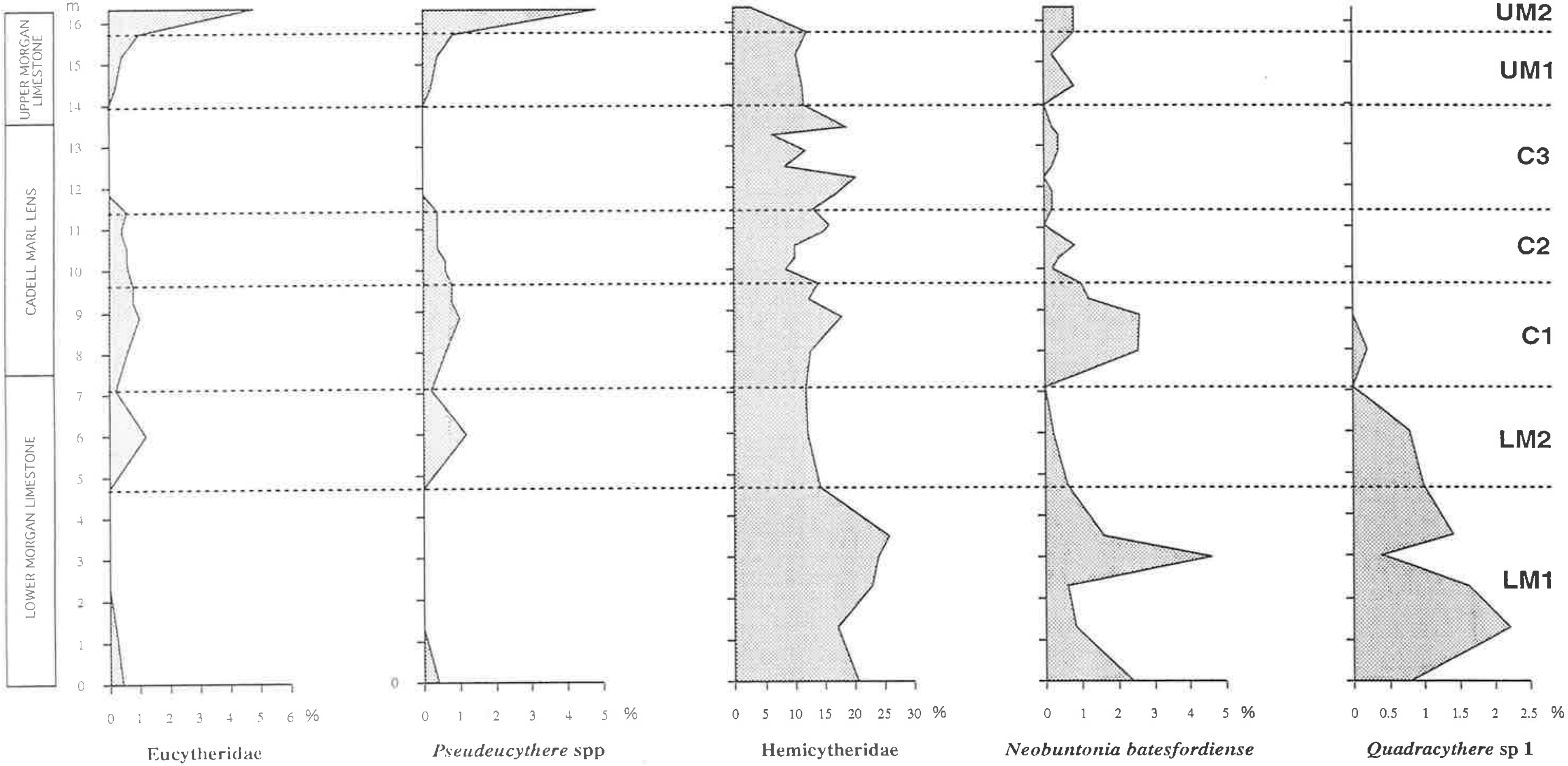


Fig. 8. Abundance variations of Eucytheridae, *Pseudeucythere* spp, Hemicytheridae, *Neobuntonia batesfordiense* & *Quadracythere* sp. 1. Section has been divided into faunal assemblages LM1-UM2 (see Chap.6)

biocoenosis. Numbers drop away to the top of the marl and then become abundant in the upper limestone. This is a very diverse genus with 9 species having been identified in the samples.

EUCYTHERIDAE

The Eucytheridae (Fig. 8, p.29) occur rarely in the lower 5m of the section and then are uncommon at around 1% of the total fauna until C6 where they disappear and are absent for the upper half of the marl. They reappear at the base of the Upper Limestone and their numbers increase steadily to reach their greatest abundance (4.8 %) at the top of the section. This pattern closely reflects that of the Pectocytheridae. According to McKenzie (1974), eucytherids are absent from sediments in Port Phillip Bay, Victoria, but occur in assemblages from oceanic littorals and Bass Strait. Population structures and their relatively small size would suggest their presence in the Cadell Marl as the result of downslope deposition. High numbers in the top of the section are characterised by the type B population structure of a shallow near shore facies biocoenosis.

3 species of *Pseudeucythere* are responsible for the pattern observed in this family's abundance graph (Fig. 8, p.29 & Plate 13, p.94).

HEMICYTHERIDAE

The Hemicytheridae exhibit a slight overall decrease going up through the section and are generally fairly abundant (except in the enigmatic M5 sample) ranging from between 25% and 6% (Fig. 8, p.29). In the lower Morgan Limestone they average over 18% of the total ostracod fauna, 13% in the Cadell Marl and only 9% in the upper limestone. A closer examination of the abundance graph shows some interesting trends. Peak abundance is at LM5 with 26% which coincidentally marks a low point for the Krithiidae and Leptocytheridae. From here numbers decrease sharply to less than 15% for the rest of the lower limestone. Against this is a reverse for the Krithiidae and Leptocytheridae which show strong increases over this interval. There is also a change in dominance between the Hemicytheridae and Bythocytheridae in the lower limestone member. The

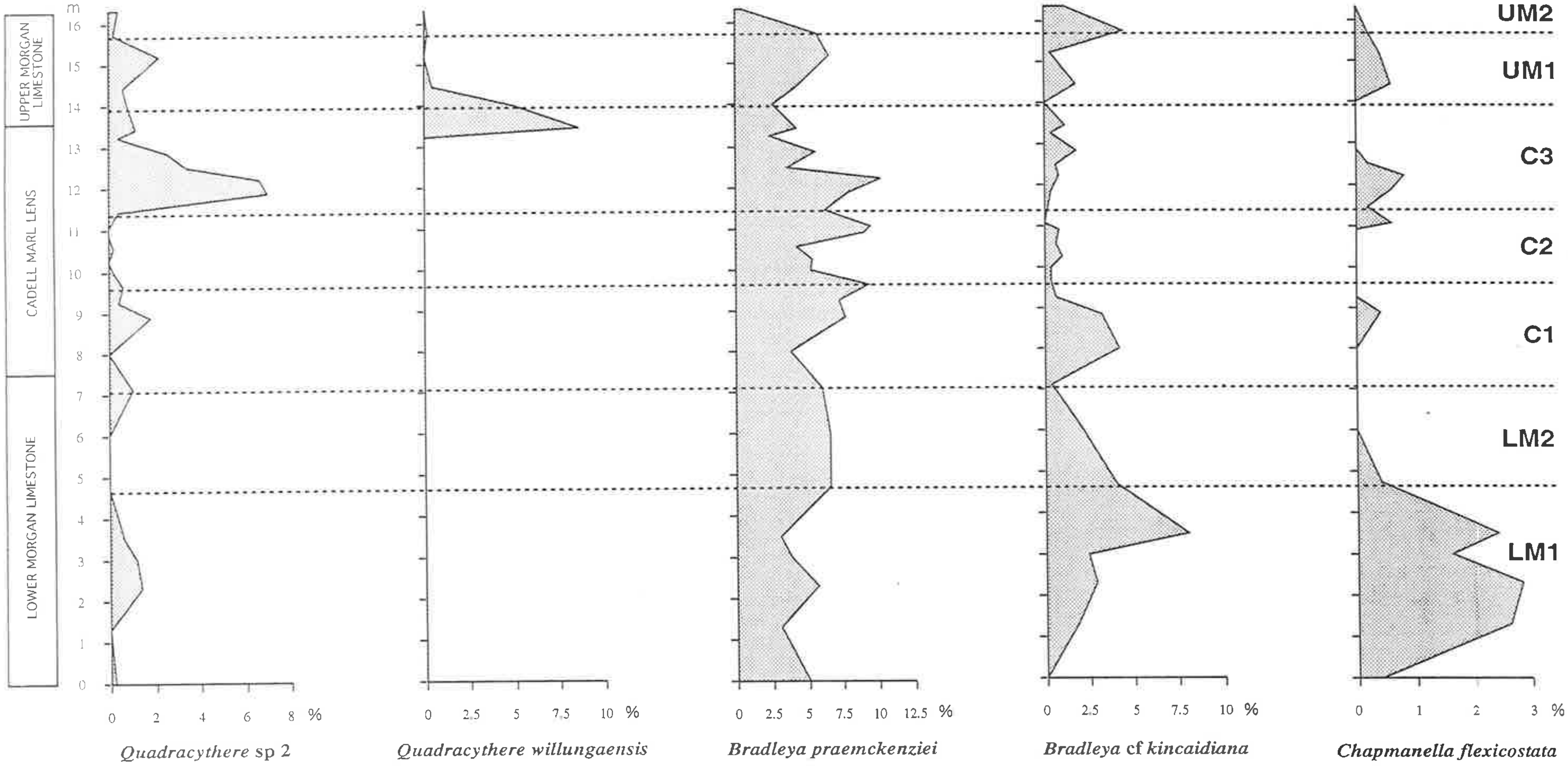


Fig. 9. Abundance variations of *Quadracythere* sp. 2, *Q. willungaensis*, *Bradleya praemckenziei*, *B* cf *kincaidiana* & *Chapmanella flexicostata*. Section has been divided into faunal assemblages LM1-UM2 (see Chap.6)

Cadell Marl is characterised by a peak of 20% at C05 bracketed by 2 sharp drops between C02 & C04 (6% - 8%) and C13 & C10 (8% - 10%). Both of these intervals correspond to turritellid zones in the section. The upper Morgan Limestone is characterised by fairly static numbers of 11% - 12% except for M5 where this family reaches its lowest abundance with less than 2%. The Hemicytheridae have been inferred as indicative of shallow marine conditions (J. Neil *pers. comm.*)

Neobuntonia batesfordiense has an average abundance of less than 1% throughout the section (Fig. 8, p.29 & Plate 12, p.92) with peaks at LM4 (4.6%) and C16/15 (2.6%) where it exhibits a type B population structure.

There have been 3 species of *Quadracythere* identified in the samples each with a correspondingly distinctive abundance graph. *Q.* sp. 1 (Fig. 8, p.29 & Plate 13, p.94) is restricted to the lower limestone unit where it ranges from 2% to 0%, showing a very strong type B population structure at its highest concentration (A:J = 9:2). *Q.* sp. 2 (Fig. 9, p.31 & Plate 13, p.94) ranges throughout the section at an average of less than 1% but has a strong peak of 7% at C6 (the 2nd *Maoricolpus* bed) with a population structure of a high energy biocoenosis. *Q. willungaensis* (Plate 13, p.94) appears at C1 with a strong peak of 8.6%, dropping to 5% at M01 and then effectively disappears from the rest of the section (Fig. 9, p.31). Both these samples have population structures reflective of a high energy biocoenosis.

2 species of *Bradleya* occur in the section - *B. praemckenziei* (Plate 13, p.94) and *B. kincaidiana* (Plate 13, p.94). *B. praemckenziei* is fairly common averaging 5.5% for the total section (Fig. 9, p.31). Numbers move between 3% and 6% in the lower limestone but are fairly static with type B populations. The Cadell Marl is characterised by short scale fluctuations with sharp peaks and drops and it is in this member that the species attains its highest numbers at C8/9 (>9%) bracketed by other peaks both the upper and lower shell beds, all reflecting moderate -lower energy biocoenoses. *B.* cf *kincaidiana* is most common in the lower limestone and base of the marl (average abundance of 3%, with peaks at LM5 and C16 of 8% and 4% respectively) but is rare in the middle of the section before peaking once more at M04 with 5.7% (Fig. 9, p.31).

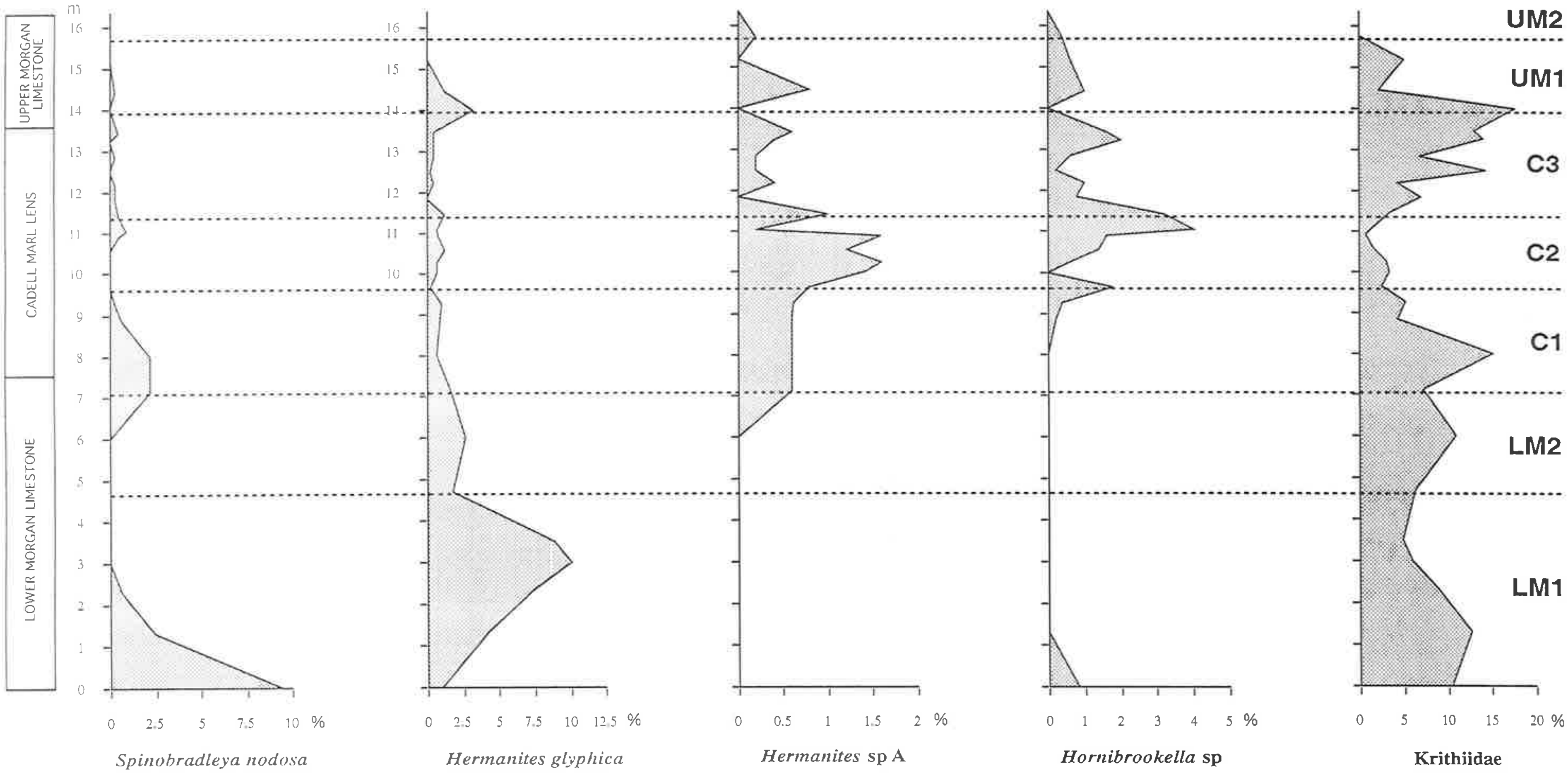


Fig. 10. Abundance variations of *Spinobradleya nodosa*, *Hermanites glyphica*, *H.* sp. *A*, *Hornibrookella* sp. & Krithiidae. Section has been divided into faunal assemblages LM1-UM2 (see Chap.6)

Chapmanella flexicostata (Plate 13, p.94), *Spinobradleya nodosa* (Plate 13, p.94) and *Hermanites glyphica* (Plate 14, p.96) have similar abundance variations (Fig. 9, p.31 & Fig. 10, p.33), being more abundant in the lower limestone where they exhibit type B populations and then rare in the marl with populations that appear to represent low energy thanatocoenoses, as no adults for these species have been found here. In the upper limestone *Hermanites glyphica* peaks with 3% with the type B population structure characteristic of a higher energy environment. A second species of *Hermanites* (*H.* sp A - Plate 14, p.96) is absent from the lower limestone and peaks in the middle of the Cadell Marl with 1.5% and is rare in the upper 4m of the section (Fig. 10, p.33). *Hornibrookella* sp (Plate 14, p.96) follows a very similar abundance pattern (Fig. 10, p.33).

KRITHIIDAE

The Krithiidae show an interesting and useful variation in abundance as one passes up through the section (Fig. 10, p.33). The lower limestone is characterized by gradually fluctuating numbers between 5% & 10%, achieving maximum abundance at a peak at the boundary with the Cadell Marl at 15% of the total fauna. As one passes into the marl, abundance drops away steadily to less than 1% at the middle. Numbers then rapidly increase to a peak of almost 18% at the base of the upper limestone, only to drop away to 0% for the top of this unit.

2 quite distinct species of *Parakrithella* sp. (Fig. 11, p.35 & Plate 14, p.96) dominate the abundances for this family whilst a single *Krithe* species (*K. nitida* - Plate 14, p.96) occurs more rarely (Fig. 11, p.35). Both *Parakrithella* species, a genus characteristic of shallow shelf depths, occur in the lower limestone member with a combined average of around 10%. *P.* sp 2 disappears above the change from the massive white bryozoal limestone to the marl/limestone alternation at the top of this unit (C18, C17). *P.* sp 1 continues to be common to abundant (7 - 14%) in the top of the lower limestone until sample C16 from which it drops away to be virtually absent in the middle of the Cadell Marl (C10). Numbers of this species rise evenly to peak at the base

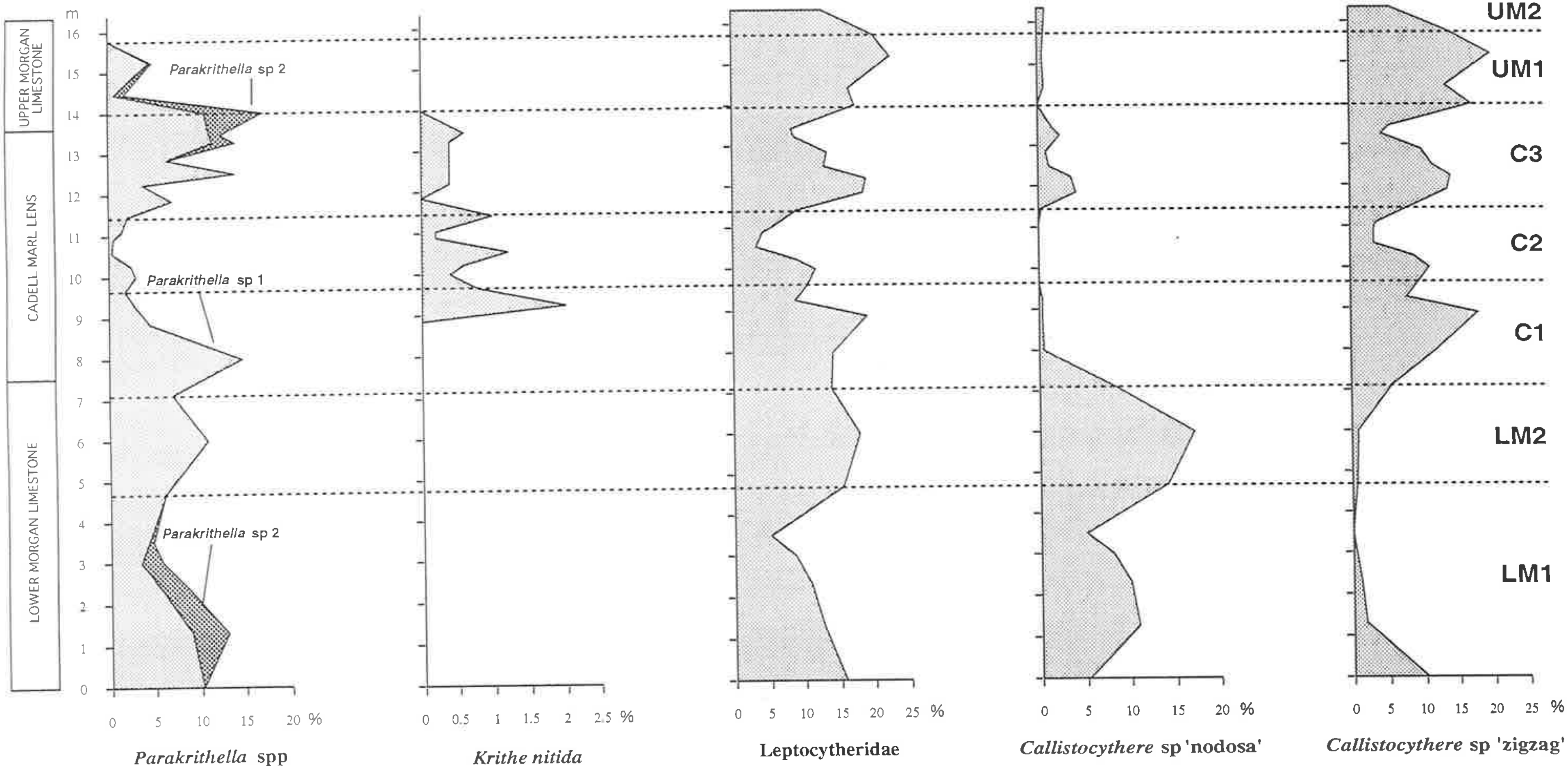


Fig. 11. Abundance variations of *Parakrithella* spp., *Krithe nitida*, Leptocytheridae, *Callistocythere* sp. "nodosa" & *Callistocythere* sp. "zigzag". Section has been divided into faunal assemblages LM1-UM2 (see Chap.6)

of the upper limestone. *P.* sp 2 reappears suddenly at the top of the Cadell Marl (C2) and peaks rapidly with 6.4% of the fauna low in the upper limestone (M01) before disappearing just as quickly. Total abundances for *Parakrithella* drop sharply above 14m (M01) to be absent in the upper samples. It should be noted that the population structure of both species of *Parakrithella* for the entire stratigraphic section is an extreme type B with ratios of adults : juveniles of 30-50 : 1 being the norm. *Krithe,* recognised as abundant in deep water environments (Whatley & Quanhong 1993, Coles *et al.* 1994), shows a reverse of the abundance graph of *Parakrithella,* being absent in the lower limestone then appearing with a peak abundance of 2% low in the Cadell Marl (9.25m - C14), then decreasing steadily until it disappears at the top of the marl.

LEPTOCYTHERIDAE

The Leptocytheridae are abundant in the measured section and average just under 13% for the lower limestone (Fig. 11, p.35). These numbers prevail into the Cadell Marl, but as one approaches Tate's "blue clay", abundance drops to between 3 & 4%. From here numbers rise again except for a drop at C01/C02 (the interval where we get a peak in the larger sized ostracods such as the Bairdiidae, Cytherellidae, Hemicytheridae, Pectocytheridae, Trachyleberididae and Xestoleberidae.) Leptocytherids are abundant in the upper limestone (16 - 22%) but diminish in the top sample.

There are 7 species of *Callistocythere* in the samples with one leptocytherid species tentatively referred this genus. The majority of specimens can be placed into a nodose species, *Callistocythere* sp "nodosa" (Plate 15, p.98), and into what the author believes to be a highly variable species, *Callistocythere* sp. "zigzag", so named for the appearance of it's ornament of ridges (Plate 14, p.96). A close examination of the several morphotypes of this latter species under the SEM has shown them to all have the same ornament pattern with variation in appearance occurring as one or more of the ornament elements becomes more developed (see Plate 14, p.96, figures H - J showing variation up section). Whitening of specimens with NH_4Cl proved to be an invaluable method for facilitating the separation of the various morphotypes under the binocular microscope.

It is possible that the variation in ornament may be linked to environmental parameters. Morphotypes can be referred to some of Neil's 1992 unpublished species but his differentiation is not followed here. He himself noted that "sculptural variability is a recognised trait of some *Callistocythere* spp." and that further investigation of substantial populations may reveal that his separate species do fall within the range of intraspecific variability of one species. The leptocytherid fauna of the lower limestone member (except for the lowest sample LM1) is dominated by the nodose species (10% - 17%) which exhibits an extreme type B population structure which alters to a more normal type B (*ie* more juveniles) at the top of the lower limestone (Fig. 11, p.35). This species dramatically decreases to disappear at the base of the marl. It reappears in small numbers in the upper part of the marl (C06 - C01) where once again it has an extreme type B population structure. Replacing *Callistocythere* "nodosa" in the Cadell Marl is the highly variable species *Callistocythere* sp. "zigzag" which peaks with 19% at C15 at the base of the marl (Fig. 11, p.35). Population structure low in the marl is a lower energy type B with abundant later instars and adults. Abundance decreases to a minimum of 3% across the middle of this unit except for a reversal at C12/13 - the lower shell bed. Population structure at C9/8 approaches type C with an adult/juvenile ratio of over 1 : 4. Except for a sudden drop at the anomalous C2 interval, abundance of this species increases from the middle of the marl to reach a peak at the middle of the upper limestone from which numbers decrease to the top of the section. A sharp peak with in this interval correlates with the "*Maoricolpus*" zone between C6 & C4 where population structure reverts to the high energy extreme type B (A:J = 4:1). It would seem that bioturbation may accentuate the effects of current energy in the samples and contribute to the winnowing out of smaller juveniles, such as in sample C3. This species was originally separated into a complex of three similar but morphologically distinct species. An examination of the adult : juvenile ratios of the 2 dominant morphotypes appeared to mirror each other suggesting the possibility that the valves of one were juveniles of the other. This has been substantiated by electron microscope study.

Callistocythere is typical of warm to temperate shallow marine environments, but has a

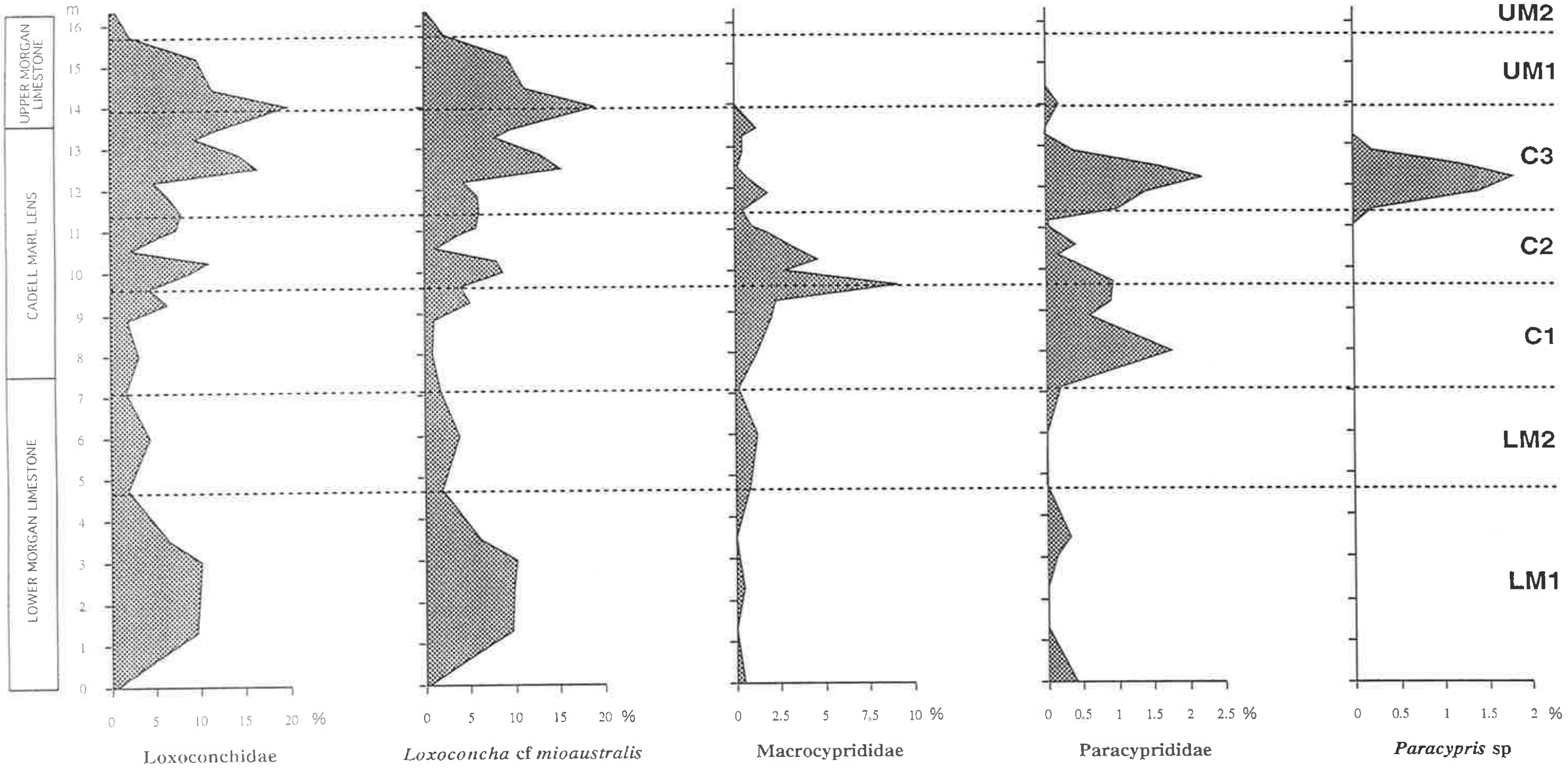


Fig. 12. Abundance variations of Loxoconchidae, *L.* cf *mioaustralis*, Macrocyprididae, Paracyprididae & *Paracypris* sp. Section has been divided into faunal assemblages LM1-UM2 (see Chap.6)

known depth range extending beyond 50m (McKenzie 1979), and in recent environments ranges extensively from the intertidal zone to the depths of Bass Strait (Yassini & Jones 1995). It appears to be a cosmopolitan genus with respect to depth.

LOXOCONCHIDAE

This family exhibits populations characteristic of a high energy biocoenosis in the lower part of the section, with numbers climbing from less than 1% to a peak of 10% in the middle of the lower limestone then decreasing to the base of the Cadell Marl (Fig. 12, p.38). Between LM6 and C5 numbers fluctuate between 2% & 8%, with a small peak occurring at C11/12 - the lower shelly bed. Population structures indicate a lower energy environment in the lower and middle marl. Abundances rise to a maximum of 20% at the top of the Marl, only to drop sharply away into the upper limestone. There is a sharp peak at C4, the upper shell bed. Population structures at the samples of the upper marl and upper limestone are on the whole extreme type B.

Loxoconcha sp. cf *L.mioaustralis* Neil 1992 (Plate 15, p.98) is the dominant species for the family and as such, its abundance graph is effectively the same as that of the family (Fig. 12, p.38). In the lower parts of the lower limestone, this species is one of the dominant species in the samples, and also in the upper samples of the marl and lower part of the upper limestone. 4 species of *Loxoconcha* and 2 species of *Microceratina* have been identified in the samples (Plates 15, p.98 & 16, p.100).

MACROCYPRIDIDAE

The Macrocyprididae are restricted to the lower Morgan Limestone and the Cadell Marl - they are absent from the upper limestone (Fig. 12, p.38). They have an average abundance of around 1% for these units but rise to a very sharp peak of over 9% of the total fauna at C13 (9.65m). Due to their relatively huge size (often > 2mm) they occur generally as broken valves. At C13 the adult : juvenile ratio is approximately 1:1, possibly indicative of a relatively high energy environment, but also a reflection of the fragility of juvenile carapaces. It should be noted that in this sample families with large species experience peaks as well - the Bairdiidae, Cytherellidae & Pontocyprididae. C13 is also the bottom unit of a rich shelly layer.

This family is represented by 2 species of *Macromckenzia* (Plate 16, p.100) including *M. porcelanica*, a species previously identified from the Miocene of southern Australia (Whatley & Downing 1983), one possible *Macrocyprina* and 1 placed in *Macroscapha* (Plate 16, p.100). Due to their large size and delicate nature of juvenile carapaces, specimens are often fragmentary and can only be identified to family level. The dominant species is *Macromckenzia porcelanica*. All species reflect a biocoenosis at the peak occurrence at C13 (the apparent skewness towards adults here is most likely an artifact of the fragility of juveniles).

PARACYPRIDIDAE

The paracyprids are generally rare in the section, averaging 0.4% for the lower limestone, 1% in the marl and 0.1% in the upper limestone. They appear to be generally confined to the marl with 2 peaks of 1.7% at C16 and 2.2% at C5 (Fig. 12, p.38) bracketting a steady decline to and rise from the middle of the marl (C8 & C9).

This family is represented by a species tentatively referred to ?*Pontocyprella* and one of *Paracypris*. ?*Pontocyprella* (Plate 16, p.100) is rare in the lower limestone but peaks strongly at the base of the Cadell Marl from which numbers decrease quite rapidly over the next 3m and then occurs sporadically through to the top of the marl. The species of *Paracypris* (Plate 16, p.100) appears quite dramatically between 11.05m and 13.25m (C8 - C2) reaching a peak of 1.8% at C5 with an extreme type B population (Fig. 12, p.38).

PARADOXOSTOMATIDAE

Paradoxostomatids (Plate 16, p.100) are generally rare (<1%) throughout the section with a small peak of almost 2% in the lower Cadell Marl (C14) (Fig. 13, p.41).

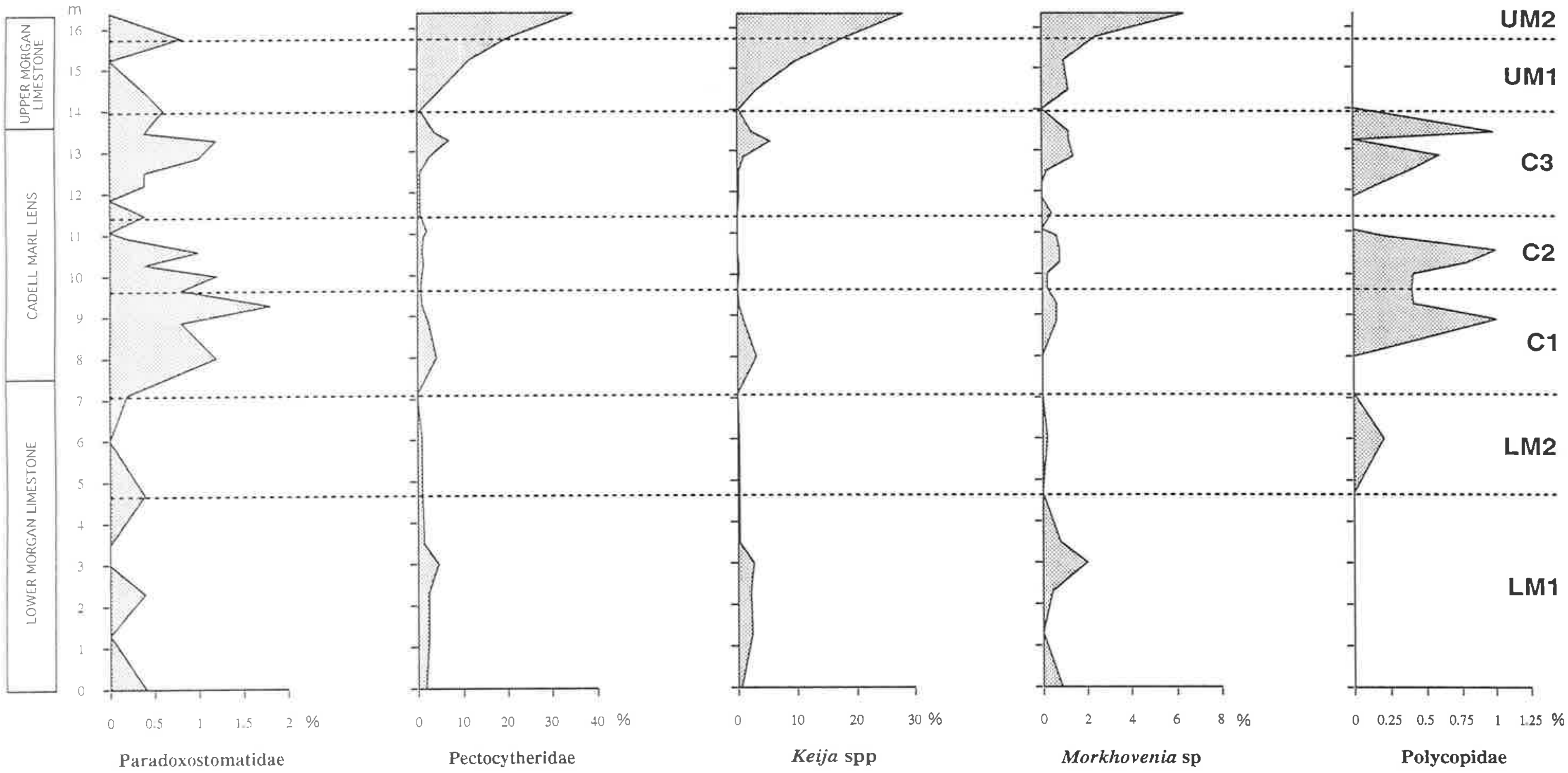


Fig. 13. Abundance variations of Paradoxostomatidae, Pectocytheridae, *Keijia* spp., *Morkhovenia* sp. & Polycopidae. Section has been divided into faunal assemblages LM1-UM2 (see Chap.6)

PECTOCYTHERIDAE

The pectocytherids show a dramatic increase in abundance up through the section, with average numbers ranging from both 1.7% in the lower limestone and in the marl, to 13.9 % in the upper limestone where they are the dominant family, reaching a peak of 34.8% at M5 (Fig. 13, p. 41). Pectocytherids are indicative of shallow marine shelf environments (McKenzie 1979).

The dominant genera for this diverse family are *Keijia* and *Morkhovenia* with 3 species of *Munseyella*, including *M. splendida*, occurring infrequently. *Keijia* (Fig. 13, p. 41 & Plate 17, p.102) is represented by 6 species and follows the abundance pattern of the family with low numbers and low diversity in the bottom 3.5m of the lower limestone (2 species - *Keijia* sp A Neil 1992 and ?*Keijia* sp B Neil 1992 accounting for 2%) with type B populations. The genus effectively disappears until the base of the Cadell Marl where *K.* ? sp B Neil, restricted to the lower 9m, briefly reappears with a peak of 3% at C16. *Keijia* occurs rarely in the marl until C2 where *K.* sp A Neil and *K.* sp 3 appear with 5.6% of the fauna characterised by strong type B populations. The upper limestone sees the genus diversify with 5 species responsible for up to nearly 30% of the total fauna for at the top of this unit. *Keijia* dominates the modern shallow marine littoral environment. *Morkhovenia* sp (Fig. 13, p. 41 & Plate 17, p.102) has a similar vertical abundance to *Keijia* spp., being present in low numbers in the bottom 4m of the lower limestone, then encountered sporadically through the Cadell Marl. As with *Keijia* spp, *Morkhovenia* steadily increases through the upper limestone to reach its greatest abundance at M5 with 6.4%. This species exhibits type C populations in the Cadell Marl and type B structures in the upper limestone samples.

The large influx of pectocytherids we find at the top of the section in the Morgan Limestone is associated in southern Victoria with the Pliocene (M Warne *pers. comm.*) This phenomenon has also been recorded in the Middle Miocene (Balcombian) Pata limestone (Neil 1995).

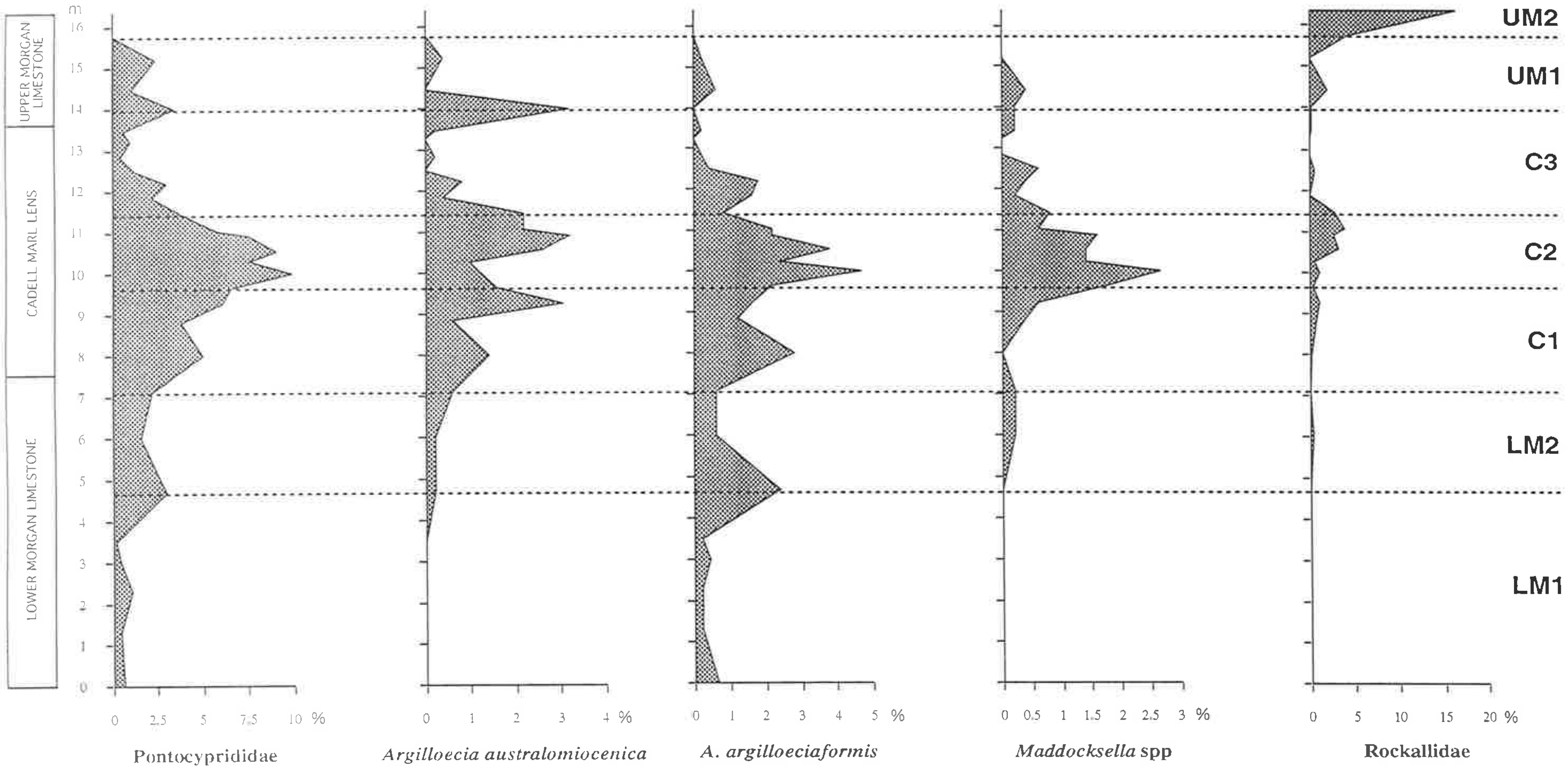


Fig. 14. Abundance variations of Pontocyprididae, *A. australomiocenica*, *A. argilloeciaformis*, *Maddocksella* spp & the Rockalliidae. Section has been divided into faunal assemblages LM1-UM2 (see Chap.6)

POLYCOPIDAE

The Polycopidae occur sporadically through the section, achieving their greatest abundance with 1% at several samples (Fig. 13, p. 41). They are restricted to the upper part of the lower limestone and the Cadell Marl.

Although the Cadell Marl is relatively rich with 5 species of *Polycope* and one referable to ?*Polycopsis* (Plate 18, p.104), all are uncommon members of the fauna. Highly sculptured polycopids are acknowledged as indices for warm seawater temperatures (20°-25°C) (McKenzie 1974). The majority of polycopid species encountered in the measured section are moderately ornamented. Their presence in the section is consistent with previous assessments of palaeotemperatures for the Early Middle Miocene of southern Australia (McKenzie 1974, Gill 1968, Whatley & Downing 1983, Warne 1990).

PONTOCYPRIDIDAE

The members of this family are rare in the bottom 3.5m of the lower limestone but increase steadily from here to peak at 8-10% between C12 and C10. Numbers steadily decrease to the top of the marl, and after two small peaks in the lower portion of the upper limestone disappear by M4 . They are absent from the top sample of the section (Fig. 14, p.43).

Two species of *Argilloecia* are responsible for the abundance pattern of the family - *A. australomiocenica* (Fig. 14, p.43 & Plate 18, p.104) and *A. argilloeciaformis* (Fig. 14, p.43 & Plate 18, p.104). The genus exhibits a gradual increase from 3.5m to peak at 10% with populations characteristic of a biocoenosis between C12 & C10 before steeply dropping away to C2. The base of the upper limestone witnesses a small peak of these species before they disappear. *Maddocksella* (Fig. 14, p.43 & Plate 18, p.104) occurs in low numbers in the marl limestone alternation at the top of the lower limestone and peaks in samples C12 & C13 (the lower) shell beds before decreasing to the top of the Cadell Marl and upper limestone. *Propontocypris* (Plate 16, p.100) is absent from the base and top of the section and predominantly rare elsewhere but examination of

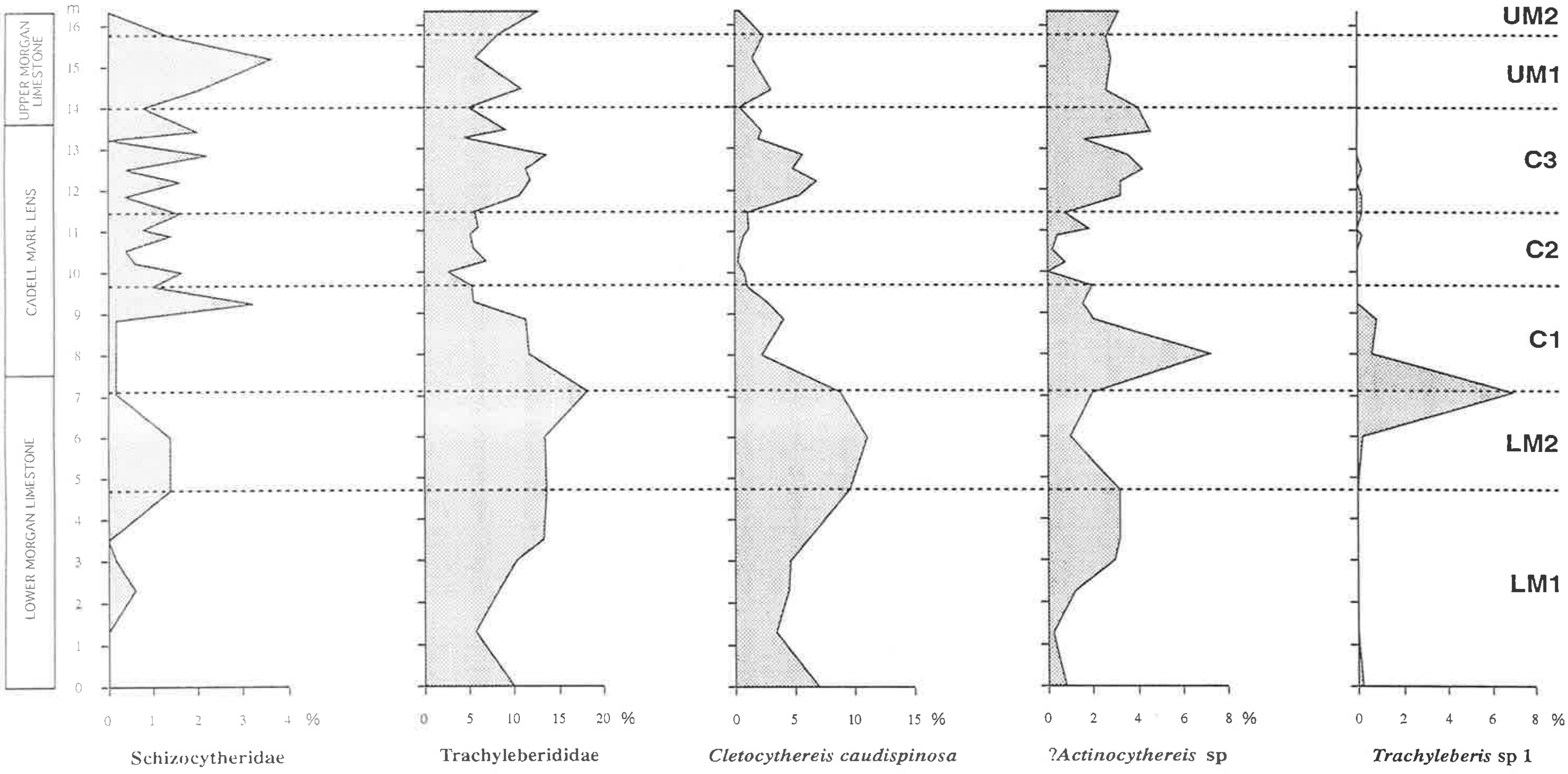


Fig. 15. Abundance variations of Schizocytheridae, Trachyleberididae, *C. caudispinosa*, ?*Actinocythereis* sp. & *Trachyleberis* sp.1. Section has been divided into faunal assemblages LM1-UM2 (see Chap.6)

smoothed data reveals the peak abundance to be around C12.

Argilloecia is characteristic of moderately deep water from 75m (McKenzie 1974) to over 100m (Majoran 1996), whilst *Maddocksella* is typical of shelf deposits from inshore to the uppermost part of the slope (McKenzie *et al.* 1991).

ROCKALLIIDAE

The Rockalliidae (Fig. 14, p.43) are represented by a single species and are confined to the Cadell Marl and the upper member of the Morgan Limestone. Their abundance mirrors that of the Pectocytheridae, with average numbers around 1 - 2% in the lower limestone and marl rapidly increasing to 16% of the fauna in sample M5.

Arcacythere sp (Plate 17, p.102) is restricted to the upper 10m of section, making only one appearance in the lower limestone, albeit with only 2 adult valves, at C18 . From the base of the Cadell Marl, numbers increase to reach a small peak at the blue clay with 3.8%. All occurrences of this species in the Marl have type C population structures associated with a low energy thanatocoenosis. This species then disappears for the rest of the marl before increasing through the upper limestone to peak with 16.4% in the uppermost sample with strong type B populations.

SCHIZOCYTHERIDAE

The Schizocytheridae (Fig. 15, p.45) occur in increasing numbers as one passes up through the section, averaging 0.5% in the lower limestone, 1.1% in the Marl and 1.3% in the upper limestone. The highest abundance for the family is at M03 with 3.6%.

Paijenborchella solitaria ponticola (Plate 16, p.100) is the sole representative of this family in the samples. It has been identified as an indicator of moderately deep water deposition (=75m) by McKenzie (1974). Percentages are very low so population analyses cannot determine whether the occurrences of this species are auto- or allochthonous.

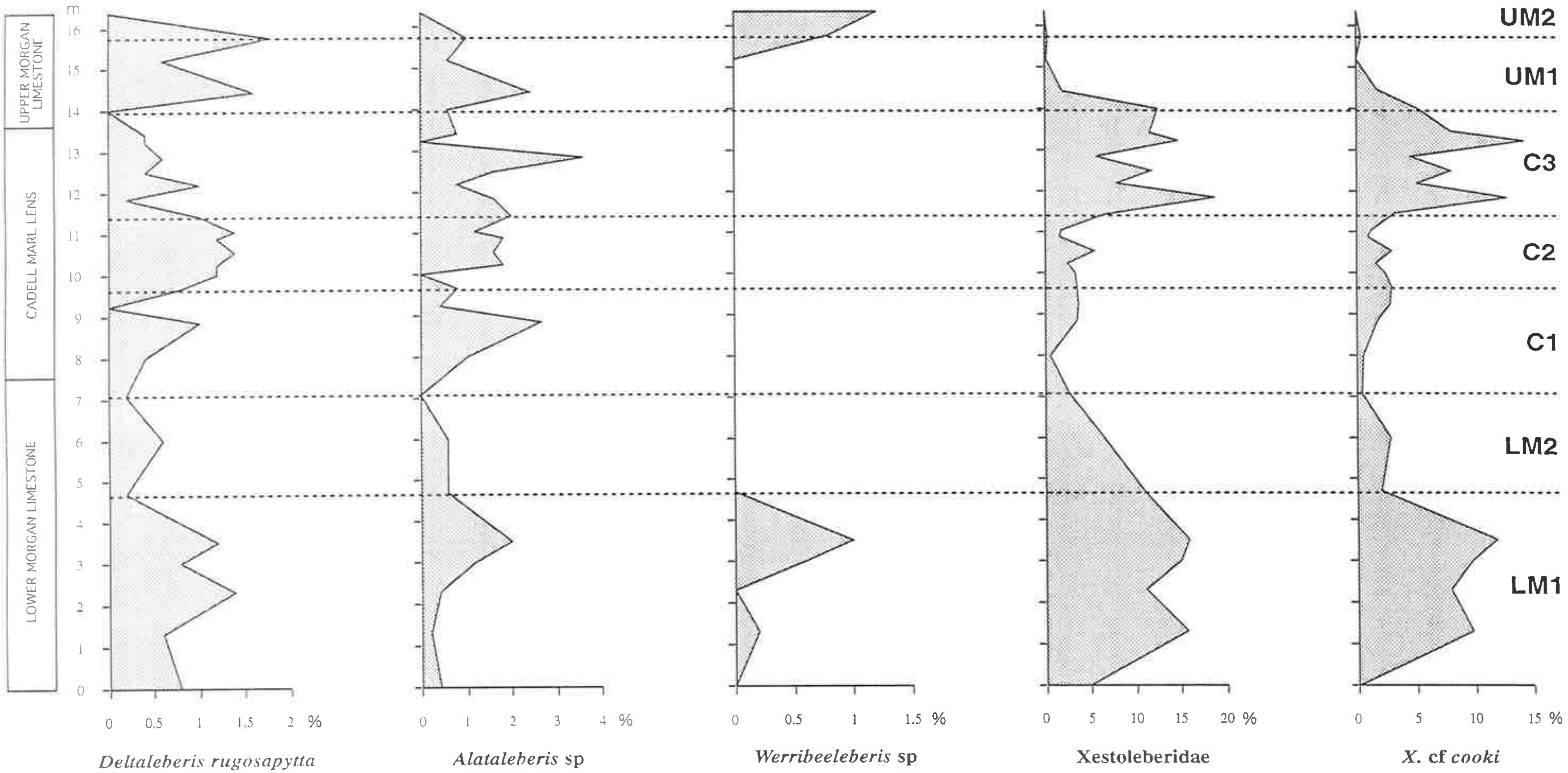


Fig. 16. Abundance variations of *Deltaleberis rugosapytta*, *Alataleberis* sp., *Werribeeleberis* sp, the Xestoleberidae & *X.* cf *cooki*. Section has been divided into faunal assemblages LM1-UM2 (see Chap.6)

TRACHYLEBERIDIDAE

The Trachyleberididae achieve their greatest abundance in the upper part of the lower limestone with 18% at the top of this unit (Fig. 15, p.45). Numbers decrease into the Cadell Marl to average 5% for the lower half. Lowest numbers for the family occur at C12, the lower shell bed. Above the blue clay, abundance increases steadily to 13% at C3 only to drop sharply at C2, the sample with anomalous preservation. Numbers fluctuate through the remainder of the section and finish on a high of 13%. The trachyleberidids are one of the few families to increase in abundance at the top of the upper limestone.

Three species account for the abundances of the family throughout the section: *Cletocythereis caudispinosa*, ?*Actinocythereis* sp. and *Trachyleberis* sp. 1. *C. caudispinosa* (Plate 18, p.104) averages 5% for the bottom 3m of section then increases to 10% for the upper 4m of the lower limestone. Abundance drops away in the lower part of the Cadell Marl then increases through the upper shell bed series (C6 - C2) before decreasing to fairly stable percentages of 2-3% in the upper limestone (Fig. 15, p.45). Population structures indicate moderate energy biocoenoses in the basal 3m followed by apparently higher energy conditions for the rest of the lower limestone and the base of the Marl. Low energy thanatocoenoses prevail in the Cadell Marl even in the upper half where total numbers increase quite strongly from 1% to almost 7%. The upper limestone reflects a low energy environment shallowing to a higher energy towards the top of the section. After experiencing low abundance in the basal 2.3m of the section, *Actinocythereis* ? sp (Plate 18, p.104) reflects higher energy conditions with increased numbers and a strong type B population (Fig. 15, p.45). The strongest peak for this species is at the base of the Marl (7.2%) from where numbers drop away steadily to a low at the middle of this unit only to steadily increase to the top. Numbers remain fairly static in the upper limestone with type B populations. One species of *Trachyleberis* (Plate 18, p.104) is responsible for the increase in family abundance at the top of the lower limestone (7.1m) (Fig. 15, p.45). This species is either extremely rare or absent from the remainder of the section but appears with 7% at this sample with a strong type B population. *Deltaleberis rugosapytta* (Fig. 16, p. 47, Plate 18, p.104) and a species of *Alataleberis* similar morphologically to *A. miocenica* but 50% larger in size (Fig. 16, p. 47, Plate 19, p.106) occur at low concentrations sporadically through the section. A single species of *Werribeeleberis* (Fig. 16, p. 47, Plate 19, p.106) occurs at low percentages (∂1%) in the basal 3m and uppermost 1m of the section.

XESTOLEBERIDAE

Numbers of the Xestoleberidae climb from an abundance of 5% at the base of the section to a peak of 16% at LM5. From here, abundance drops away to the top of this lower unit (<1%) and occurs in low numbers (<5%) in the lower half of the Marl. Once above the middle of this unit, abundance escalates in the upper half of the marl with strong peaks at the 3 *Maoricolpus* beds C6, C4 and C2 with 19%, 12% and 15% respectively. Once above the base of the upper limestone, members of the family become rare and are absent from the top of the section (Fig. 16, p. 47).

Xestoleberis cf *cooki* and *Foveoleberis ?minutissima* are relatively common with both showing similar distribution graphs whilst 2 unidentified species have been tentatively referred to *Microxestoleberis* with another rare minute species assigned as *?Xestoleberis*. *X.* cf *cooki* (Fig. 16, p. 47 & Plate 19, p.106) is absent at the base but then accounts for over 10% up to sample LM5 (3.5m) with population structures indicative of a moderate energy biocoenosis grading into higher energy conditions. Abundance drops to (∂ 2%) the top of the lower limestone with high energy biocoenoses and increase slightly in the lower 3m of the Cadell Marl. No adult specimens of this species were found in this part of the section, indicative of a low energy thanatocoenosis. There are strong peaks in the upper marl at C6 (13%), C4 (8%) and C2 (14%) all indicating moderate energy biocoenoses and then abundance drops away in the upper limestone to less than 1% or absent. *Foveoleberis ?minutissima* (Fig. 17, p.50 & Plate 19, p.106) averages around 5% in the basal 3.5m of the limestone then peaks with (8.8%) at LM6 before dropping away to the base of the Cadell Marl. Population

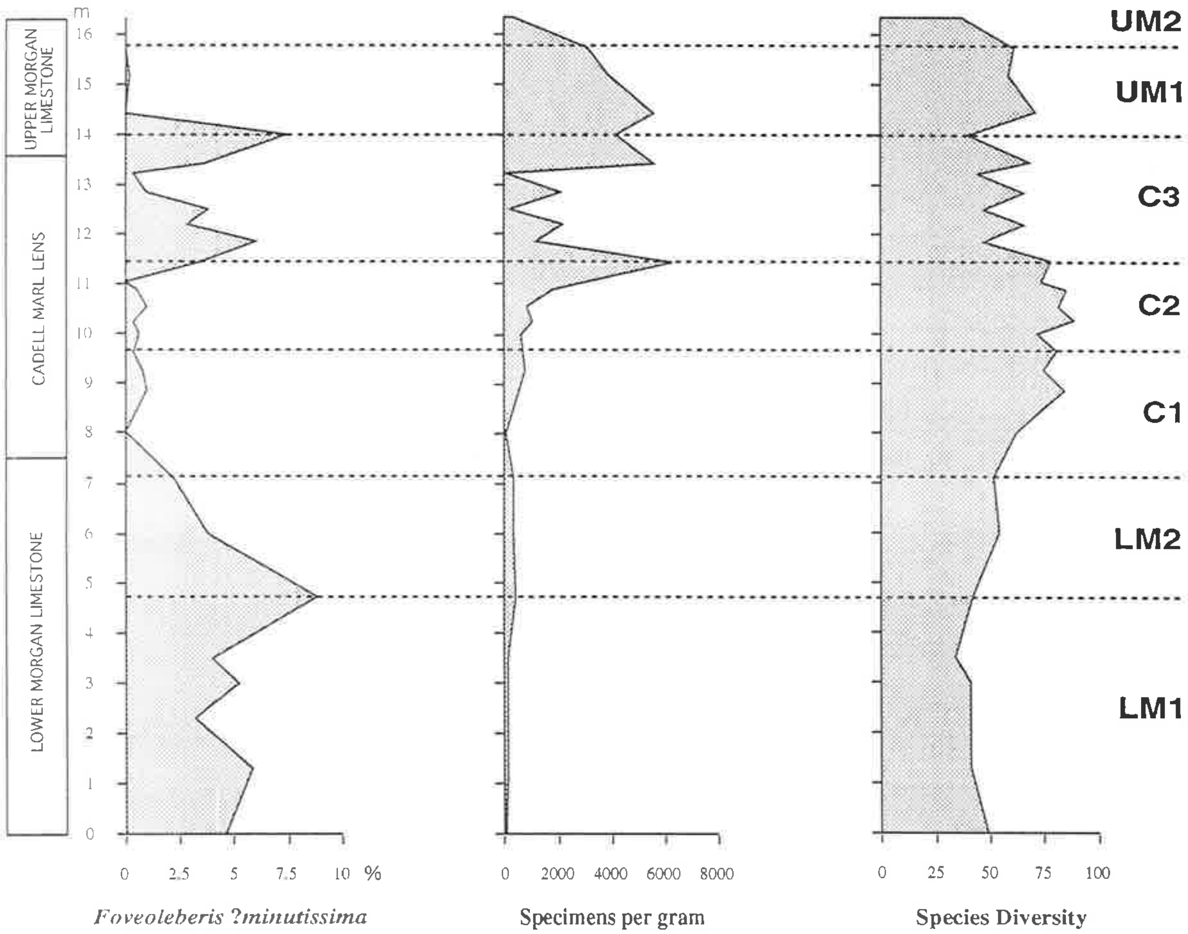


Fig. 17. Abundance variations of *Foveoleberis ?minutissima*, specimen abundance and species diversity for the section. Section has been divided into faunal assemblages LM1-UM2 (see Chap.6)

structures are consistent with a moderate-high energy biocoenosis. The lower 3m of the Marl are characterised by low numbers and no adults (*vide X.* cf *cooki*) reflecting low energy conditions. Repeating the pattern of *X.* cf *cooki* once more, *F. ?minutissima* increases in the upper marl to peak at the turritellide beds and base of the upper limestone, reaching a maximum at M1 with 7.4%. This part of the section is characterised by type B populations. Above M1, *F. ?minutissima* is effectively absent. Xestoleberids are typical of the phytal sublittoral zones (McKenzie & Peypouquet 1984), and *F. ?minutissima* has been recorded as ranging from marginal marine to sheltered marine embayments in recent waters of New South Wales (Yassini & Jones 1995).

6. SUCCESSIONAL OSTRACOD ASSEMBLAGES

In the past many workers reconstructing palaeoenvironments have relied on taxonomic uniformitarianism, using living species to infer the environmental requirements of fossil counterparts. One serious shortcoming of this approach is that the ecology of organisms may well have evolved through time, rendering such comparisons of doubtful value. One method to deal with this problem is to study the entire assemblage as a whole rather than as individual fossils as it is unlikely that all species in the assemblage will have changed their environmental preferences synchronously (Boscence & Allison 1995).

In order to identify any large scale patterns hidden amongst the variation abundances of ostracod families and species of the Morgan Limestone and Cadell Marl type section, it was decided to conduct a cluster analysis based on the species composition of each sample. This enabled the identification of similarity between samples and the recognition of significant changes in ostracod assemblages. The Ward method cluster analysis of the 29 samples discriminates 7 clusters of discernible ostracod assemblages (see Fig.18, p.53). The clusters appear to correlate well with lithologies in the measured section, and can be broadly divided into 2 large groups of ostracod faunas representing those of the lower/middle Cadell Marl and those of the Lower Morgan Limestone and upper Cadell Marl/Upper Morgan Limestone.

A summary of the results and interpretations of the cluster analysis can be seen on Table 1, p.54.

Lower Morgan 1

Samples: LM1, LM2, LM3, LM4, LM5, LM6

Height: 0.00m - 4.70m

This assemblage comes from the white bryozoal limestone of the basal 4.7m of section.

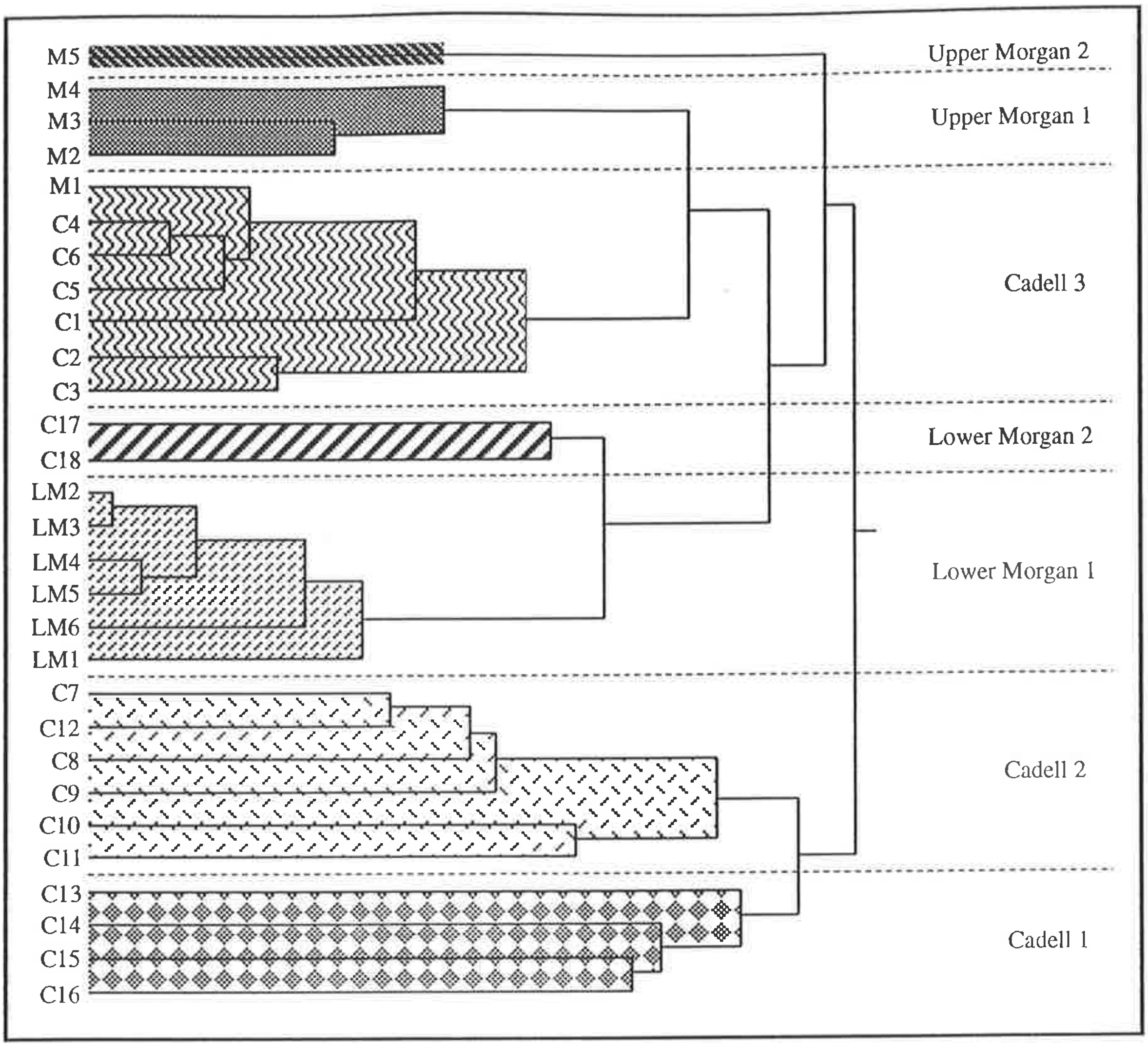


Figure 18. Results of a Ward Method cluster analysis of the 29 samples from the Morgan Limestone and Cadell Marl. 7 clusters can be easily recognised which correspond to distinct lithologies. Note separation of faunas into 2 broad groups representing those of the lower and middle Cadell Marl (Cadell 1 & 2) and those of the rest of the section.

Celleporaria colonies are common (see Plate 4, p.8). The ostracod fauna is composed of high numbers of Hemicytheridae (av. 21%) and Bairdiidae (av. 15%) with less abundant Leptocytheridae (av. 11%), Xestoleberidae (av. 12%), Trachyleberididae (av. 10%) and shallow water Krithiidae (av. 8%). It is also characterised by a slight increase in abundance towards the top of the assemblage for the Bythocytheridae, Trachyleberididae and Pontocyprididae, and a decrease for the Hemicytheridae, Krithiidae and Loxoconchidae. This assemblage has the highest average abundance of bairdiids,

INTERVAL	ASSEMBLAGE	LITHOLOGY	SPECIES DIVERSITY (no. of spp)	SIGNIFICANT OCCURRENCES	INTERPRETATION
15.75 - 16.35m	UPPER MORGAN 2	Recrystallized *Maoricolpus* limestone & brown gypsiferous clay with common *Ditrupa*.	38	Dominance of the Pectocytheridae/ Rockalliidae (28% *Keijia*). Type B populations, with specimens of large species often broken.	High energy nearshore environment with fluctuating sea level & nutrients producing alternation of gypsiferous *Ditrupa* clays and *Maoricolpus* limestones.
14.45 - 15.75m	UPPER MORGAN 1	Alternation of recrystallized limestones and brown clays. Lower limestones with *Celleporaria*, upper limestones with *Maoricolpus*.	64	Strong peak of Cytheruridae & Pontocyprididae at base. Rapidly increasing abundance of Rockalliidae & Pectocytheridae (4 → 25%) up through the assemblage. Strong type B popualtions. Rapidly decreasing numbers of Xestoleberidae & Loxoconchidae.	High energy nearshore environment with fluctuating sea level & nutrients produces the limestone/clay alternation. Overall change from meso/oligotrophy to high eutrophy (*Celleporaria* to *Maoricolpus*).
11.85 - 14.00m	CADELL 3	Alternation of soft marls and hard *Maoricolpus* dominated shell beds.	40 in marls 70 in shell beds	Strong cyclicity between 2 distinct faunas. Shell beds have high numbers of Leptocytheridae, Hemicytheridae, *Parakrithella* spp. and xestoleberids, and peaks for cytherellids. Softer marls have a cytherurid / leptocytherid fauna. Greatest abundance of xestoleberids, loxoconchids & *Parakrithella* in section. Rare *Krithe*.	Overall shallowing sequence from mid shelf (Cadell Marl) to inner shelf (Upper Morgan Lst) conditions overprinted by fluctuating sea level & nutrients which cause strong cyclicity of lithology and associated ostracod faunas.
10.00 - 11.45m	CADELL 2	Heavily burrowed marls	80	Strong increases to peak abundance for Cytheruridae, Cytheridae and Pontocyprididae. Strong decreases in macrocyprids. Lowest percentage of krithiids. Type C populations.	Mid shelf environment with a possible slight shallowing or nutrient drop from Cadell 1 below.
8.00 - 9.65m	CADELL 1	*Maoricolpus* dominated shelly marls.	76	Peaks for Bythocytheridae (with type C populations), Macrocyprididae and *Krithe nitida*. Common *Hanaiceratina arenacea*.	Maximum depth of sequence at mid/outer shelf conditions. Either expansion of OMZ bringing high nutrients and deeper water ostracoda into Murray Basin, or, high runoff flooding shelf with nutrients.
6.00 - 7.10m	LOWER MORGAN 2	*Celleporaria* limestone and marl alternation.	53	Increased numbers of bythocyprids, trachyleberidids with deacresed abundances of xestoleberids and loxoconchids.	Deepening of inner shelf environment from underlying LM1 and development of offshore conditions
0.00 - 4.70m	LOWER MORGAN 1	*Celleporaria* limestone.	41	High numbers of Hemicytheridae, inner shelf bairdiids, xestoleberids, loxoconchids and shallow krithiids (*Parakrithella* spp.). Increasing abundance of trachyleberidids and pontocyprids towards top of assemblage. Type B populations.	Moderate energy nearshore environment deepening towards the top.

Table 1. Summary of ostracod assemblages and their significance.

hemicytherids and xestoleberids for the section. It is the second least diverse assemblage with an average of 41 species per sample and is the assemblage with by far the lowest specimen abundance, with an average of 160 specimens per gram of sediment examined (see Fig. 17, p.50). Rare species (those represented by one specimen) account for only 22% of the fauna. Lower Morgan 1 is most similar to the overlying Lower Morgan 2.

The Hemicytheridae have been inferred as indicative of shallow marine conditions (J. Neil *pers. comm.*) *Neobuntonia batesfordiense* occurs at its greatest abundance in this assemblage (4.6% at sample LM4) with a type B population structure. This species appears to have a variable depth range, from inner to middle shelf depths, as witnessed by its stratigraphic range in the Middle Miocene of the Port Phillip Basin (Warne 1988). *Bradleya praemckenziei* is common and has been interpreted as belonging to the deep water '*dictyon* ' group of *Bradleya* (McKenzie & Peypouquet 1984) but Whatley & Zhao (1993) have since discounted this. It would appear that *B. praemckenziei* is a cosmopolitan species with respect to water depth. *Chapmanella flexicostata*, *Spinobradleya nodosa* and *Hermanites glyphica* are all at their most abundant in Lower Morgan 1 where they exhibit type B populations, and all three are common members of the high energy inshore Muddy Creek Marl (Neil 1992).

Neonesidea chapmani, the dominant bairdiid in this assemblage is a cosmopolitan species but is more common than *N. australis* in shallower inner shelf environments (Warne 1988). Warne also noted that *Bairdoppilata* species dominate those of *Neonesidea* in shallow facies with the reverse being true for deeper water environments. *Bairdoppilata* has not been identified from any sample. This genus is characteristic of inner shelf nearshore environments. The population structure exhibited by *N.chapmani* is type B, characteristic of a moderate energy biocoenosis. *Paranesidea barwonensis* and *Neonesidea* sp. A are restricted to this assemblage and the overlying Lower Morgan 2 whilst specimens referable to *N. fredericki*, a species reflective of inner shelf nearshore environments (Warne 1988), occur only here.

Population structures for the two species of Xestoleberidae, *Xestoleberis* cf *cooki* and

Foveoleberis ?minutissima, are indicative of a moderate energy biocoenosis. Xestoleberids are typical of the phytal sublittoral zones (McKenzie & Peypouquet 1984) and a strong presence is inferred as reflective of high marine algal or seagrass concentrations at the site of deposition. *F. ?minutissima* has been recorded as ranging from marginal marine to sheltered marine embayments in recent waters of New South Wales (Yassini & Jones 1995).

McKenzie (1974) has proposed that most loxoconchids are typical of depths less than 50m and prefer inshore environments, a distribution reinforced by ranges for species of the family in NSW coastal waters (Yassini & Jones 1995). Their abundance in the basal 3.5m of the lower limestone followed by a sharp drop in numbers may reflect a change from in- to offshore conditions associated with a rise in sea level.

The Krithiidae are represented in this assemblage by fairly stable numbers of two species of *Parakrithella*, a genus characteristic of shallow shelf depths. The large increase in numbers of Bythocytheridae at the top of this assemblage is attributable to increasing numbers of a single species of *Bythoceratina* characterised by population structures of a high energy biocoenosis. McKenzie (1974) uses this genus as a shallow offshore environmental indicator in the Kalimnan-Cheltenhamian of South Eastern Australia.

Interpreted Environmental Conditions:

The large numbers of the various hemicytherids, the absence of *Bairdoppilata* and the environmental preferences of the other bairdiids present would suggest the assemblage represents a moderate energy inner shelf environment. This interpretation is supported by the presence of significant numbers of loxoconchids, xestoleberids and shallow water krithiids. The upper samples of the assemblage may also reflect a slight deepening or change from in- to offshore conditions.

Lower Morgan 2

Samples: C17, C18

Height: 6.00m - 7.10m

Lower Morgan 2 comes from the *Celleporaria* limestone/marl alternation between the massive white limestone of the bottom of the section and the base of the Cadell Marl Lens. The dominant families of this assemblage are the Trachyleberididae (av. 16%), Leptocytheridae (av. 16%), Hemicytheridae (av. 12%), Bythocytheridae (av. 10%), Bairdiidae (av. 11%), Cytheruridae (av. 10%) and Krithiidae (av. 9%). Significant increases from the assemblage below are witnessed for the bythocypridids and trachyleberidids, whilst decreases are observed in the abundances of hemicytherids, loxoconchids and xestoleberids. Species diversity has increased from the conditions at Lower Morgan 1 to 53 species (average), rare species are much more common (39%) along with general specimen abundance (351/g) (see Fig. 17, p.50). Lower Morgan 2 is most similar to Lower Morgan 1.

Interpreted Environmental Conditions:

The increase in numbers of Trachyleberididae, Bythocytheridae, and the steadily decreasing numbers of the shallow water hemicytherids, loxoconchids and xestoleberids appears to reflect either a deepening of conditions to an middle shelf environment and/or a further development of offshore conditions.

Cadell 1

Samples C16, C15, C14, C13

Height: 8.00m - 9.65m

This assemblage represents the lower part of the Cadell Marl with a change of lithology from the limestones of the Lower Morgan assemblages to orange/brown/grey soft marls with common shelly material. *Celleporaria* has disappeared from the sediments and is replaced by a *Maoricolpus* dominated macrofauna. The major ostracod families characteristic of this assemblage are the Cytheruridae (av. 15%), Hemicytheridae (av. 14%), Leptocytheridae (av. 13%) and Trachyleberididae (av. 8%). Strong increases (relative to their actual abundances) are seen for the Bythocyprididae, Cytherellidae, Cytheruridae, Macrocyprididae, Paracyprididae, Paradoxostomatidae and Pontocyprididae. Families which decrease significantly are the Bairdiidae, Bythocytheridae, Krithiidae, Trachyleberididae and Xestoleberididae. Species diversity increases strongly to 76 and rare species decrease to account for 27% of the fauna. Specimen abundance continues the increase as we pass through the section (520 specimens/g) (see Fig. 17, p.50). Cadell 1 is most similar to the assemblage directly above, Cadell 2. These 2 assemblages are the most dissimilar to those of the Morgan Limestone.

In this assemblage, the Bythocyprididae achieve their greatest abundance (1.2%), as do the Macrocyprididae (9.2%). Although the dominant bythocypridid, *Bythocypris (Bythocypris) subrectangula*, is mainly a inner shelf species (Warne 1990), its type C population structure reflects downslope deposition of allochthonous valves from a shallower environment.

Macrocyprids reach their greatest abundance (9% at C13) in this assemblage and many workers have recognised that the Macrocyprididae are especially abundant in and characteristic of deep sea assemblages (Maddocks 1990) and common in the Oxygen Minimum Zone (Cronin 1983). In the Middle Tertiary of Victoria, macrocyprids range from mid to outer shelf depths (Warne 1989). Their presence at this interval of the measured section would suggest the deepest point of deposition for the Cadell Marl at mid-outer shelf depths, at sample C13, possibly associated with an expanded OMZ and associated high nutrient conditions.

The Bythocytheridae experience a large drop in abundance, with the dominant member of the family in the 2 Lower Morgan assemblages, *Bythoceratina* sp, being replaced by *Hanaiceratina arenacea.* This species is an acknowledged warm water and moderately deep water (75m) indicator (McKenzie 1974).

Another significant occurrence in this assemblage is the continued decrease of the overall numbers of the Krithiidae (specifically *Parakrithella* spp), counterbalanced by the appearance and peak of *Krithe nitida* at C14. *Krithe* is recognised as abundant in deep water environments (Whatley & Quanhong 1993, Coles *et al.* 1994) and has been recorded from depths between 245 and 2730m off Australia today (McKenzie & Peypouquet, 1984).

The extensive bioturbation of this assemblage and the presence of abundant *Maoricolpus* gastropods is indicative of high nutrient levels.

Interpreted Environmental Conditions:

This assemblage is characterised by peaks for both the Macrocyprididae and *Krithe*, the appearance of deeper water bythocytherids, and low numbers of inner shelf fauna. It should reflect a either a continuing deepening of the environment of deposition to a maximum for the section to middle/outer shelf depths or an expansion of the Oxygen Minimum Zone bringing increased nutrients and the deeper water forms up slope onto the middle shelf.

Cadell 2

Samples: C12, C11, C10, C9, C8, C7

Height: 10.00m - 11.45m

Cadell 2 comes from the middle of the Marl and is characterized by soft orange/grey marls with abundant burrowing and includes Tate's "blue clay" (C8). Dominant families are Cytheruridae (av. 31.6%), Hemicytheridae (av. 12.1%) and Pontocyprididae (av. 7.4%). Significant increases are seen for the Cytheruridae and Cytheridae whilst decreases in abundance occur for the bairdiids, bythocyprids, krithiids, Leptocytheridae, Macrocyprididae, Paracyprididae and Trachyleberididae. The Cytheruridae (36%), Pontocyprididae (10%) and Cytheridae (2.2%) attain their greatest abundances in this assemblage. The Krithiidae (0.8%) reach their lowest abundance for the Marl whilst the Leptocytheridae and Trachyleberididae have their lowest frequencies for the section. Species diversity is the largest of all assemblages at an average of 80 (maximum of 89 at C11), whilst rare species make up 32% of these. Specimen abundance has increased by a factor of 4 over Cadell 1 to reach 2300 specimens per gram (Fig. 17, p.50). Cadell 2 is most similar to the underlying Cadell 1 faunal assemblage.

This assemblage is characterised by greatest numbers of cytherids, cytherurids, and pontocypridids. The cytherid *Saida*, which is at its most abundant in Cadell 2, is a warm water indicator (McKenzie 1974) and its presence here reflects the subtropical surface temperatures prevalent in the early Middle Miocene of southern Australia, during the Miocene climatic optimum. McKenzie (1974) has identified it as characteristic of shallow depths between 25-75m, whilst Yassini & Jones (1995) recorded it as ranging from rare on the inner shelf to common in Bass Strait. The other member of the family present in this assemblage is *Loxocythere*, which is widely distributed in a variety of Recent environments off southeastern Australia.

The Pontocyprididae are dominated by two species of *Argilloecia*, which is characteristic of moderately deep water from 75m (McKenzie 1974) to over 100m (Majoran 1996), whilst *Maddocksella* is typical of shelf deposits from inshore to the uppermost part of the slope (McKenzie *et al.* 1991).

The Cytheruridae dominate this assemblage. *Kangarina* is a deep water dweller in the Mediterranean but occurs in the littoral zone in Victoria. In the Tertiary of southern Australia it is generally associated with assemblages indicative of shallow (25 - 75m) warm to warm-temperate marine environments and open ocean conditions (McKenzie 1974). Yassini & Jones (1995) report it as uncommon across the inner and middle shelf off the NSW coast.

Population structures of *Hemicytherura* spp are typical of a low energy biocoenosis in this assemblage. *Semicytherura* spp also peak in Cadell 2 with 5% where they too exhibit a population structure characteristic of a low energy biocoenosis.

Cytheropterines have been interpreted as indicative of conditions deeper than shallow marine (Majoran in press). The most abundant ostracod in the whole section is the cytherurid species *Oculocytheropteron microfornix*, which attains its maximum numbers (20%) in assemblage Cadell 2. Whatley & Downing (1983) recorded *Oculocytheropteron microfornix* is the second most abundant species (10%) of the biocoenosis in their Balcombian sample from Fossil Beach at Mornington, which both they and McKenzie (1974) believed to represent deposition at middle to outer shelf depths between 70 - 150m. Although high numbers of cytherurids have been interpreted as characteristic of near shore environments (McKenzie 1974), Whatley & Downing's (1983) specific study of the Balcombe Clay also enables further inferences to be made about the palaeobathymetry of the Cadell Marl. In the Victorian sample, the association of dominant *Krithe nitida* and *Oculocytheropteron microfornix* is reflective of middle to outer shelf conditions. These two species occur together in the Cadell Marl in their highest numbers low in the marl in assemblage Cadell 1 (at sample C13), after which *Krithe* rapidly decreases whilst *O. microfornix* increases to reach its greatest abundance at Tate's "Blue Clay". *O. microfornix* may prefer slightly shallower conditions than *Krithe*, as witnessed by the increase in the abundance of the former as we travel up section through a presumably shallowing sequence and witness rapid decreases in the deeper water macrocypridids and pontocypridids, and increases of loxoconchids, xestoleberids and allochthonous *Parakrithella*. The large differences in abundances between the Balcombe Clay and Cadell Marl may either be a reflection of shallower depths experienced the Murray Basin or it could be also a reflection of oceanic versus more protected conditions between the two localities. Majoran (in press) has postulated that *O. microfornix* is characterised by a relatively broad bathymetrical range and palaeoecological tolerance.

The extensive bioturbation of this assemblage is indicative of high nutrient levels. This is also reflected by Cadell 2 having the highest diversity for the section and specimen abundance leaping to 2300/g.

Interpreted Environmental Conditions:

This assemblage is characterised by the dominance of the cytherurids. We witness peaks for these and for the moderately deep water pontocypridids. Increased numbers of loxoconchids and decreased macrocyprids and absence of turritellid gastropods reflect either a slight shallowing of conditions from Cadell 1 to the middle shelf or possibly, a decrease of high nutrient conditions.

Cadell 3

Samples: C6, C5, C4, C3, C2, C1, M1

Height: 11.85m - 14.00m

The upper Cadell assemblage from the upper Marl and base of the Upper Morgan Limestone is composed of an alternation of soft orange/grey marls and hard brown shelly marls (the "*Maoricolpus*" beds). The most abundant families are the Leptocytheridae (av. 14%), Hemicytheridae (av. 13%), Xestoleberidae and Loxoconchidae (av. 12%) and Krithiidae (av. 11%). Although significant overall increases in abundance are seen for the shallow water krithiids, leptocytherids, loxoconchids, trachyleberidids and xestoleberids and large decreases are witnessed in the Cytheruridae, Macrocyprididae and Pontocyprididae, this assemblage is characterised by an oscillation between two distinct faunal types.

Species diversity has decreased from Cadell 2 to an average of 54 but the cyclicity of this assemblage causes an alternation between 40 species in the *Maoricolpus* beds to almost 70 species in the marls. Rare species account for 37%. Average specimen abundance is slightly less than Cadell 2 with 2200 specimens per gram (Fig. 17, p.50). This assemblage is most similar to the overlying Upper Morgan 1.

The cyclicity of lithology from resistant shell beds to softer marls at a scale of 10s of cms (see stratigraphic column) and the corresponding progression of their associated characteristic ostracod faunas overprint the large scale faunal changes mentioned above. These large scale changes culminate with the inshore loxoconchids reaching their highest numbers for the section, and the phytal xestoleberids returning to abundances found in the lower Morgan Limestone. *Neonesidea australis* peaks for the section at sample C2, whilst the single species of *Paracypris* appears quite dramatically in this assemblage reaching a peak of 2% at sample C5 with an extreme type B population. *Quadracythere willungaensis* also briefly peaks with 8% at C1. Numbers for *Parakrithella* rapidly increase to the top of the assemblage, whilst *Krithe* lingers on in the section with 2 or 3 valves per sample, disappearing finally in sample M1.

C6, the lowest *Maoricolpus* bed above the blue clay, is characterised by Leptocytheridae, Hemicytheridae, Trachyleberididae, Xestoleberidae and Krithiidae, all with population structures of a moderate energy biocoenosis, and low numbers of Bairdiidae and Cytheruridae. This may reflect shallower conditions and an associated higher energy regime coupled with an influx of nutrient rich waters onto the middle/inner shelf . C5, a marly interbed with uncommon *Maoricolpus*, has high numbers of Cytheruridae, Hemicytheridae, Leptocytheridae and Trachyleberididae coupled with drops in the abundance for the Xestoleberidae, Krithiidae and Bairdiidae, possibly reflecting a deepening of the environment and/or a reduction of nutrient levels. C4, the next shell bed, returns to the conditions of C6 with increased bairdiids, cytherellids, krithiids, loxoconchids and xestoleberids, with reduced hemicytherids, cytherurids and leptocytherids. C3, a burrowed marly interbed, sees increases in cytherurids and hemicytherids with decreases in cytherellids, krithiids and xestoleberids, as occurs in C5. C2 comes from a hard, partly cemented marly limestone with uncommon *Maoricolpus* and is similar in lithology to the hard bed between samples C16 - C17. Preservation of the ostracods is as either internal casts of carapaces or strongly recrystallised valves and specimen abundance is one of the lowest with only 83 specimens/g. The fauna is composed of high numbers of Bairdiidae, shallow Krithiidae and Xestoleberidae and shows strong increases from the previous sample for the bairdiids, cytherellids and xestoleberids with decreases in the numbers of Hemicytheridae, Leptocytheridae, Loxoconchidae and Trachyleberididae. It is suggestive of a moderate energy inner shelf biocoenosis. Sample C1, a soft dark grey marl, documents the last record of *Krithe* and M1, a brown clay with high numbers of Hemicytheridae, Loxoconchidae and Xestoleberidae documents the highest numbers of shallow water *Parakrithella* (17%). It suggests shallow inshore conditions.

The sequence of these samples appears to be consistent with a regime of fluctuating sea levels overprinting a general shallowing to the top of the marl. The presence of rare deep water *Krithe* throughout the assemblage suggests depth conditions to be at the upper limit for this genus, also reflected by the highest abundance of *Parakrithella* spp. A fluctuation of nutrients through this part of the section would certainly account for the comings and goings of the turritellid *Maoricolpus* and the phytal xestoleberids.

Interpreted Environmental Conditions:

Continued deposition at middle shelf depths shallowing to inner shelf conditions as we pass up into the Upper Morgan Limestone. Short scale fluctuations of nutrient levels/sea level occur at a Milankovitch periodicity producing an oscillation between high nutrient *Maoricolpus* beds with a xestoleberid/cytherellid/krithiid fauna with strong type B populations, and lower nutrient leptocytherid/cytherurid fauna.

Upper Morgan 1

Samples: M2, M3, M4

Height: 14.45m - 15.75m

This assemblage comes from the Upper Morgan Limestone cyclic alternation of red/brown clays with minor gypsum and brown recrystallised limestones. The lowest limestone bed in this assemblage has common *Celleporaria*, but above sample M3 the recrystallised limestones change to a *Maoricolpus* dominated macrofauna (see p.13). The bairdiids continue their decline in abundance, finally disappearing from the section at M4, whilst the Cytheruridae (av. 21%) and Leptocytheridae (av. 19%) are abundant, both with type B populations. Hemicytheridae are common (av. 11%) but significant changes are seen in the Pectocytheridae and Rockalliidae which increase dramatically in combined abundance from the base of this assemblage from 4% to 25% at the top. Members of the Trachyleberididae and Loxoconchidae become less common towards the top of the assemblage and the Xestoleberidae disappear. Population structures and percentages of broken valves are indicative of high energy conditions. This assemblage has the most abundant Ostracoda with an average of over 4200 specimens per gram with 22 rare species in an average of 64. Upper Morgan 1 is most similar to Cadell 3.

The lowest clay of this assemblage (sample M2) appears to suggest a return to the conditions of Cadell 2, with large numbers of Cytheruridae dominated by

Oculocytheropteron microfornix, a return of the pontocypridids (albeit at reduced percentages) and low numbers of *Parakrithella*. The moderately deep water schizocytherid, *Paijenborchella*, also achieves its greatest numbers in this sample. The deep water indicator, *Krithe*, is absent, suggesting if conditions have deepened, they have not reached the depths of Cadell 2. As noted before, Majoran (in press) has postulated that *O. microfornix* is characterised by a relatively broad bathymetrical range and palaeoecological tolerance, so its presence in large numbers in the sample M2 may be reflective of something other than a simple change in depth, for instance a change in substrate conditions or nutrient levels.

Cytheralison pravacauda, indicative of shallow offshore deposition (25-50m) (McKenzie 1974) attains its highest numbers for the section in this sample.

Associated with the transition from *Celleporaria* to *Maoricolpus* limestones above sample M3 is an increase in the abundance of Cytherellidae, consistent with a possible return to higher nutrient conditions.

As with the underlying Cadell 3 assemblage, a fluctuation of depositional conditions at a 5th order (Milankovitch) time scale produces cyclicity of alternating clays and limestones, whilst the rapidly increasing abundance of the pectocytherids/rockalliids point to this assemblage suggesting a shallowing of conditions towards a near shore environment. This large increase is, however, opposed by an apparently conflicting decrease of other shallow marine Ostracoda such as the loxoconchids, xestoleberids and *Parakrithella* spp. The change to *Maoricolpus* limestones and increased filter feeding cytherellids may suggest that the dominance by the Pectocytheridae and Rockalliidae could be nutrient driven. Furthermore, an examination of the abundance variations of these families through the section reveals a strong preference for clay sediments, indicating that their distribution may be also be significantly substrate controlled, and a subsequent dominance by them reflective of bottom conditions prohibitive to the other neritic species.

Interpreted Environmental Conditions:

Deposition of nearshore sediments under conditions of fluctuating sea level and nutrients.

Upper Morgan 2

Sample: M5

Height: 16.35 m

This assemblage comes from the top of the Upper Morgan Limestone and is from a red/brown clay with extensive gypsum rosettes *in situ*, overlying a tan/brown recystallised limestone with abundant *Marginopora*. Above this is a brown recrystallised limestone with common moulds of *Maoricolpus* and carditiid bivalves, as well as fenestrate bryozoa and the infaunal spatangoid *Lovenia forbesi*. This bed grades upwards into a heavily burrowed sandy calcarenite with no visible macrofauna. It is the most unusual assemblage in the section, with a relatively low diversity of 38 species, of which 11 are represented by a single specimen. Two families, the Pectocytheridae (34%) and the Rockalliidae (16%), accounts for 50% of the fauna. Trachyleberididae are reasonably common and the Eucytheridae attain their greatest abundance (5%) in this sample. Upper Morgan 2 is most similar to the sediments of Upper Morgan 1, and is the most different faunally from the lower and middle marl assemblages.

Keijia is the most abundant genus with 28% for this sample, a genus which dominates the modern shallow marine littoral environment. Low numbers or absence of other acknowledged shallow water families are probably a result of unfavourable substrate/nutrient conditions. Predominant type B population structures and broken/abraded valves of the larger trachyleberidids and hemicytherids suggest high energy conditions.

Interpreted Environmental Conditions:

Continued deposition of nearshore sediments under conditions of fluctuating sea level and nutrients.

7. DISCUSSION

7.1 Depositional environment

Open coast assemblages appear to be dominated by leptocytherids and cytherurids (McKenzie 1974). The assemblages from protected environments such as those today in Port Phillip Bay, Victoria, also are characterized by large numbers of these families with the addition of significant numbers (>10%) of trachyleberidids, hemicytherids, pontocypridids and bairdiids. Changes in the ratios of these families in the lower limestone may indicate a change in oceanic conditions from a protected Murray Basin to open offshore conditions with the Padthaway Ridge acting as a "gate" to the Murray Basin entrance. Lower sea levels may have seen the Padthaway "Archipelago" blocking the entrance to the Basin creating a double effect of low sea level and protected conditions, whilst raised sea levels would have seen the basin become more open to oceanic conditions as witnessed by the change in dominance between the Trachyleberididae, Hemicytheridae and Bythocytheridae in faunal assemblages Lower Morgan 1 and 2. An examination of the distribution of the planktonic polycopids, which are effectively restricted to the marl, appears to support an interpretation of conditions with a strong open oceanic influence. *Polycope* and *Paijenborchella* today live in waters off the northwest of Australia and Indonesia (Keij 1966, McKenzie 1974, McKenzie & Peypouquet 1984) and along with *Saida* and *Hanaiceratina* act as indicators of warm surface temperatures around 25°C. The Polycopidae are pelagic and their appearance in the uppermost part of the lower limestone may signal a deepening of sea level clearing the barrier of the Padthaway Ridge and the Murray Basin being opened to open ocean conditions. They are absent from the upper limestone member, these sediments seemingly corresponding to deposition as the sea retreated to the south during a period of regression.

As a result of their filter feeding habit and brooding reproductive cycle, the Cytherellidae have been identified as a family that thrives in low oxygen conditions (Whatley 1991, Boomer & Whatley 1992, Lethiers & Whatley 1994) and a dominance of an ostracod fauna by this family has been interpreted as indicative of high environmental stress associated with expanded oxygen minimum zones (Majoran 1995). The Cytherellidae are not common in the measured section, attaining their greatest numbers with only 5% at C16, C13 and C4, all of which are shell beds. If the presence of the Cadell Marl is reflective of an oxygen crisis, it would be expected to be observed by a dominance of the Cytherellidae in the ostracod fauna. This is not the case. The shell beds are dominated by the turritellide gastropod *Maoricolpus murrayana*, a filter feeder. If these represent an autochthonous fauna, one could interpret the dominance of the turritellids as an indication of a environment rich in nutrients in which filter feeding would be advantageous. Zones of upwelling along continental margins are rich in nutrients and subsequently often poorly oxygenated due to high biological activity. The relative absence of cytherellids in the section would appear to deny this for the sequence, although this family does have peaks in the *Maoricolpus* beds (albeit with percentages of only 5%).

An Oxygen Minimum Zone (OMZ) edge effect whereby shelf benthos living landward of the main zone of upwelling could benefit from increased nutrients and not be adversely impacted by low oxygen conditions (Mullins *et al.* 1985) could account for increased diversity and specimen abundance of infaunal macroinvertebrates (specifically filter feeding turritellids) in the shell beds of the Cadell Marl and correspondingly high inferred nutrient levels without the increased abundance and dominance of the filter feeding cytherellids as one finds in the Late Eocene of the St Vincent Basin (Majoran 1995). Further evidence in support of an expanded OMZ is the strong peak of the Macrocyprididae at C13, a family common in this zone (Cronin 1983).

Li & McGowran (1994) have identified four major upwelling events in the Miocene of the Gippsland Basin, the first two occurring in the latest Oligocene-early Miocene (24.5 Ma and 22 Ma), one in the late early Miocene (17.5-17 Ma) and the final in the Late Miocene (9-8 Ma) (see fig. 19). The third event correlates nicely with the Mannum Fm of the

Murray Basin and lies immediately below the large swing towards shallow sea levels below the Miocene climatic optimum in the Exxon sea level curves, possibly witnessed as deposition of the Finniss Clay. Their study shows no major upwelling associated with the climatic optimum and Cadell Marl, but there is at this level a sharp peak reversal to increased numbers of infaunal foraminifera indicative of high nutrient conditions.

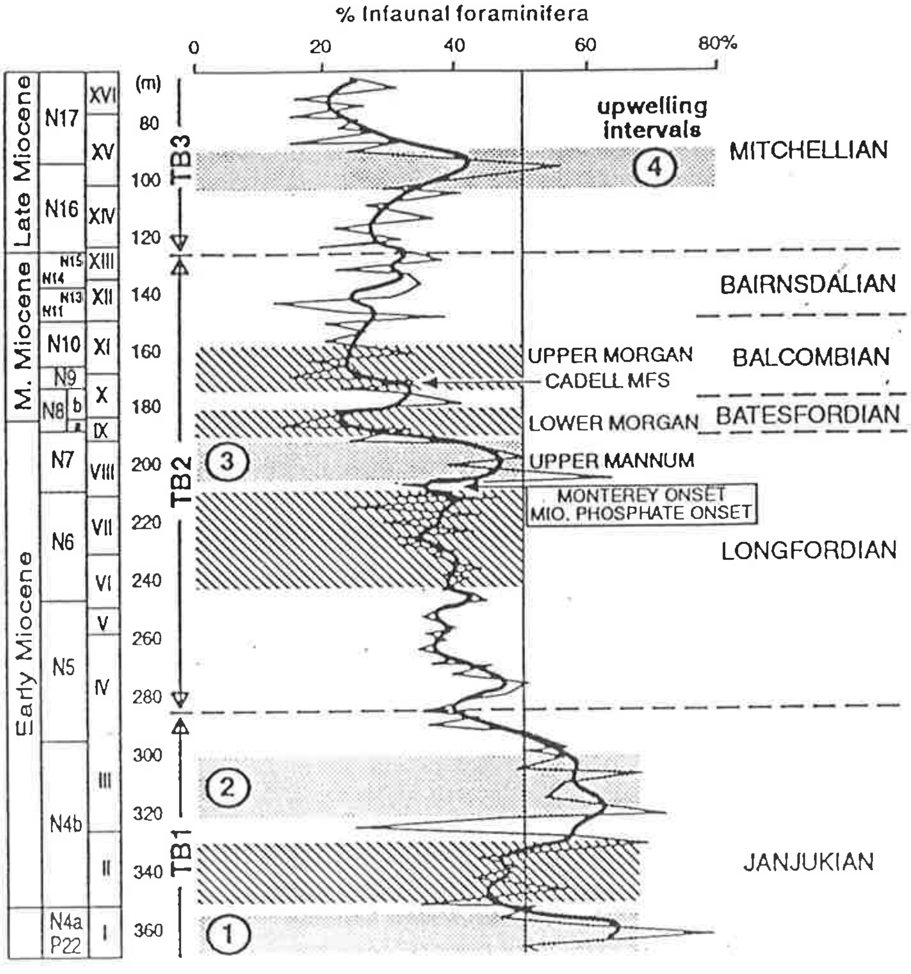


Figure 19. From Li & McGowran (1994). Showing ratio of infaunal/epifaunal foraminifera for the Miocene sequence of the Gippsland Basin, expressed as % infauna. Note 4 stippled upwelling events but also significant reversal to high infauna (& nutrients) at the Miocene climatic optimum, corresponding to the Cadell Marl (Cadell MFS in figure). Striped intervals are periods of warm & relatively oligotrophic water (cf. Morgan Limestone).

One outstanding question concerns the source of high nutrient levels in the sediments of the section. They could be introduced into the basin via the leading edge of the expanded OMZ, but high levels may come from landward as well. Lowered sea levels may result in increased erosion and therefore increased input of terrigenous sediment into inner shelf environments. The environmental conditions postulated for the *Maoricolpus* beds of Cadell 3 and Upper Morgan 2 may be more directly linked to increased levels of nutrients, directly associated with increased erosion and run off from the proto Mt Lofty Ranges into the Murray Basin during periods of lower sea level. One possible scenario to account for the alternation of *Maoricolpus* limestones and pectocytherid clays is as follows: The site of deposition for the sediments is a marginal marine environment at the western edge of the Murray Basin. Milankovitch oscillations are responsible for small scale fluctuations of sea level. At times of low sea level, increased erosion produces increased terrigenous input and a flush of nutrient rich run off into the western margins of the basin, producing clay rich environments favourable for the dominance of the pectocytherids/rockalliids. These periods of lower sea level are associated with higher energy conditions, evidenced by strong type B populations of ostracods in these sediments. High energy is also reflected in the jumbled nature of the mollusc fauna, and in fact some of the shell beds certainly appear to be lags or current deposited (see Plate 6, p.10). Small scale sea level rise is associated with reduced run off and establishment of nearshore carbonate sedimentation.

Brown and Stephenson (1991) proposed that the Cadell Marl Lens reflected deposition in lagoonal and restricted marine platform environments of the Murravian Gulf, whilst others believe it is merely an equivalent of the shallow to marginal marine Geera Clay, deposited in the western portion of the Murray Basin (N. P. James *pers comm.*). Sedimentologically, it is possible that the marl may reflect a simple lagoonal accumulation bearing a maximum flooding surface at Tate's "blue clay". Shallow conditions for this interval seem to be supported by foraminiferal evidence, with the marl being dominated by epifaunal discorbids and miliolids, although a quarter of specimens are broken and must be allochthonous (Li *pers. comm.*). The abundance of the miliolids in the Cadell Marl is contentious. Modern forms represent lagoonal or warm inner shelf depths, although they are abundant in the deeper parts of modern South Australian gulf waters (Cann 1992). It is also possible that the miliolids have been introduced into the sample by bottom currents.

The presence of acknowledged deep water krithiids (*Krithe* sp), macrocypridids and pontocyprids, are indicative of deeper marine conditions. It would appear that the ostracod fauna of the Cadell Marl (specifically that of assemblage Cadell 1) precludes a shallow marginal marine depositional environment.

Van Harten (1988) noted that during transgressive phases, species diversity increases, while it decreases with subsequent regressions. Riding (1984) also recorded this association with Palaeozoic benthic marine algae. Examination of species diversity through the measured section (fig. 17) appears to reinforce these observations. Diversity doubles from the assemblages of the Lower Morgan Limestone into the Cadell Marl, peaking in Cadell 2. The overall pattern of species diversity above here is a steady decrease to the top of the section. Changing species diversities of the section would appear to reflect transgressive conditions through the lower limestone culminating in the lower/middle marl followed by regression to the top of the upper limestone member.

7.2 Correlation with Global Sea levels

Haq et al. (1987) reconstructed a global sea level history from the Triassic using sequence stratigraphy concepts in the examination of seismic, well and outcrop data gathered by the Exxon oil company. These charts integrated the latest magneto-, chrono- and biostratigraphies (foraminiferan, nannofossil, radiolarian, diatom & dinoflagellate) with sequences recognised in outcrop and subsurface sections.

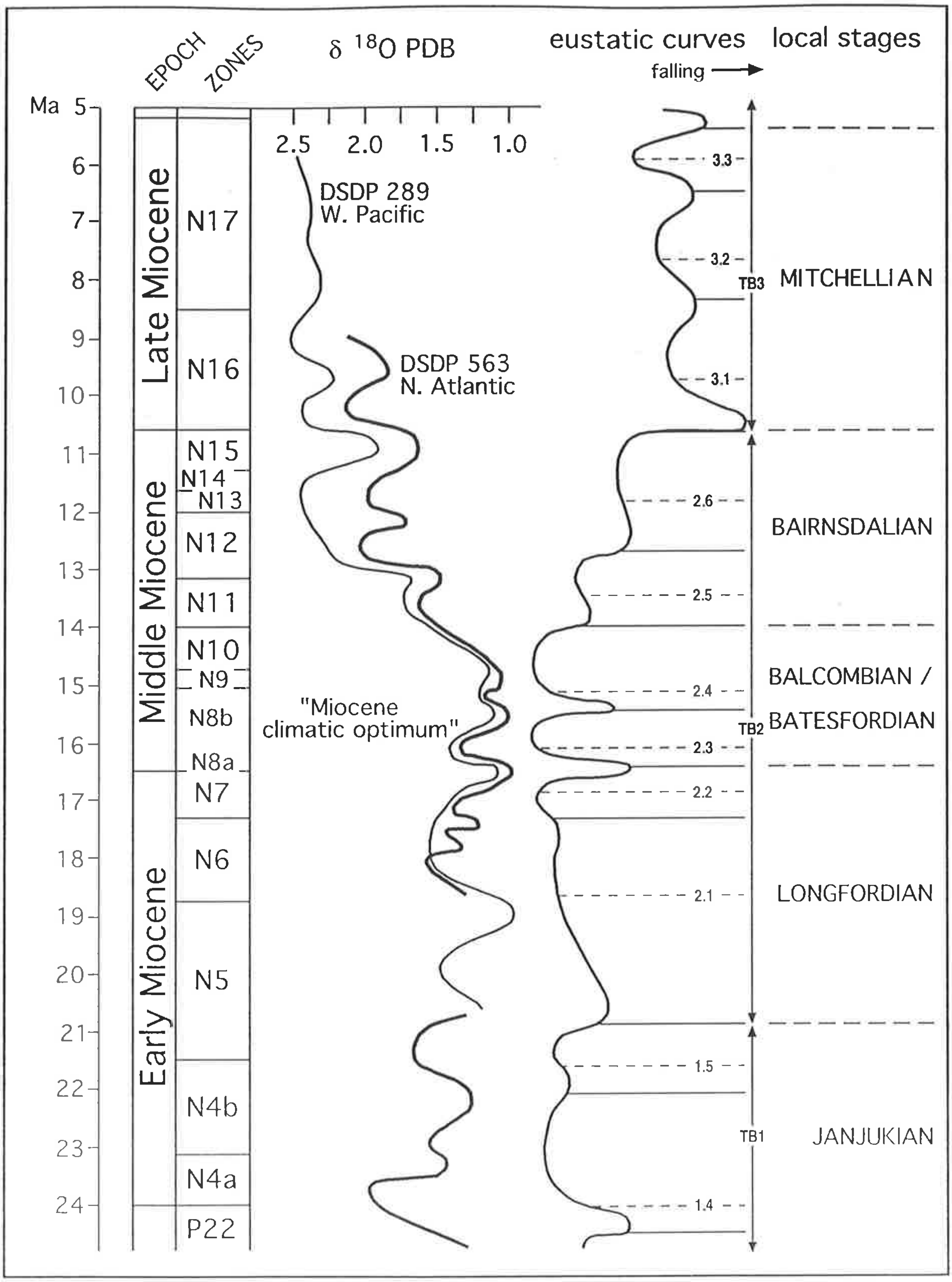


Figure 20. Adapted from Li & McGowran (1994), showing chronology of the Miocene, isotopic $\delta^{18}O$ (reflecting ocean temperature), the Exxon sea level curve, Tertiary stratigraphic cycles and SE Australian Neogene stages.

Two large sea level falls in this Exxon eustatic curve straddle the early/middle Miocene boundary (at the Miocene climatic optimum) (see Fig. 20, p.72). The first, late in the planktonic foramiferan zone N7 (late Longfordian) below the early/middle Miocene boundary, seems to correlate nicely with the deposition of the Finniss Clay, a regressive unit of variegated plastic clays with locally well developed gypsum nodules, which lies between the Mannum & Morgan Formations. The Exxon curve then shows a transgression peaking at the boundary between zones N8a & N8b at the maximum flooding surface of sequence 2.3 of third order cycle TB2. The second great sea level fall occurs during zone N8b after the early/middle Miocene boundary. Interpretation of the ostracod assemblages of the section at the Morgan Limestone/Cadell Marl type locality suggests deposition during a rise followed by a fall of sea level. The lower Morgan limestone carries the N8a marker species *Praeorbulina sicana* (Li *pers. comm.*), placing this unit nicely in the rising sea level conditions of the early Batesfordian. The high stand experienced low in the Cadell Marl (assemblage Cadell 1) thus appears to correlate well with the high sea level of the Exxon eustatic curve during the middle Batesfordian (lowermost N8b). If the upper part of the Cadell Marl corresponds to zone N8b, as suggested by the identification of *Praeorbulina glomerosa* (Li *pers. comm.*) in the sample C7, it is likely that the possible shallowing conditions of this part of the section may be correlated with part of the second Exxon fall that separates the Batesfordian from the Balcombian during late N8b.

Foraminiferal evidence for the dating of the upper Morgan member is uncertain. It is suggested that the upper Morgan strata are most likely representative of an N9 or younger age (Li *pers. comm.*). The absence, however, of the N9 marker species *Orbulina suturalis* in the upper limestone member may suggest that this unit is N8b as well. If this is the case, the upper limestone reflects a continued a continued shallowing from the upper marl, as suggested by faunal assemblage Upper Morgan 1, and so equates this part of the section with the second Exxon swing in the late Batesfordian. If, however, the upper Morgan Limestone is younger than N9, and the absence of the foraminiferal markers (*Orbulina* spp) the result of non-deposition rather than diachronous displacement (Loutit 1991) then it may represent deposition during the rapid shallowing in the late Balcombian (N10).

This confusion about the age and relationships of the upper Morgan and Pata Limestones needs clarification if we are to correlate the Neogene sedimentary sequence of the Murray Basin with world sea level curves and with sequences in other Australian Tertiary basins.

As previously discussed, Upper Morgan 2 is the most unusual assemblage in the section with low diversity and one family, the pectocytherids, accounting for 34% of the fauna. It lies directly above Upper Morgan 1 which appears to reflect a shallow environment. *Keijia* is the dominant genus with 28% in Upper Morgan 2 and dominates the modern shallow marine littoral environment. Neil (1995) analysed the ostracod faunas at several sites within the Cenozoic of southeastern Australia. One of these was a sample from the Pata Limestone at Kingston-on-Murray, South Australia. He found the ostracod assemblage of this sample to be highly unusual with the lowest generic diversity and highest numbers of *Keijia* (20.8%) of any of the 13 assemblages he examined. The similarity of the unusual Upper Morgan 2 (sample M5) with 28% *Keijia* species and Neil's Pata limestone sample is striking. This ostracod evidence could suggest that the Upper Morgan Limestone at the Cadell Marl type section was either deposited under conditions identical to those of the Pata Limestone, or, it may in fact be the equivalent of the Pata Limestone. On the strength of foraminiferal evidence, Li & McGowran (*pers comm.*) find it possible that the Pata and Upper Morgan Limestones may be contemporaneous and deposited during N9 or younger zones. Ludbrook (1961) recorded the large foraminiferan *Marginopora vertebralis* as infrequent in the Cadell Marl, common in the Upper Limestone (also observed in the measured section of this study) and common in the Pata Limestone at Loxton, but also identified the N9 marker species *Orbulina suturalis* from low in the Pata Limestone. Her description of the subsurface section obtained from drainage shaft 18 at Loxton includes 14' of glauconitic sandy marl between the Pata and Morgan Limestones with a macroinvertebrate fauna consisting of *Dentalium*, *Nuculana*, *Barbatia*, Carditidae species and *Corbula*. Sedimentologically and palaeontologically this unit appears to be very similar to the Cadell Marl, but whether it is equivalent to the Cadell Marl or a sedimentary analogue in a later depositional sequence is at present unknown. Obviously a closer micropalaeontological examination of the glauconitic sandy marl between the Pata and Morgan Limestones is warranted. The results of the author's study of the ostracod fauna of the Upper Morgan Limestone suggests that although we cannot propose any age correlation between this and the Pata Limestone, both were certainly deposited under similar conditions.

Brown & Stephenson (1991) identified the upper member of the Morgan Limestone as marking the beginning of the Middle Miocene (Balcombian) regression and that the Pata Limestone was deposited as regression increased, it being found only in the depocentre of the Murray Basin. An examination of Ludbrook's (1961) borehole log through the Pata and upper Morgan Limestones at Loxton reveals a sedimentary sequence reminiscent of the Lower Morgan/Cadell/Upper Morgan section, although on this occasion the sequence is ?Upper Morgan/14' of glauconitic sands/Pata Limestone. If the Pata corresponds to zone N10, as may be possible remembering Ludbrook's identification of the the N9 marker species *Orbulina suturalis* from low in the Pata Limestone, then it would represent deposition during the large scale regression which began at the middle of the Balcombian (early N10) and reached maximum lowstand at N16 (see Fig. 20, p.72). If this is true, the glauconitic sands reported by Ludbrook would correspond to the Balcombian highstand prior to this regression and interestingly occupy a similar stratigraphic position to the Cadell Marl in the earlier Batesfordian sequence.

If the Upper Morgan Limestone is contemporaneous with the Pata Limestone and correlates with the large regression at the end of the Balcombian (N10) and if the second great sea level fall of the early middle Miocene (N8b) is represented in the measured section by the shallowing sequence in the upper parts of the Cadell Marl, we must have a hiatus in sedimentation during foraminiferan zone N9. Correspondingly, there should be an unconformity or disconformity between the upper marl and the upper limestone member.

Unconformities in shallow marine sequences represent lowstands of sea level and result from non deposition or subaerial erosion of the continental shelf. Such instances have been well recorded in the Cenozoic strata of New Zealand (Loutit & Kennett 1981). The Cenozoic sediments of the southern Australian continental margin were deposited during four depositional sequences bounded by unconformities (McGowran 1979). His third sequence (the latest Oligocene to late middle Miocene) documents a large scale transgression commencing in foraminiferal zones N3-N4 and reaching its maximum near the early-middle Miocene boundary, a time apparently documented in the sediments by a widespread hiatus. Hiatuses do not only occur in periods of lowstanding sea level but can occur at times of particularly high sea level (Loutit & Kennett 1981). Highstands of sea level, especially after a period of rapid rise often result in sediment starvation of middle and outer shelf areas with terrigenous sediments being trapped in estaurine and other nearshore environments. Is it possible that the Balcombian (N9/10) high stand and hiatus may be seen in the section of this study at the base of the upper limestone member? We do see in sample M2 a return to conditions similar to those of assemblage Cadell 2, which may represent a deepening of the depositional environment, but are probably more reflective of changing nutrient and/or substrate conditions. Stratigraphically there is a change in the section from marls to the alternation of strongly recrystallised limestone and thin clays. These thin clays have well developed gypsum rosettes, a feature shared with the Finniss Clay, the shallow marine regressive unit corresponding to the first Exxon sea level fall. There is however no physical evidence such as an erosional contact seen at the Morgan Limestone/Cadell Marl type locality and the faunal change across the boundary between the Cadell Marl and upper Morgan Limestone appears in outcrop to be contained within a conformable sequence. It is therefore most likely that the Upper Morgan Limestone alternation of clays and recrystallised limestones was deposited during the lowstand conditions at the end of the Batesfordian (N8b).

7.3 Comparison with other southern Australian early Neogene sequences.

The changes in ostracod assemblages in the Late Tertiary sediments of Port Phillip and Western Port Basins generally correlate with global eustatic events. Different regions of these basins have different ostracod assemblages through their depositional histories, caused by interactions between fluctuating sea levels and basin subsidence or uplift (Warne 1993). In the western Port Phillip Basin, at the Batesford limestone quarry, most of the Batesford Limestone/Fyansford Formation sequence falls within the *P. sicana* zone (N8), except for the uppermost part of the section which contains *P. glomerosa* corresponding to N8b or N9. The ostracod assemblage succession documents a change from inner to mid-outer shelf depths from zones N8a to N8b and is accompanied by a change from nearshore carbonates to offshore marls and clays, a shift we see in the Murray Basin from through the lower Morgan Limestone and into Cadell Marl. In the eastern region of the Port Phillip Basin the ostracod assemblages indicate a similar trend. Warne has also identified an erosional event on both sides of the Port Phillip Basin in sediments from the uppermost *P. sicana* zone (Batesfordian). In the deeper eastern part of the basin, this event is marked not by any observable lithological variation, but by extensive sorting and abrasion of the ostracod fauna, whilst in the shallower western area, this sorting and abrasion is accompanied by the presence of a calcarenite within the marly sequence. If, as Warne says (p. 272), the general deepening across southern Victoria occurs in the upper part of the *P. sicana* zone, then this erosional event correlates well with both the second short lived sea fall of the Exxon curves and the shallowing sequence through the upper Cadell Marl and upper Morgan Limestone.

Warne & Whatley (1994) record the appearance of deep water Ostracoda in the latest Early Miocene to earliest Middle Miocene sequence of the Kingfish 8 well section in the Gippsland Basin and in similar aged sediments at Fossil Beach in the Port Phillip Basin. Abele *et al.* (1988) noted this period as the time when Bass Strait opened between the Tasman Sea and Southern Ocean, as well as when the sea transgressed inland to its northernmost limit. Warne & Whatley also recorded the domination of cytherellids in the faunas of Kingfish 8, indicative of a shallowing of the oceanic oxygen minimum zone, which moved upslope to occupy the shelf break/outer shelf during the the latest Early Miocene to earliest Middle Miocene (Batesfordian). Similarly aged ostracod faunas of the Barracouta 1 well also reflect this phenomenon (Warne & Idris, 1995). This expansion correlates nicely with what appears to be happening in the Murray Basin with the deposition of the Cadell Marl, occurring at the high nutrient leading edge of the OMZ which failed to penetrate further than the entrance to the basin.

The ostracod fauna of the Muddy Creek Marl, deposited during zones N8, N9 and N10 in the Tyrendarra Embayment of the Otway Basin, has been well documented by Neil (1992, 1994, 1995). The fauna, although contemporaneous with both the Middle Miocene sequences of the Port Phillip and Murray Basins, differs greatly in its composition, being dominated by hemicytherids (35% of the fauna). Neil interpreted the sediments as the result of deposition in a high energy shallow inshore environment, consistent with its geographical location at the northernmost margin of the embayment and marks the inland limit of the Batesfordian highstand. Hemicytherids in the Cadell Marl section average around 18% in the lower limestone and decrease to 13% in the Cadell Marl and 9% in the upper limestone. Unfortunately no vertical variation in familial abundance has been published for Neil's sequence, and so direct correlation with the Exxon sea level curves and the Cadell section are not possible. The fauna is however significantly different from this present study and must be a reflection of the differing geographical aspects. The lower Morgan Limestone (faunal assemblage LM1) with its relatively high numbers of hemicytherids (up to 25%) best approximates the inner shelf protected conditions experienced in the Muddy Creek Marl. It would appear that the maximum inland transgression of the Batesfordian sea resulted in the deposition of shallow inshore sediments in the Hamilton region of Victoria (Muddy Creek Marl), and deeper offshore sediments at the opening of the Murray Basin (Cadell Marl).

Recent extensive studies by Majoran (1995, 1996a, 1996b) of the Eocene/ Oligocene sequence of the St Vincent Basin to the south of Adelaide have concentrated on palaeoenvironmental interpretations based on the ostracod faunas of these strata. A comparison between the faunas of the Late Eocene Blanche Point Formation (BPF) and the Late Eocene/Early Oligocene Port Willunga Formation (PWF) has revealed contrasting ostracod populations reflecting differing depth regimes for these formations. The Blanche Point Formation contains abundant numbers of cytherellids, krithiids, pontocypridids, paracypridids and trachyleberidids, with species of *Paracypris*, *Kuiperiana*, *Krithe*, *Tasmanocypris*?, *Argilloecia*, *Trachyleberis*, *Cytherella* and *Bythocypris* indicative of a palaeodepth of between 120 - 200m. Separated from the BPF by the regressive non-marine to marginal marine Chinaman Gully Formation, the PWF is characterised by more abundant bairdiids, xestoleberids, hemicytherids and loxoconchids, with species of *Quadracythere*, *Hornibrookella*?, *Loxoconcha*, *Microcytherura*, *Schizocythere*, *Cytheralison*, *Kangarina* and *Xestoleberis* suggesting a much shallower palaeodepth of less than 50m. There is a major contrast in trachyleberidid, loxoconchid and hemicytherid species between the BPF and PWF. A similar occurrence can also be witnessed in the Cadell Marl type section. The sediments of the lower limestone member contain large numbers of bairdiids, hemicytherids, loxoconchids, xestoleberids are similar in faunal composition to the Port Willunga Formation and reflect shallow inner shelf deposition. As we pass up into the lower Cadell Marl, the increased numbers of pontocypridids, paracypridids, trachyleberidids, *Krithe* and *Bythocypris* represents a move in depth towards the conditions of the Blanche Point Formation. The return to large numbers of xestoleberids, loxoconchids and to a lesser extent, hemicytherids and bairdiids in the upper Cadell Marl would appear to correspond to a shallowing to depths similar to the PWF.

7.4 The Trophic Resource Continuum

Nutrient levels play a major role in the response of biotic activity in a changing marine environment. Oceanic waters have been organised across a spectrum from low

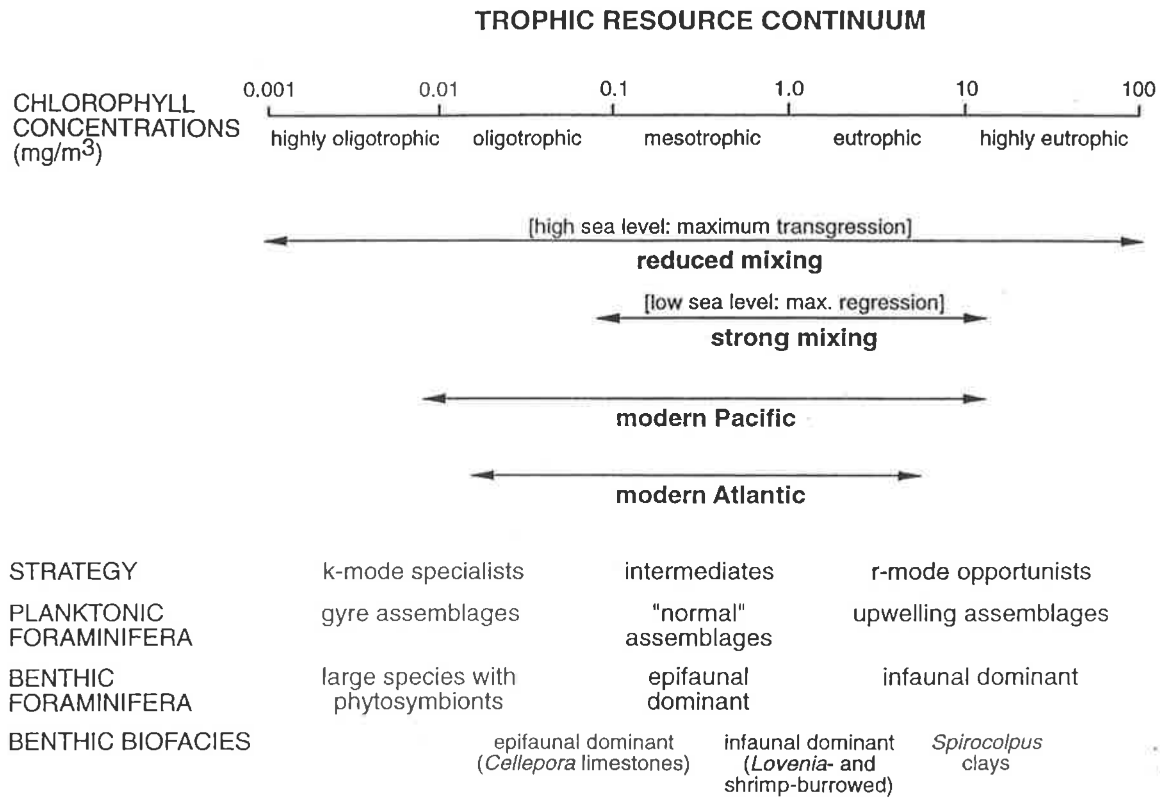


Figure 21. The Trophic Resource Continuum (from McGowran & Li, 1996).

availability of biolimiting nutrients (oligotrophy) to high availability (eutrophy) (Hallock 1987, McGowran & Li 1996), known as the Trophic Resource Continuum (TRC). The TRC does not shift in response to climatic and oceanic change, rather it expands at both ends. This expansion produces an increased range of neritic habitats (McGowran & Li 1996) and at times of global warming and transgression, small changes in sea level produce large swings along the TRC. Current theories propose that relative to bryozoan communities at large, *Celleporaria* are opportunists which exploit high nutrient conditions, and that the TRC should be modified to place them as mesotrophic (McGowran, *pers. comm.*).

McGowran & Li (1996) have suggested that during the 2nd order Miocene highstand the foraminiferal community of the Gippsland Basin reflected such large swings in the TRC. At the oligotrophic end they observe the most pronounced influxes of large tropical photosymbiotic foraminifera (*Lepidocyclina*, *Flosculinella* etc.), whilst at the eutrophic end of the spectrum can be found the dominance of molluscan assemblages by the filter feeding turritellid *Maoricolpus*. At the second order scale, the response of the biosphere to maximum transgression and global warming is the effective stratigraphic 'coappearance' of these two end members. This feature can also be witnessed in the Batesfordian sediments of the type section of the Morgan Limestone/Cadell Marl. *Lepidocyclina howchini* is restricted to an interval 1 - 4.9m thick approximately 1m below the base of the section measured for this study (Lindsay & Giles 1973, & the author's personal observations). This horizon is located within the *Celleporaria* dominated bryozoal limestones.

Above this, sediments change to an alternation of marls and *Celleporaria* hardbands, followed by a series of *Maoricolpus* dominant and absent marls. Conditions swing back towards oligotrophy in the upper Morgan limestone with the reappearance of recrystallised *Celleporaria* limestones, only to return once again to eutrophic *Maoricolpus* limestones.

It is possible that the 7 specific ostracod assemblages recognised in the Morgan Limestone/Cadell Marl sequence may be the product of an expanded TRC at the second order oscillation/climatic optimum with small scale Milankovitch changes in sea level generating fluctuations between highly oligotrophic *Lepidocyclina* limestone, meso-oligotrophic *Celleporaria* limestones and highly eutrophic *Maoricolpus* beds. The seven distinct ostracod assemblages for the section may simply be a reflection of differing nutrient conditions during small scale sea level changes. Unfortunately, the scale of this project is too limited stratigraphically to identify any third order taxic patterns of recurrent ostracod assemblages.

8. CONCLUSIONS

The procession of ostracod assemblages through the section tells a story of an interaction between changing depth and nutrient levels.

These assemblages appear to reflect a change from inner shelf onshore conditions to inner shelf offshore conditions through the lower Morgan Limestone, deepening to middle shelf depths low in the Cadell Marl. Conditions shallow from the middle of the marl to the top of this unit, this signal being overprinted by fluctuating nutrient conditions producing alternation of *Maoricolpus* beds. The upper limestone member was deposited on the inner shelf under oscillating nutrient levels.

Current theories based on consideration of the Trophic Resource Continuum suggest that the sequence may simply reflect an ostracod fauna responding to changing nutrients in the neritic environment produced by small scale fluctuations in sea level.

The Batesfordian highstand is recorded in the sediments of the Gippsland, Port Phillip and Otway Basins, so it must be expected to be observed in the Batesfordian strata of the Murray Basin. The foraminiferal dating of the section places the deposition of the Morgan Limestone/Cadell Marl sequence during a time of rising and falling sealevel peaking at the highstand of cycle 2.3 in the Batesfordian. This appears to correlate well with the suggested highstand in the lower Cadell Marl (assemblage Cadell 1) (see Fig. 22, p.83).

5th order fluctuations in sea level overprinting the third order Miocene oscillation and associated Batesfordian highstand have produced a cyclicity of lithology from meso/oligotrophic *Celleporaria* limestones to highly eutrophic *Maoricolpus* marls and limestones with each of these depth/lithology/nutrient associations characterised by a distinctive ostracod asemblage.

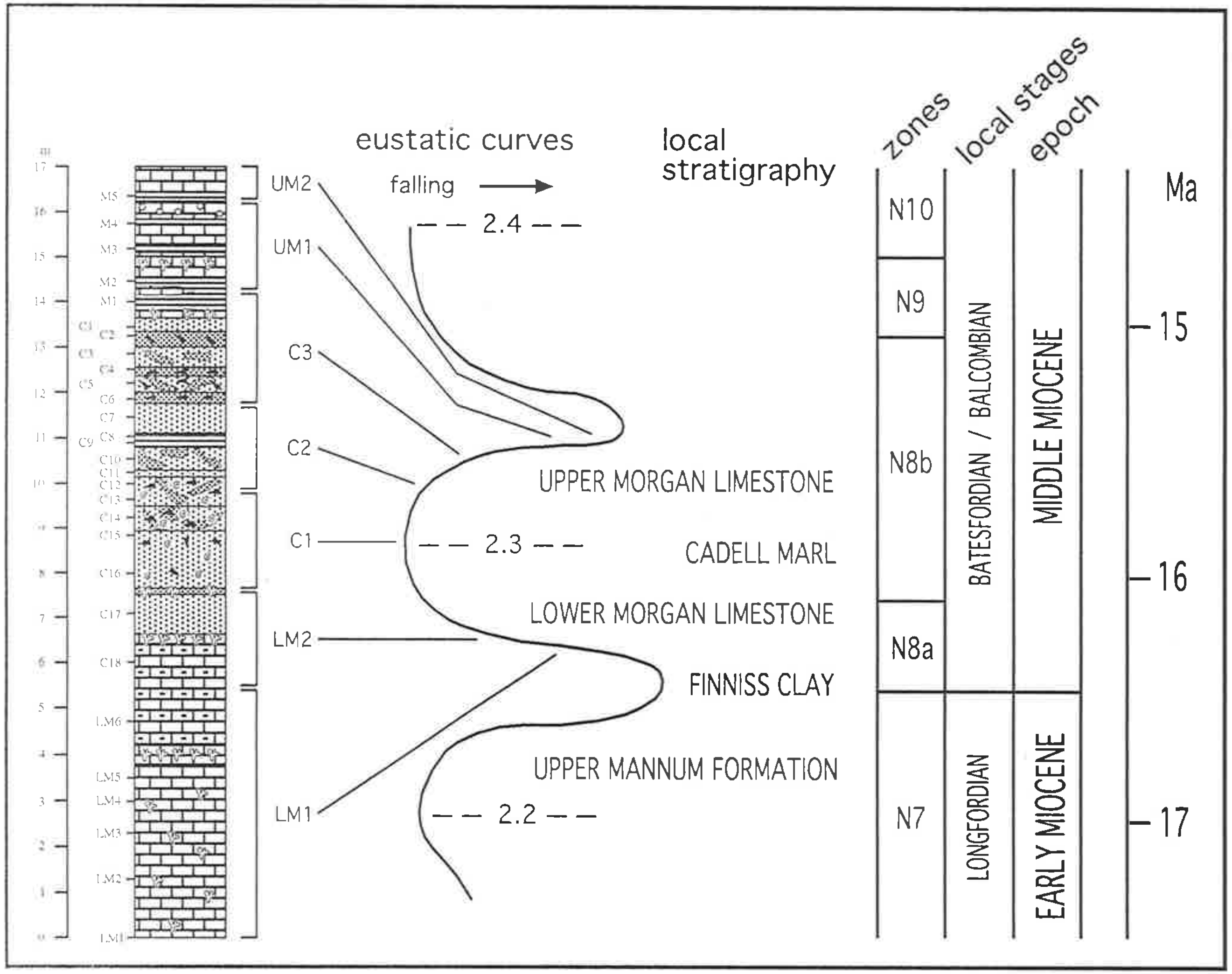


Figure 22. Correlation of measured section, faunal assemblages, Exxon sea level curve of Haq *et al.* 1987, Tertiary cycles, local stratigraphy & chronology of the Early-Middle Miocene of Berggren *et al.* 1995.

9. SPECIES PLATES

Figures of species cited in the text appear on the following plates, numbered consecutively from 9 to 19.

Figured specimens are mounted on electron microscope stubs and are housed in the Invertebrate Paleontology collection of the South Australian Museum. Individual figured specimens have been allocated South Australian Museum Palaeontology (SAM P) register numbers which appear in the plate captions.

The abbreviations A, J, LV and RV are used for adult, juvenile, left valve and right valve respectively. Captions also provide the formation from which the specimen comes, along with the relevant sample number and magnification.

PLATE 9

A. *Neonesidea chapmani* Whatley & Downing 1983. ARV external, SAM P36163. Lower Morgan Limestone, sample L6. x65.

B. *Neonesidea australis* (Chapman 1914). ARV external, SAM P36164. Lower Morgan Limestone, sample L2. x65.

C. *Paranesidea barwonensis* Warne 1986. ARV external, SAM P36165. Lower Morgan Limestone, sample L6. x75.

D. *Neonesidea* sp A. ARV external, SAM P36166. Lower Morgan Limestone, sample C19. x75.

E. *Neonesidea fredericki* Warne 1988. ALV internal, SAM P36167. Lower Morgan Limestone, sample C19. x75.

F. *Bythocypris* (*Bythocypris*) *subrectangula* Warne 1990. ARV internal, SAM P36168. Cadell Marl, sample C15. x75.

G. ?*Bythocypris* (*Bythocypris*) sp A Warne 1990. ALV external, SAM P36169. Lower Morgan Limestone, sample C17. x110.

H. *Cytheralison pravacauda* Hornibrook 1952. ALV external, SAM P36170. Cadell Marl, sample C4. x100.

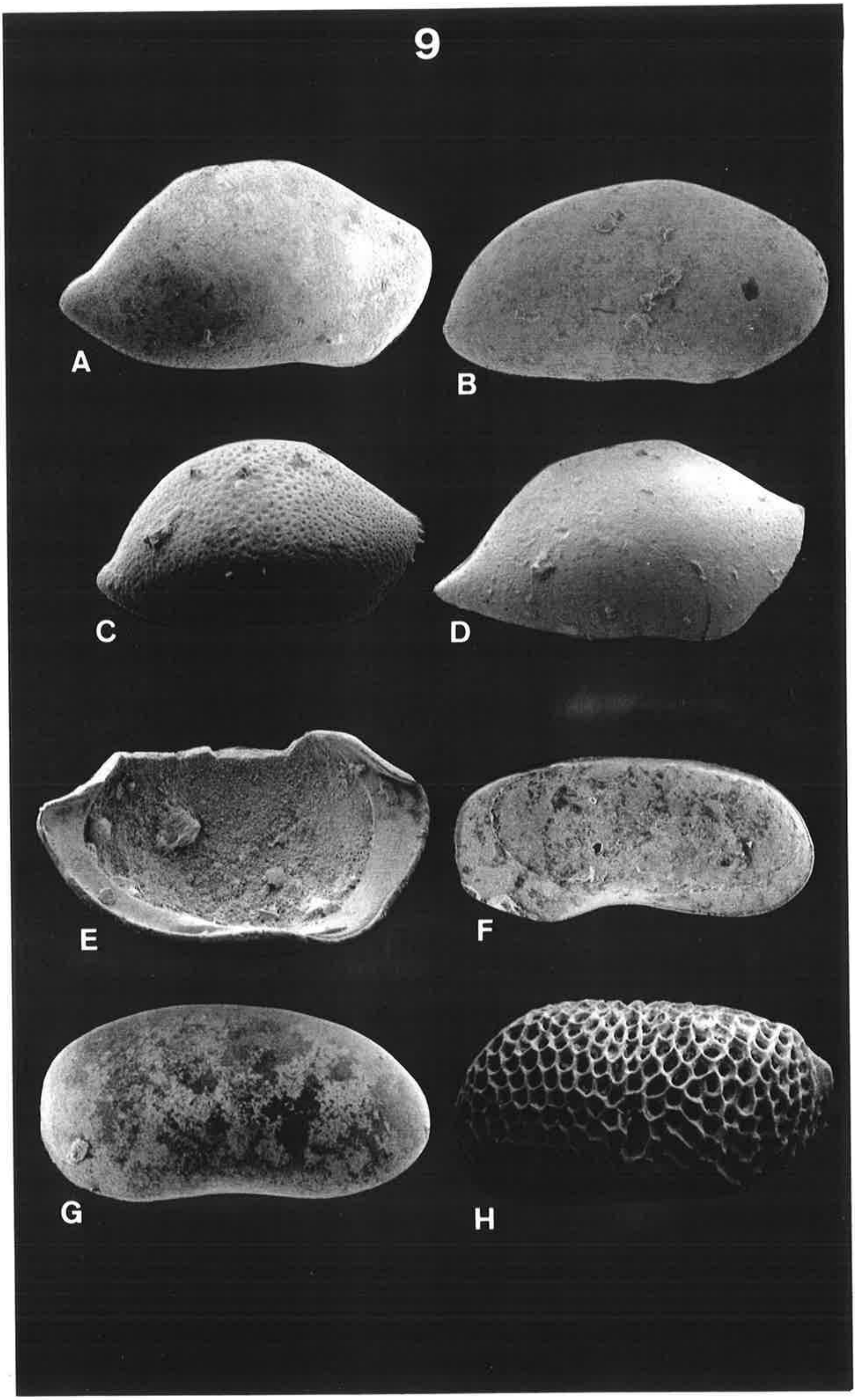

9
A
B
C
D
E
F
G
H

PLATE 10

A. *Hanaiceratina arenacea* (Brady 1880). ALV external, SAM P36171. Cadell Marl, sample C13. x100.

B. *Cytherella* sp. ALV external, SAM P36172. Cadell Marl, sample C11. x100.

C. *Platella parapunctata* (Whatley & Downing 1983). ALV external, SAM P36173. Lower Morgan Limestone, sample C19. x80.

D. *Cytherelloidea intermedia* (Chapman & Crespin 1928). ARV external, SAM P36174. Lower Morgan Limestone, sample L6. x80.

E. *Cytherelloidea australomiocenica* Whatley & Downing 1983. JLV external, SAM P36175. Lower Morgan Limestone, sample L2. x140.

F. *Saida* sp cf. *Saida* sp 1 Warne 1987. ALV external, SAM P36176. Cadell Marl, sample C9. x150.

G. *Saida* sp 1. ARV external, SAM P36177. Cadell Marl, sample C10. x150.

H. *Loxocythere* sp 1. ALV external, SAM P36178. Cadell Marl, sample C9. x150.

I. *Loxocythere* sp 2. ARV external, SAM P36179. Cadell Marl, sample C9. x150.

J. *Loxocythere* sp 3. ARV external, SAM P36180. Cadell Marl, sample C11. x150.

10

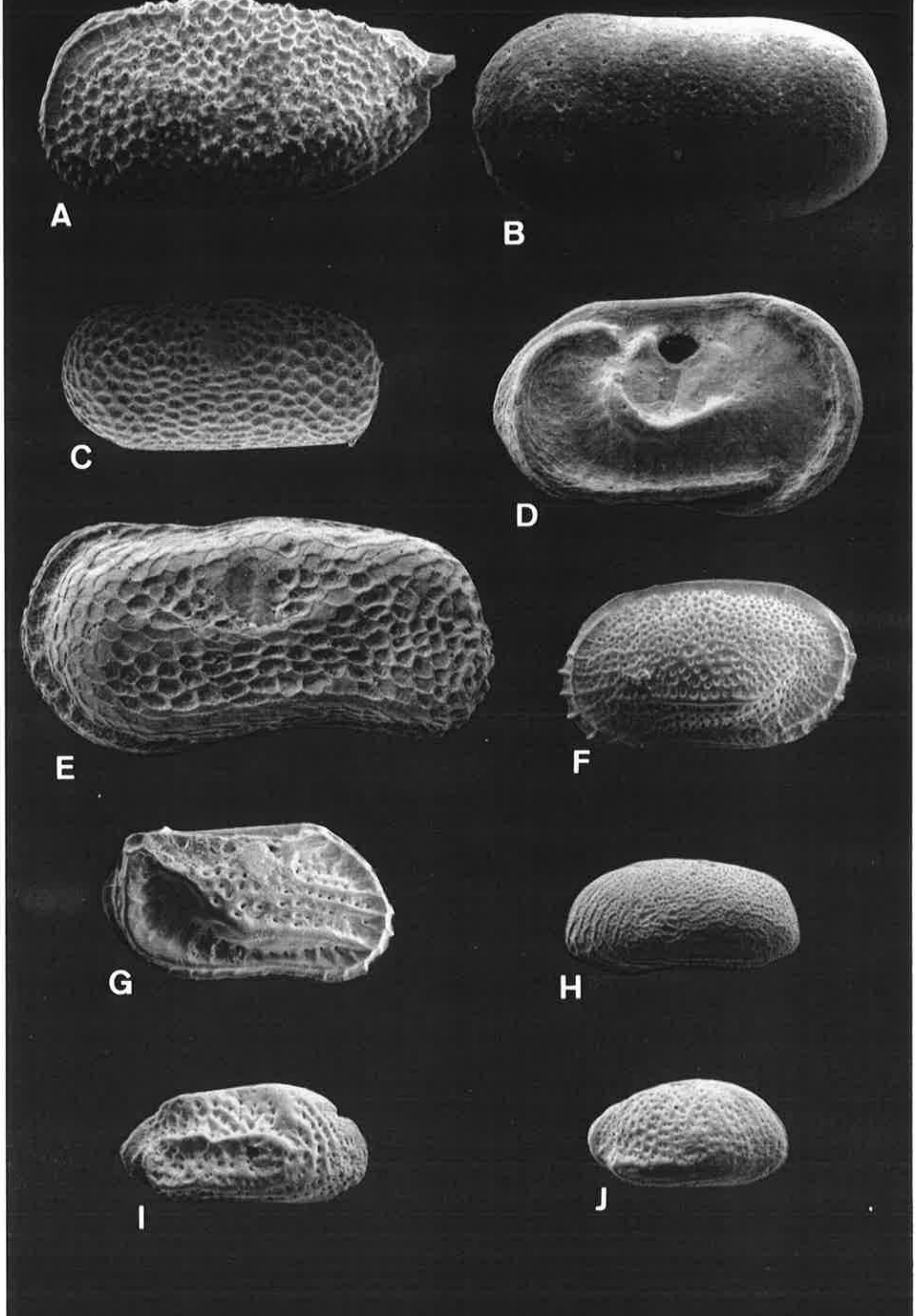


PLATE 11

A. *Oculocytheropteron microfornix* (Whatley & Downing 1983). ARV external, SAM P36181. Lower Morgan Limestone, sample C19. x150.

B. *Oculocytheropteron parawellmani* (Whatley & Downing 1983). ARV external, SAM P36182. Lower Morgan Limestone, sample C19. x130.

C. *Cytheropteron antipodum* Whatley & Downing 1983. ARV external, SAM P36183. Cadell Marl, sample C15. x180.

D. *Oculocytheropteron* sp 1. ALV external, SAM P36184. Lower Morgan Limestone, sample L5. x110.

E. *Cytheropteron*? *mchenryi* Majoran (in press). ARV external, SAM P36185. Lower Morgan Limestone, sample C19. x150.

F. *Kangarina macropus* Whatley & Downing 1983. ALV external, SAM P36186. Cadell Marl, sample C7. x180.

G. *Kangarina* sp. ARV external, SAM P36187. Cadell Marl, sample C10. x180.

H. *Hemicytherura* cf. *H. pentagona* Hornibrook 1952. ARV external, SAM P36188. Cadell Marl, sample C10. x220.

I. *Hemicytherura* cf. *H reekmani* McKenzie, Reyment & Reyment 1991. ARV external, SAM P36189. Cadell Marl, sample C10. x190.

J. *Hemicytherura* sp. ARV external, SAM P36190. Cadell Marl, sample C13. x250.

11

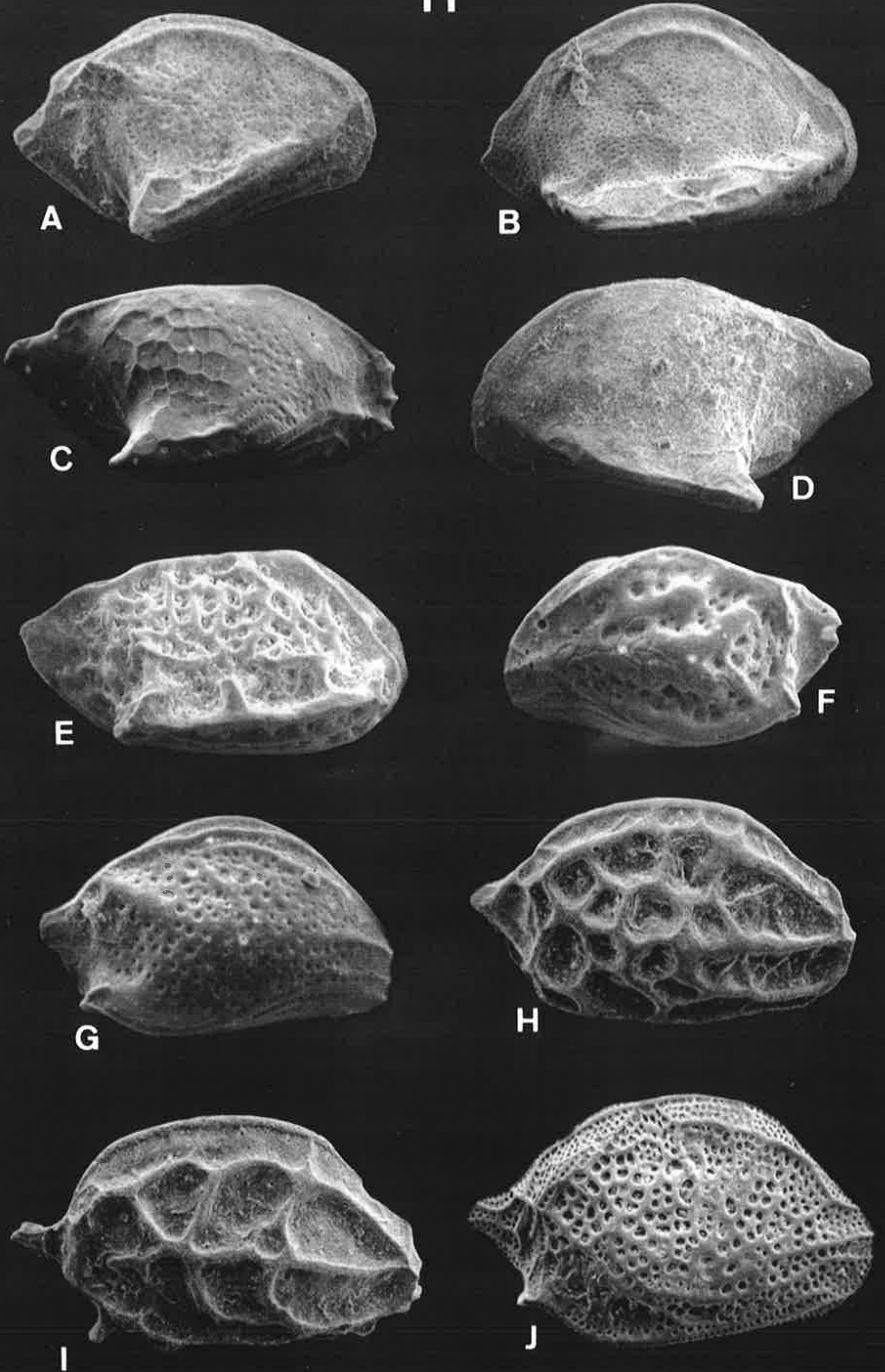


PLATE 12

A. *Semicytherura* sp 1. ALV external, SAM P36191. Upper Morgan Limestone, sample M3. x200.

B. *Semicytherura* sp 2. ALV external, SAM P36192. Lower Morgan Limestone, sample C17. x160.

C. *Semicytherura* sp 3. ALV external, SAM P36193. Cadell Marl, sample C10. x200.

D. *Semicytherura* sp 4. ARV external, SAM P36194. Cadell Marl, sample C13. x200.

E. *Semicytherura* sp 5. ARV external, SAM P36195. Cadell Marl, sample C13. x230.

F. *Semicytherura* sp 6. ARV external, SAM P36196. Cadell Marl, sample C14. x200.

G. *Semicytherura* sp 7. ARV external, SAM P36197. Cadell Marl, sample C14. x230.

H. *Semicytherura* sp 8. ALV external, SAM P36198. Upper Morgan Limestone, sample M3. x190.

I. *Bythoceratina* sp. ALV external, SAM P36199. Lower Morgan Limestone, sample L6. x110.

J. *Neobuntonia batesfordiense* (Chapman 1914). ARV external, SAM P36200. Lower Morgan Limestone, sample L4. x80.

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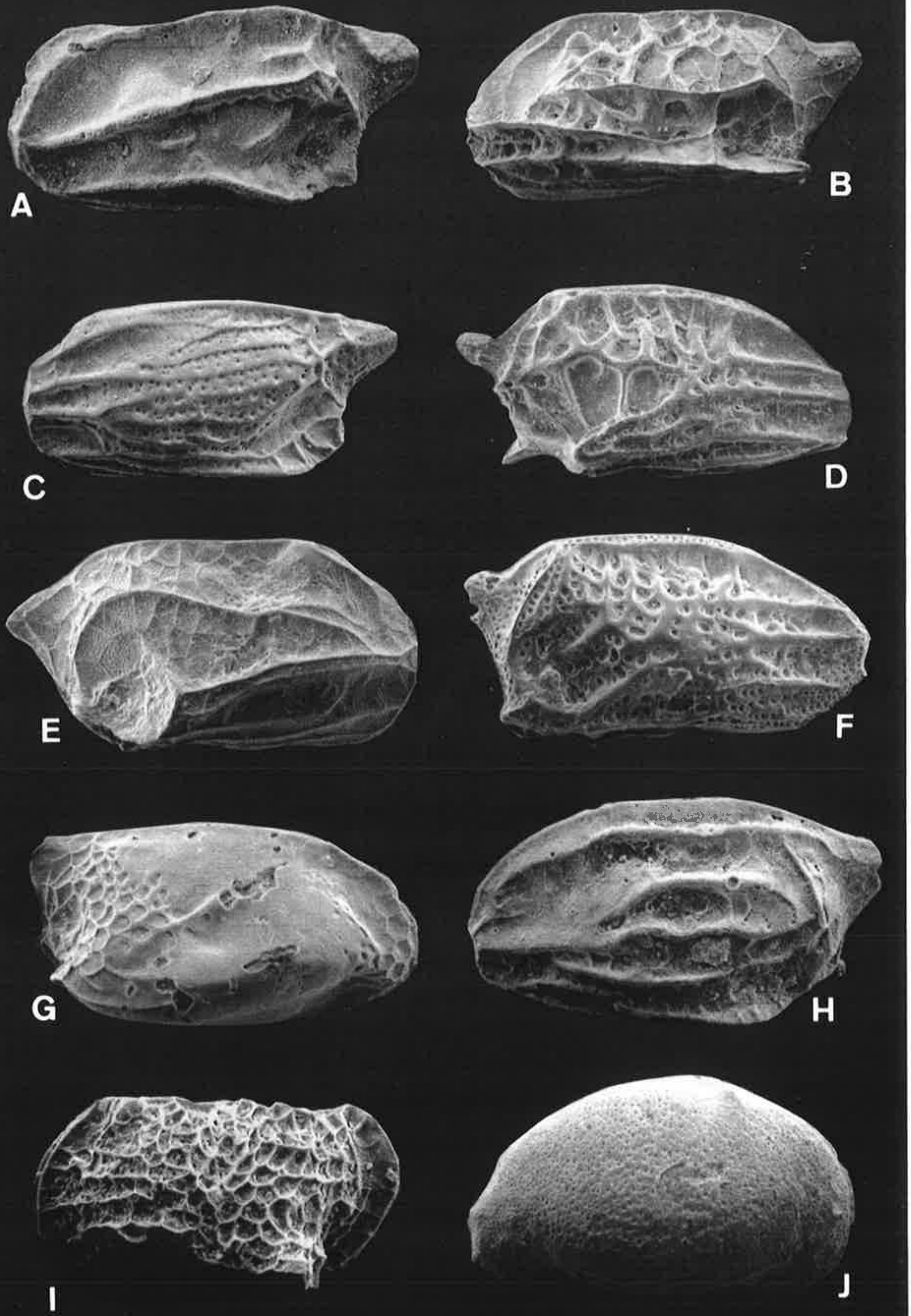

PLATE 13

A. *Pseudeucythere pseudosubovalis* (Whatley & Downing 1983). ARV external, SAM P36201. Upper Morgan Limestone, sample M5. x220.

B. *Pseudeucythere submytila* (Whatley & Downing 1983). ALV external, SAM P36202. Upper Morgan Limestone, sample M5. x180.

C. *Pseudeucythere parapubera* (Whatley & Downing 1983). ALV external, SAM P36203. Upper Morgan Limestone, sample M5. x200.

D. *Quadracythere* sp 1. ALV external, SAM P36204. Lower Morgan Limestone, sample L2. x80.

E. *Quadracythere* sp 2. ALV external, SAM P36205. Cadell Marl, sample C5. x80.

F. *Quadracythere willungaensis* Majoran 1996. ALV external, SAM P36206. Cadell Marl, sample C1. x90.

G. *Bradleya praemckenziei* Whatley & Downing 1983. ALV external, SAM P36207. Cadell Marl, sample C8. x80.

H. *Bradleya* cf *B. kincaidiana* (Chapman 1926). ALV external, SAM P36208. Lower Morgan Limestone, sample L5. x60.

I. *Chapmanella flexicostata* (Chapman 1914). ALV external, SAM P36209. Cadell Marl, sample C5. x80.

J. *Spinobradleya nodosa* Neil 1994. ALV external, SAM P36210. Lower Morgan Limestone, sample C19. x80.

13

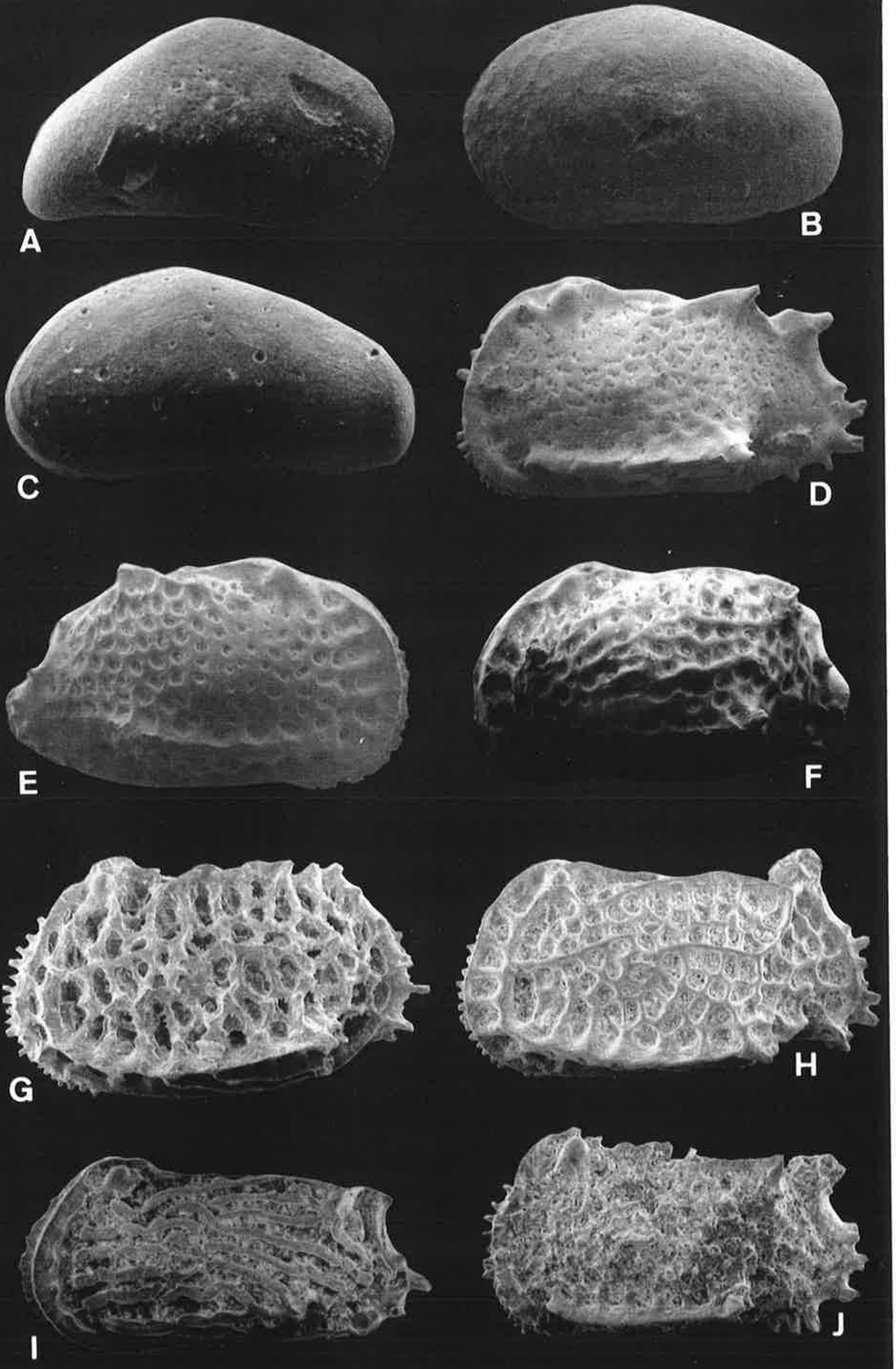

PLATE 14

A. *Hermanites glyphica* Neil 1994. ARV external, SAM P36211. Lower Morgan Limestone, sample L3. x80.

B. ?*Hermanites* sp A. JLV external, SAM P36212. Cadell Marl, sample C14. x120.

C. *Hornibrookella* sp. ARV external, SAM P36213. Upper Morgan Limestone, sample M2. x120.

D. *Parakrithella* sp 1. ALV external, SAM P36214. Lower Morgan Limestone, sample C18. x150.

E. *Krithe nitida* Whatley & Downing 1983. ARV external, SAM P36215 Cadell Marl, sample C13. x150.

F. *Krithe nitida* Whatley & Downing 1983. ARV internal, SAM P36216. Cadell Marl, sample C14. x150.

G. *Parakrithella* sp 2. ALV external, SAM P36217. Upper Morgan Limestone, sample M1. x150.

H. *Callistocythere* sp "zigzag". ALV external, SAM P36218. Cadell Marl, sample C5. x150.

I. *Callistocythere* sp "zigzag". ALV external, SAM P36219. Cadell Marl, sample C16. x150.

J. *Callistocythere* sp "zigzag". ALV external, SAM P36220. Upper Morgan Limestone, sample M4. x150.

14

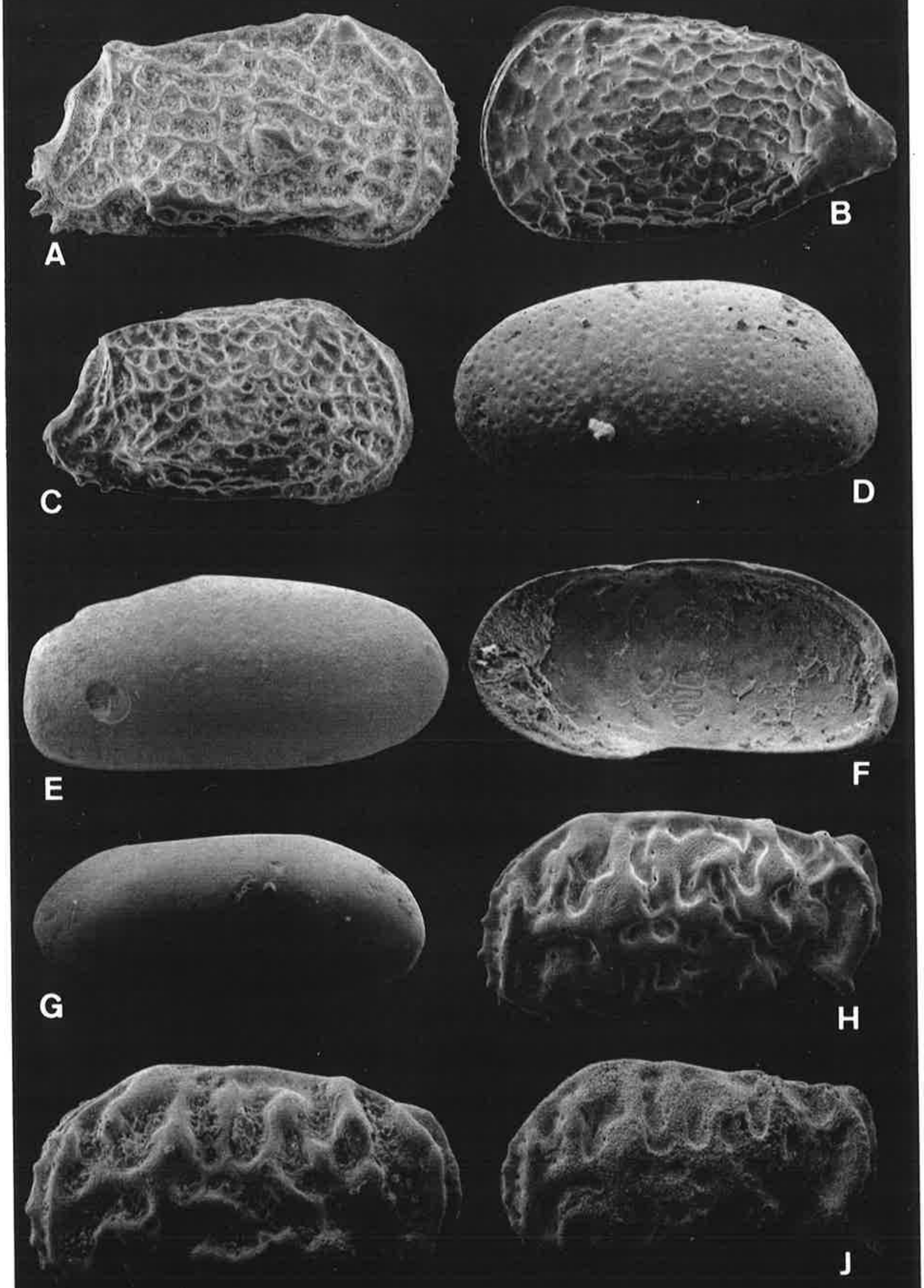

PLATE 15

A. *Callistocythere* sp "nodosa". ARV external, SAM P36221. Lower Morgan Limestone, sample C19. x150.

B. *Callistocythere* sp 1. ALV external, SAM P36222. Upper Morgan Limestone, sample M5. x150.

C. *Callistocythere* sp 3. ALV external, SAM P36223. Upper Morgan Limestone, sample M3. x170.

D. *Callistocythere* sp 2 . ALV external, SAM P36224. Upper Morgan Limestone, sample M3. x150.

E. *Callistocythere* sp 4 . ALV external, SAM P36225. Cadell Marl, sample C7. x150.

F. *Loxoconcha* sp. cf *L. mioaustralis* Neil 1992. ALV external, SAM P36226. Upper Morgan Limestone, sample M2. x130.

G. *Loxoconcha* cf *L. punctabella* McKenzie, Reyment & Reyment 1991. ARV external, SAM P36227. Upper Morgan Limestone, sample M2. x120.

H. *Loxoconcha* sp 2. ALV external, SAM P36228. Lower Morgan Limestone, sample C18. x130.

I. *Loxoconcha* cf *L. mcgowrani* McKenzie, Reyment & Reyment 1991. ARV external, SAM P36229. Cadell Marl, sample C16. x120.

J. *Microceratina* sp 1. ALV external, SAM P36230. Cadell Marl, sample C8. x150.

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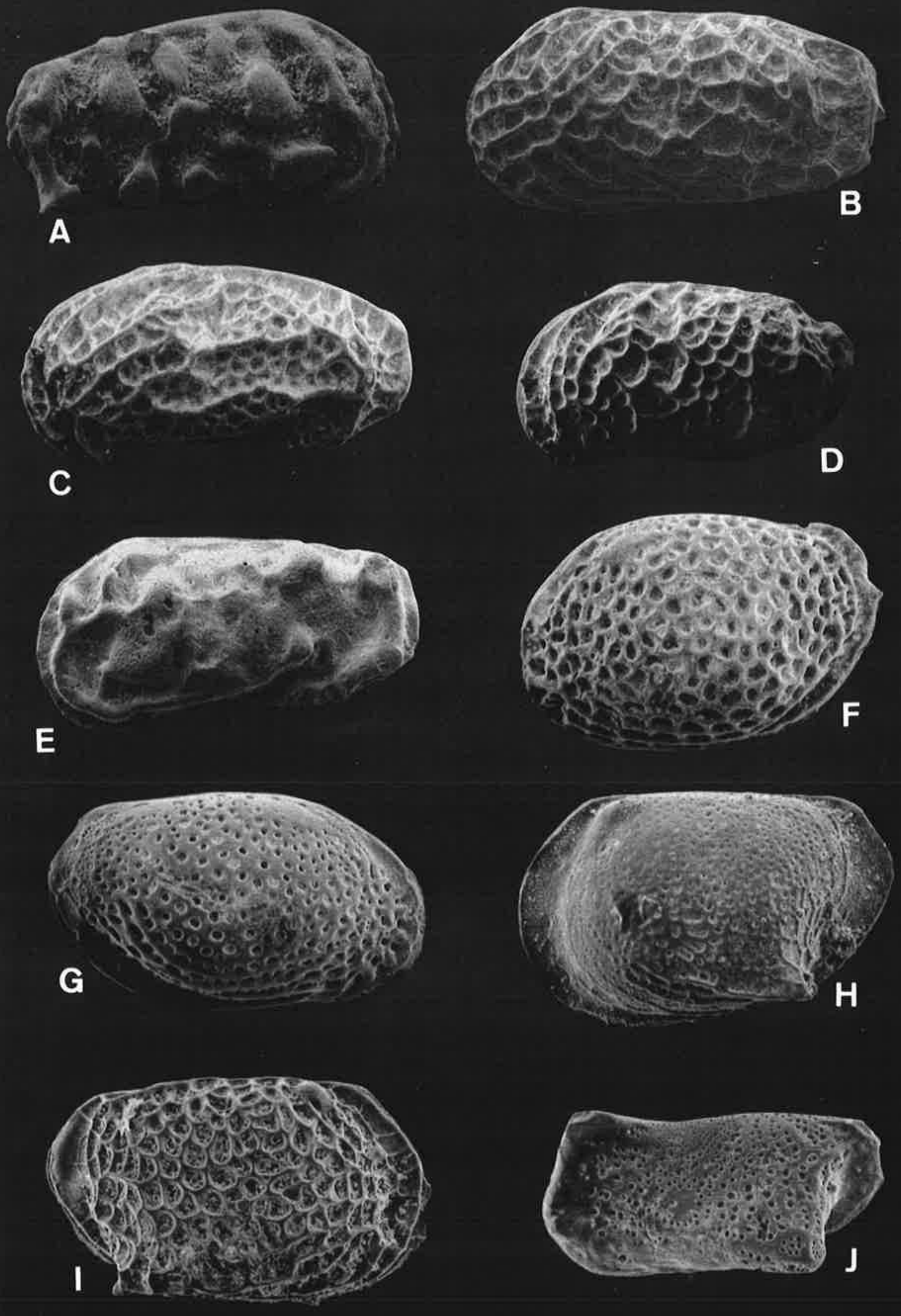

PLATE 16

A. *Microceratina* sp 2. ALV external, SAM P36231. Cadell Marl, sample C10. x120.

B. *Macromckenzia porcelanica* (Whatley & Downing 1983). ALV external, SAM P36232. Cadell Marl, sample C13. x60.

C. *Macromckenzia* sp A. JLV external, SAM P36233. Cadell Marl, sample C12. x120.

D. *Macroscapha* sp. JRV external, SAM P36234. Cadell Marl, sample C12. x50.

E. ?*Pontocyprella* sp. ALV external, SAM P36235. Cadell Marl, sample C16. x110.

F. *Paracypris* sp. ALV internal, SAM P36238. Cadell Marl, sample C5. x70.

G. *Propontocypris* sp 2. ALV external, SAM P36237. Cadell Marl, sample C9. x150.

H. *Propontocypris* sp 1. ALV external, SAM P36236. Lower Morgan Limestone, sample L6. x110.

I. *Paradoxostoma* sp 1. ARV external, SAM P36239. Cadell Marl, sample C12.

J. *Paijenborchella solitaria ponticola* Whatley & Downing 1983. ALV external, SAM P36240. Cadell Marl, sample C1. x130.

16

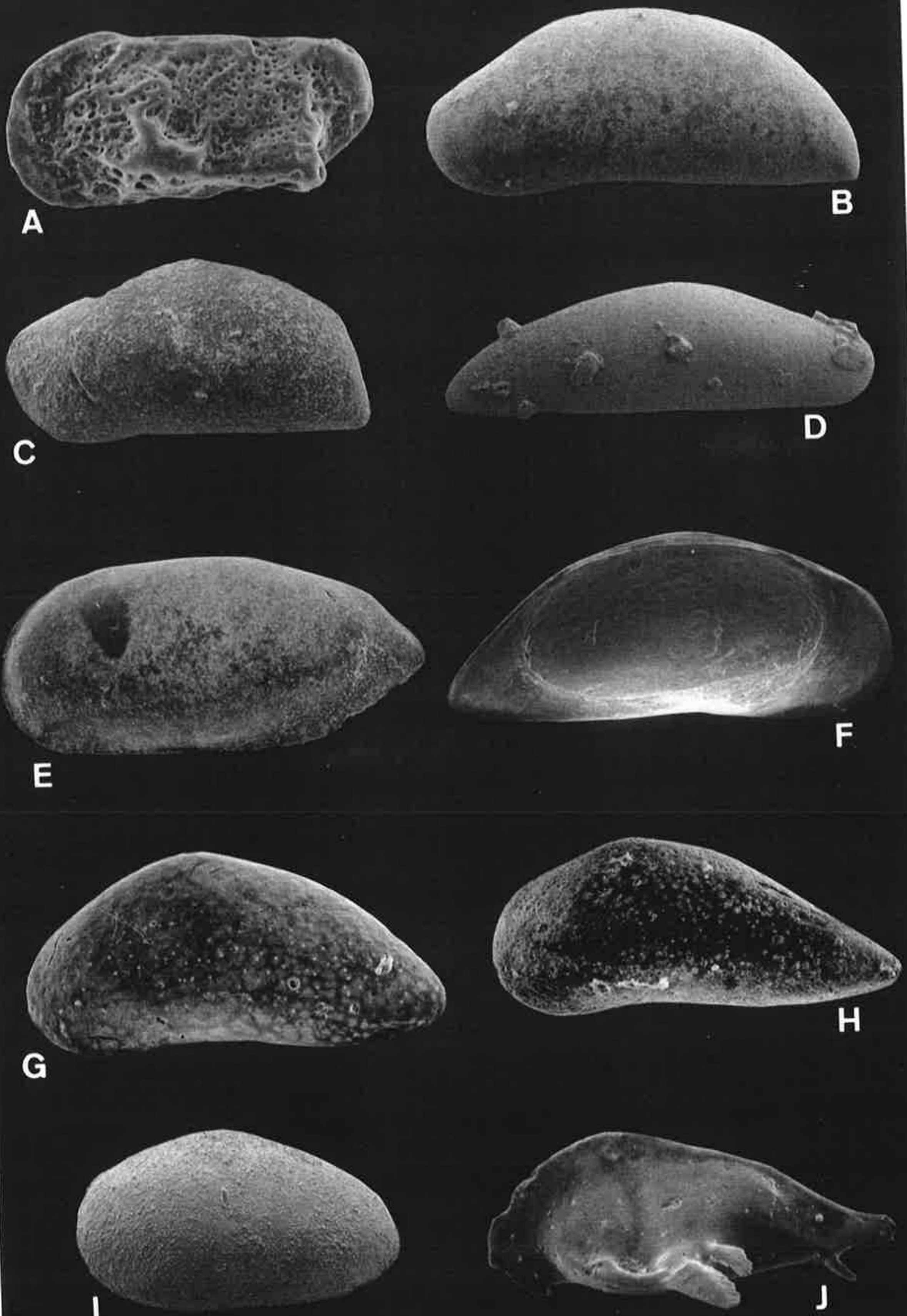

PLATE 17

A. *Keijia* sp A Neil 1992. ALV external, SAM P36241. Upper Morgan Limestone, sample M4. x150.

B. ?*Keijia* sp B Neil 1992. ARV external, SAM P36242. Lower Morgan Limestone, sample L2. x150.

C. *Keijia* sp 3. ARV external, SAM P36243. Upper Morgan Limestone, sample M5. x150.

D. *Keijia* sp 4. ALV external, SAM P36244. Upper Morgan Limestone, sample M5. x150.

E. *Keijia* sp 5. ARV external, SAM P36245. Upper Morgan Limestone, sample M5. x150.

F. *Arcacythere* sp. ALV external, SAM P36246. Upper Morgan Limestone, sample M5. x150.

G. *Munseyella splendida* Whatley & Downing 1983. ALV external, SAM P36247. Upper Morgan Limestone, sample M3. x200.

H. *Munseyella* sp 1. ARV external, SAM P36248. Cadell Marl, sample C8. x200.

I. *Munseyella* sp 2. JLV external, SAM P36249. Cadell Marl, sample C9. x200.

J. *Morkhovenia* sp. ALV external, SAM P36250. Lower Morgan Limestone, sample L4. x150.

17

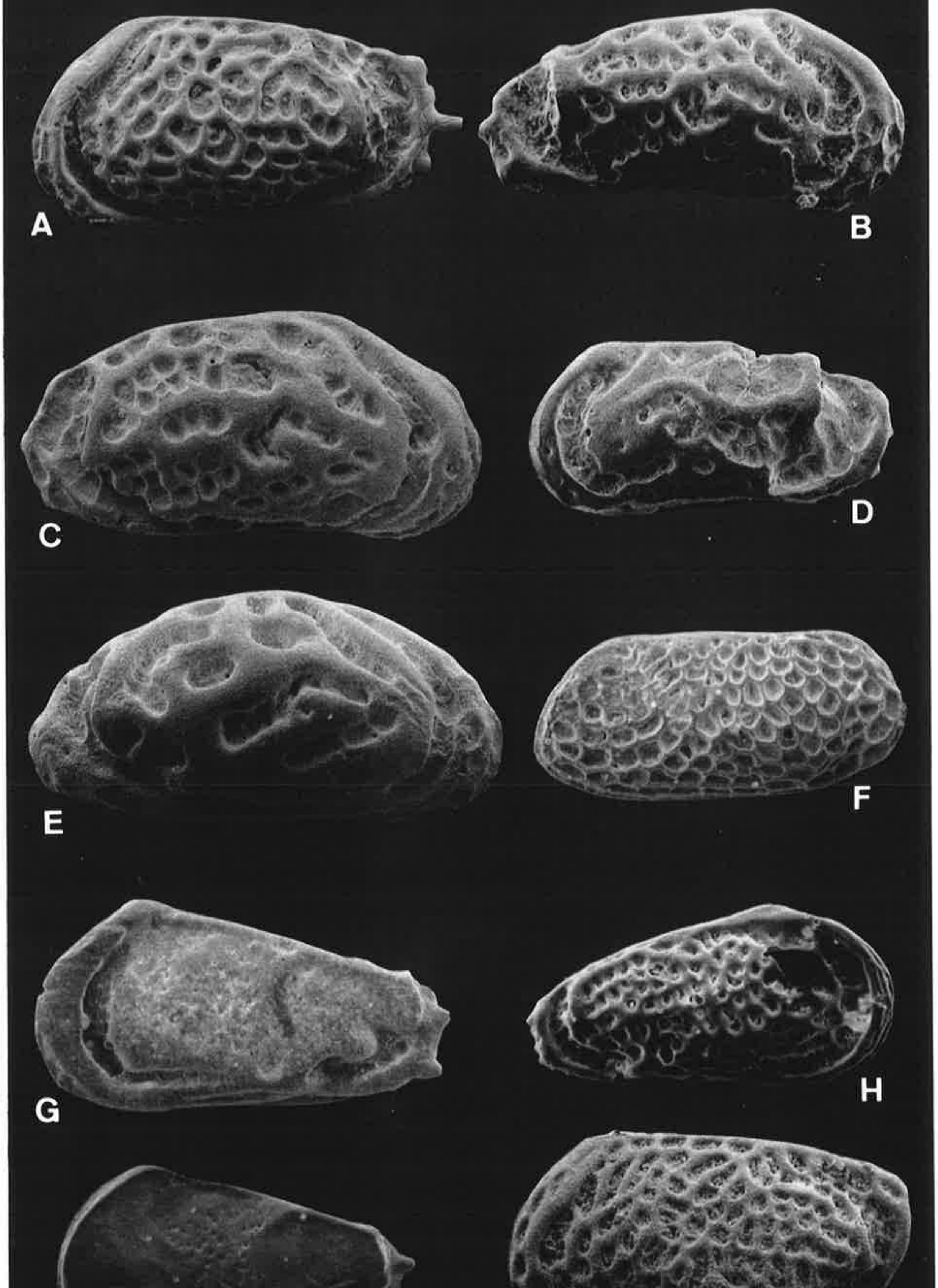

PLATE 18

A. *Polycope* sp A. ARV external, SAM P36251. Cadell Marl, sample C14. x130.

B. *Polycope melbournensis* Warne 1990. ARV external, SAM P36252. Cadell Marl, sample C13. x130.

C. ?*Polycopsis* sp. ARV external, SAM P 36253. Cadell Marl, sample C12. x110.

D. *Argilloecia australomiocenica* Whatley & Downing 1983. Carapace external, SAM P36254. Cadell Marl, sample C9. x160.

E. *Argilloecia argilloeciaformis* Whatley & Downing 1983. ALV external, SAM P36255. Cadell Marl, sample C12. x90.

F. *Maddocksella tumefacta* (Chapman 1914). ARV internal, SAM P36256. Cadell Marl, sample C11. x90.

G. *Cletocythereis caudispinosa* (Chapman & Crespin 1982). ARV external, SAM P36257. Cadell Marl, sample C7. x100.

H. ?*Actinocythereis* sp. ARV external, SAM P36258. Cadell Marl, sample C16. x80.

I. *Trachyleberis* sp A. ARV external, SAM P36259. Lower Morgan Limestone, sample C17. x80.

J. *Deltaleberis rugosapytta* McKenzie, Reyment & Reyment 1991. ALV external, SAM P36260. x100.

18

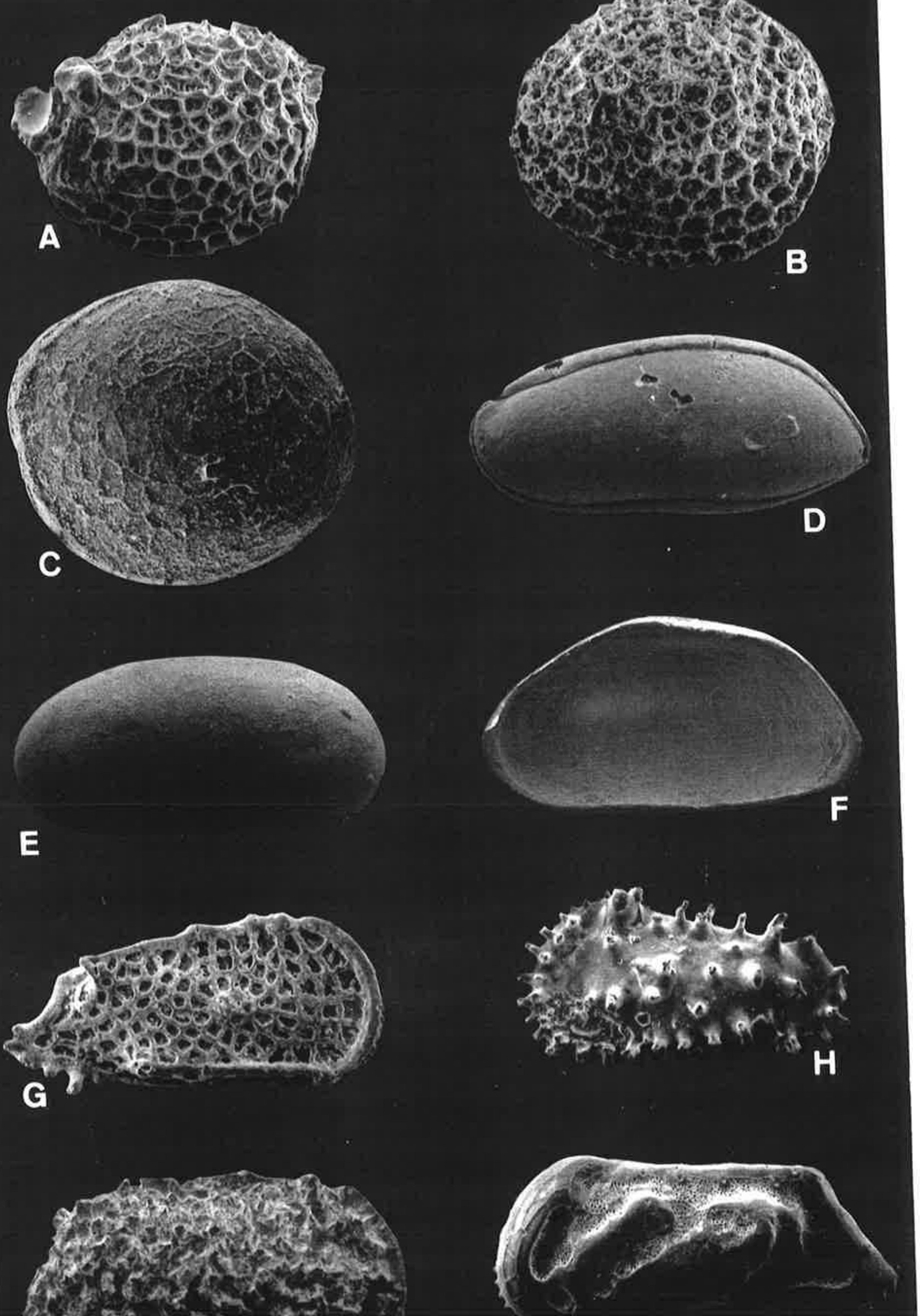

PLATE 19

A. *Alataleberis* sp. ALV external, SAM P36261. Cadell Marl, sample C7. x60.

B. *Werribeeleberis* sp. ARV external, SAM P36262. Upper Morgan Limestone, sample M5. x100.

C. *Xestoleberis* sp. cf *X. cooki* Whatley & Downing 1983. ARV external, SAM P36263. Lower Morgan Limestone, sample C18. x110.

D. *Foveoleberis ?minutissima* (Chapman 1926). ALV external, SAM P36264. x90.

E. *Microxestoleberis* sp 1. ARV external, SAM P36265. Cadell Marl, sample C10. x170.

F. *Microxestoleberis* sp 2. ARV external, SAM P36266. Cadell Marl, sample C10. x190.

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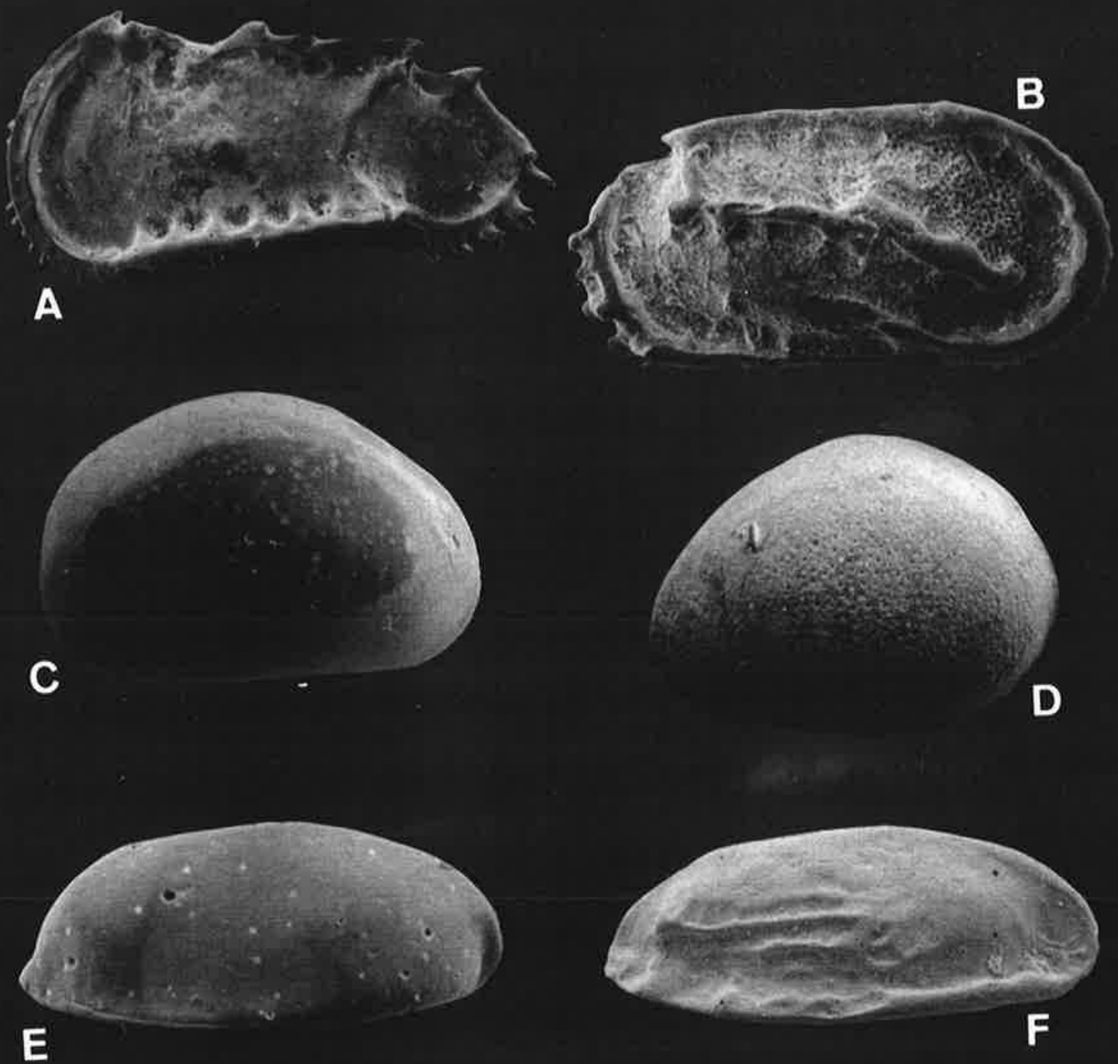

10. APPENDIX

SPECIES LISTS & ABUNDANCES

The following appendix contains species lists and abundances for each of the 29 samples from the measured section. Species are arranged in decreasing order of abundance.

LM1	0.00m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Neonesidea chapmani	8	59	67	13.79
Callistocythere sp "zigzag"	40	11	51	10.49
Parakrithella sp 1	46	4	50	10.29
Spinobradleya nodosa	17	30	47	9.67
Cletocythereis caudispinosa	7	28	35	7.20
Callistocythere sp 'nodosa'	19	7	26	5.35
Bradleya praemckenziei	5	20	25	5.14
Foveoleberis ?minutissima	12	11	23	4.73
Oculocytheropteron microfornix	13	8	21	4.32
Neobuntonia batesfordiense	4	9	13	2.67
Bythoceratina sp	7	5	12	2.47
Cytherella sp	5	6	11	2.26
Kangarina macropus	9	1	10	2.06
Cytheropteron? mchenryi	9	1	10	2.06
Loxocythere sp 1	1	8	9	1.85
Hermanites glyphica	0	5	5	1.03
Neonesidea australis	0	5	5	1.03
Platella parapunctata	4	1	5	1.03
?*Actinocythereis* sp	2	2	4	0.82
Deltaleberis rugosapytta	0	4	4	0.82
Hornibrookella sp	0	4	4	0.82
Morkhovenia sp	3	1	4	0.82
Neonesidea sp A	0	4	4	0.82
Oculocytheropteron sp 1	3	1	4	0.82
Quadracythere sp 1	2	2	4	0.82
Argilloecia argilloeciaformis	1	2	3	0.62
Alataleberis sp	1	1	2	0.41
Chapmanella flexicostata	1	1	2	0.41
?*Keijia* sp B Neil	2	0	2	0.41
Loxoconcha cf *mioaustralis*	1	1	2	0.41
Neonesidea fredericki	2	0	2	0.41
Oculocytheropteron parawellmani	2	0	2	0.41
Paradoxostoma sp 1	1	1	2	0.41
?*Pontocyprella* sp	2	0	2	0.41
Cletocythereis rastromarginata	0	1	1	0.21
Keijia sp A Neil	0	1	1	0.21
Loxoconcha sp cf *punctabella*	1	0	1	0.21
Macrocypridid sp. indet	0	1	1	0.21
Macromckenzia porcelanica	0	1	1	0.21
Cytheropteron antipodum	1	0	1	0.21
Pseudeucythere parapubera	1	0	1	0.21
Pseudeucythere pseudosubovalis	1	0	1	0.21
Quadracythere sp 2	0	1	1	0.21
Retibythere? sp	0	1	1	0.21
Trachyleberis sp 1	1	0	1	0.21
Werribeeleberis sp	1	0	1	0.21
Xestoleberis cf *cooki*	0	1	1	0.21
Indeterminate			1	0.21
			486	

LM2	1.30m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Callistocythere sp 'nodosa'	39	15	54	10.89
Xestoleberis cf *cooki*	8	41	49	9.88
Loxoconcha cf *mioaustralis*	23	25	48	9.68
Neonesidea chapmani	12	36	48	9.68
Parakrithella sp 1	41	4	45	9.07
Foveoleberis ?minutissima	13	16	29	5.85
Hermanites glyphica	3	18	21	4.23
Parakrithella sp 2	20	0	20	4.03
Cletocythereis caudispinosa	11	6	17	3.43
Neonesidea australis	5	12	17	3.43
Bradleya praemckenziei	6	9	15	3.02
Cytherella sp	10	4	14	2.82
Chapmanella flexicostata	4	9	13	2.62
?*Keija* sp B Neil	6	6	12	2.42
Spinobradleya nodosa	4	8	12	2.42
Quadracythere sp 1	11	2	11	2.22
Bradleya cf *kincaidiana*	3	6	9	1.81
Callistocythere sp "zigzag"	2	7	9	1.81
Oculocytheropteron sp 1	3	3	6	1.21
Neonesidea sp A	0	5	5	1.01
Platella parapunctata	4	1	5	1.01
Neobuntonia batesfordiense	1	3	4	0.81
Bythoceratina sp	2	1	3	0.60
Cletocythereis rastromarginata	3	0	3	0.60
Deltaleberis rugosapytta	0	3	3	0.60
Cytheropteron? mchenryi	3	0	3	0.60
Quadracythere sp 2	2	0	2	0.40
?*Actinocythereis* sp	1	0	1	0.20
Alataleberis sp	0	1	1	0.20
Argilloecia argilloeciaformis	0	1	1	0.20
Argilloecia sp A	0	1	1	0.20
Callistocythere sp 4	0	1	1	0.20
Cytherelloidea australomiocenica	1	0	1	0.20
Neonesidea fredericki	1	0	1	0.20
Oculocytheropteron microfornix	0	1	1	0.20
Pseudeucythere parapubera	0	1	1	0.20
Werribeeleberis sp	0	1	1	0.20
Indeterminate	0	0	3	0.60
			490	

LM3	2.30m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Callistocythere sp 'nodosa'	40	9	49	9.92
Loxoconcha cf *mioaustralis*	31	18	49	9.92
Neonesidea chapmani	14	27	41	8.30
Xestoleberis cf *cooki*	2	37	39	7.89
Hermanites glyphica	8	28	36	7.29
Parakrithella sp 1	28	1	29	5.87
Bradleya praemckenziei	5	23	28	5.67
Neonesidea australis	13	14	27	5.47
Cletocythereis caudispinosa	11	11	22	4.45
Foveoleberis ?minutissima	5	11	16	3.24
Parakrithella sp 2	15	0	15	3.04
Bradleya cf *kincaidiana*	4	10	14	2.83
Chapmanella flexicostata	5	9	14	2.83
Quadracythere sp 1	6	5	11	2.23
?*Keija* sp B Neil	6	4	10	2.02
Platella parapunctata	9	1	10	2.02
Oculocytheropteron microfornix	0	9	9	1.82
Deltaleberis rugosapytta	1	6	7	1.42
Quadracythere sp 2	3	4	7	1.42
?*Actinocythereis* sp	6	0	6	1.21
Bythoceratina sp	5	1	6	1.21
Cytherella sp	2	4	6	1.21
Callistocythere sp 'zigzag'	4	1	5	1.01
Neobuntonia batesfordiense	2	2	4	0.81
Neonesidea sp A	1	3	4	0.81
Argilloecia sp A	3	0	3	0.61
Paijenborchella solitaria ponticola	1	2	3	0.61
Spinobradleya nodosa	1	2	3	0.61
Alataleberis sp	1	1	2	0.40
Cletocythereis rastromarginata	2	0	2	0.40
Kangarina macropus	1	1	2	0.40
Macroscapha sp 1	1	1	2	0.40
Morkhovenia sp	1	1	2	0.40
Oculocytheropteron sp 1	1	1	2	0.40
Paradoxostoma sp 1	1	1	2	0.40
Argilloecia argilloeciaformis	1	0	1	0.20
Argilloecia australomiocenica	0	1	1	0.20
Oculocytheropteron parawellmani	0	1	1	0.20
Indeterminate	0	0	0	0.00
			490	

LM4	3.00m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Loxoconcha cf *mioaustralis*	26	25	51	10.20
Hermanites glyphica	10	40	50	10.00
Xestoleberis cf *cooki*	13	36	49	9.80
Callistocythere sp 'nodosa'	34	6	40	8.00
Neonesidea australis	7	29	36	7.20
Foveoleberis ?minutissima	6	20	26	5.20
Cletocythereis caudispinosa	9	14	23	4.60
Neobuntonia batesfordiense	5	18	23	4.60
Neonesidea chapmani	5	18	23	4.60
Bradleya praemckenziei	6	13	19	3.80
Parakrithella sp 1	15	2	17	3.40
?*Actinocythereis* sp	5	10	15	3.00
Bradleya cf *kincaidiana*	3	9	12	2.40
?*Keija* sp B Neil	10	2	12	2.40
Parakrithella sp 2	12	0	12	2.40
Morkhovenia sp	8	2	10	2.00
Quadracythere sp 2	2	7	9	1.80
Chapmanella flexicostata	2	6	8	1.60
Platella parapunctata	8	0	8	1.60
Alataleberis sp	5	1	6	1.20
Bythoceratina sp	3	3	6	1.20
Deltaleberis rugosapytta	1	3	4	0.80
Oculocytheropteron microfornix	2	2	4	0.80
Neonesidea sp A	1	2	3	0.60
Oculocytheropteron sp 1	3	0	3	0.60
Werribeeleberis sp	1	2	3	0.60
Argilloecia argilloeciaformis	1	1	2	0.40
Callistocythere sp 'zigzag'	2	0	2	0.40
Cytherella sp	0	2	2	0.40
Cytheropteron? *mchenryi*	2	0	2	0.40
Quadracythere sp 1	2	0	2	0.40
Callistocythere sp 1	0	1	1	0.20
Copytus ? sp	1	0	1	0.20
Keija sp A Neil	1	0	1	0.20
Loxocythere sp 1	1	0	1	0.20
Macroscapha sp 1	1	0	1	0.20
Oculocytheropteron parawellmani	1	0	1	0.20
Paijenborchella solitaria ponticola	1	0	1	0.20
?*Pontocyprella* sp	1	0	1	0.20
Indeterminate	0	0	1	0.20
			491	

LM5	3.50m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Xestoleberis cf *cooki*	25	34	59	11.80
Hermanites glyphica	6	38	44	8.80
Neonesidea australis	9	32	41	8.20
Bradleya cf *kincaidiana*	10	30	40	8.00
Neonesidea chapmani	9	29	38	7.60
Loxoconcha cf *mioaustralis*	20	11	31	6.20
Cletocythereis caudispinosa	19	11	30	6.00
Callistocythere sp 'nodosa'	23	2	25	5.00
Parakrithella sp 1	21	0	21	4.20
Foveoleberis ?*minutissima*	9	11	20	4.00
Bythoceratina sp	15	4	19	3.80
?*Actinocythereis* sp	8	8	16	3.20
Bradleya praemckenziei	1	14	15	3.00
Chapmanella flexicostata	2	10	12	2.40
Alataleberis sp	4	6	10	2.00
Platella parapunctata	10	0	10	2.00
Neobuntonia batesfordiense	1	7	8	1.60
Oculocytheropteron sp 1	4	4	8	1.60
Quadracythere sp 1	1	6	7	1.40
Deltaleberis rugosapytta	6	0	6	1.20
Cytherella sp	2	3	5	1.00
Werribeeleberis sp	3	2	5	1.00
Morkhovenia sp	4	0	4	0.80
Arculacythereis? sp	0	3	3	0.60
Parakrithella sp 2	2	1	3	0.60
Quadracythere sp 2	2	1	3	0.60
?*Keija* sp B Neil	2	0	2	0.40
Loxoconcha cf *punctabella*	1	1	2	0.40
?*Pontocyprella* sp	1	1	2	0.40
Pterygocythereid gen. sp. indet	0	2	2	0.40
Argilloecia argilloeciaformis	0	1	1	0.20
Munseyella splendida	1	0	1	0.20
Pseudocythere cf *micropuncta*	1	0	1	0.20
Indeterminate			2	0.40
			496	

LM6	4.70m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Callistocythere sp 'nodosa'	63	8	71	14.20
Neonesidea chapmani	8	47	55	11.00
Bythoceratina sp	20	32	52	10.40
Cletocythereis caudispinosa	25	23	48	9.60
Foveoleberis ?minutissima	15	29	44	8.80
Bradleya praemckenziei	0	33	33	6.60
Parakrithella sp 1	30	1	31	6.20
Bradleya cf *kincaidiana*	2	18	20	4.00
?*Actinocythereis* sp	8	8	16	3.20
Argilloecia argilloeciaformis	2	10	12	2.40
Xestoleberis cf *cooki*	5	6	11	2.20
Loxoconcha cf *mioaustralis*	7	3	10	2.00
Oculocytheropteron microfornix	1	9	10	2.00
Hermanites glyphica	2	7	9	1.80
Neonesidea australis	2	5	7	1.40
Paijenborchella solitaria ponticola	3	4	7	1.40
Cytherella sp	2	4	6	1.20
Propontocypris sp 2	4	2	6	1.20
Quadracythere sp 1	2	3	5	1.00
Callistocythere sp 'zigzag'	4	0	4	0.80
Macromckenzia porcelanica	3	1	4	0.80
Neonesidea sp A	1	3	4	0.80
Paranesidea barwonensis	1	3	4	0.80
Alataleberis sp	1	2	3	0.60
Cytherelloidea intermedia	1	2	3	0.60
Mckenzieartia sp	1	2	3	0.60
Neobuntonia batesfordiense	0	3	3	0.60
Argilloecia sp A	0	2	2	0.40
Chapmanella flexicostata	0	2	2	0.40
Oculocytheropteron parawellmani	0	2	2	0.40
Paradoxostoma sp 1	0	2	2	0.40
Platella parapunctata	2	0	2	0.40
Argilloecia australomiocenica	0	1	1	0.20
Bythocypris sp 1	0	1	1	0.20
Bythocythere sp	1	0	1	0.20
Callistocythere sp 2	1	0	1	0.20
Cytherelloidea australomiocenica	0	1	1	0.20
Deltaleberis rugosapytta	1	0	1	0.20
Keija sp A Neil	1	0	1	0.20
?*Keija* sp B Neil	1	0	1	0.20
Pellucistoma sp	1	0	1	0.20
			500	

C18	6.00m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Callistocythere sp 'nodosa'	40	46	86	17.10
Cletocythereis caudispinosa	11	45	56	11.13
Parakrithella sp 1	52	3	55	10.93
Oculocytheropteron microfornix	13	25	38	7.55
Bradleya praemckenziei	11	22	33	6.56
Bythoceratina sp	18	7	25	4.97
Neonesidea chapmani	4	16	20	3.98
Foveoleberis ?minutissima	5	14	19	3.78
Loxoconcha cf *mioaustralis*	3	16	19	3.78
Xestoleberis cf *cooki*	10	4	14	2.78
Hermanites glyphica	1	12	13	2.58
Bradleya cf *kincaidiana*	4	7	11	2.19
Neonesidea australis	3	5	8	1.59
Paijenborchella solitaria ponticola	2	5	7	1.39
Cytherella sp	0	6	6	1.19
Kangarina macropus	4	2	6	1.19
?Actinocythereis sp	2	3	5	0.99
Macrocypridid sp. indet	0	5	5	0.99
Pseudeucythere parapubera	1	4	5	0.99
Callistocythere sp 'zigzag'	2	2	4	0.80
Pellucistoma sp	4	0	4	0.80
Quadracythere sp 1	1	3	4	0.80
Alataleberis sp	1	2	3	0.60
Argilloecia argilloeciaformis	0	3	3	0.60
Argilloecia sp A	2	1	3	0.60
Deltaleberis rugosapytta	0	3	3	0.60
Loxoconcha cf *punctabella*	0	3	3	0.60
Loxocythere sp 2	0	3	3	0.60
Oculocytheropteron parawellmani	1	2	3	0.60
Platella parapunctata	2	1	3	0.60
Arcacythere sp	2	0	2	0.40
Munseyella splendida	0	2	2	0.40
Neonesidea sp A	0	2	2	0.40
Cytheropteron? mchenryi	2	0	2	0.40
Retibythere? sp 1	0	2	2	0.40
Argilloecia australomiocenica	1	0	1	0.20
Cytherelloidea australomiocenica	0	1	1	0.20
Cytherelloidea intermedia	0	1	1	0.20
Keijia sp A Neil	0	1	1	0.20
Loxoconcha sp 2	1	0	1	0.20
Maddocksella sp	0	1	1	0.20
Morkhovenia sp	0	1	1	0.20
Munseyella sp 1	1	0	1	0.20
Neobuntonia batesfordiense	0	1	1	0.20
Paranesidea barwonensis	1	0	1	0.20
Phlyctobythocythere? sp	1	0	1	0.20
Phlyctobythocythere? sp2 Whatley & D.	1	0	1	0.20
Polycopsis? sp	0	1	1	0.20
Pseudeucythere submytila	1	0	1	0.20

C18 cont'd				
Retibythere? sp 2	0	1	1	0.20
Semicytherura sp 1	0	1	1	0.20
Semicytherura sp 3	1	0	1	0.20
Trachyleberis sp 1	0	1	1	0.20
Indeterminate			2	0.40
			497	

C17	7.10m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Bythoceratina sp	39	10	49	9.82
Cletocythereis caudispinosa	17	27	44	8.82
Callistocythere sp 'nodosa'	18	24	42	8.42
Neonesidea chapmani	5	35	40	8.02
Oculocytheropteron microfornix	15	21	36	7.21
Parakrithella sp 1	29	6	35	7.01
Trachyleberis sp 1	13	22	35	7.01
Bradleya praemckenziei	6	24	30	6.01
Callistocythere sp "zigzag"	18	10	28	5.61
Neonesidea australis	4	24	28	5.61
Foveoleberis ?minutissima	5	6	11	2.20
Neonesidea sp A	2	9	11	2.20
Spinobradleya nodosa	4	7	11	2.20
?*Actinocythereis* sp	7	3	10	2.00
Loxoconcha cf *mioaustralis*	9	0	9	1.80
Hermanites glyphica	1	7	8	1.60
Kangarina macropus	4	3	7	1.40
Paranesidea barwonensis	2	4	6	1.20
Quadracythere sp 2	3	2	5	1.00
Argilloecia sp A	0	4	4	0.80
Argilloecia argilloeciaformis	0	3	3	0.60
Argilloecia australomiocoenica	0	3	3	0.60
Hermanites sp A	0	3	3	0.60
Pseudocythere micropuncta	1	2	3	0.60
Bradleya cf *kincaidiana*	2	0	2	0.40
Cytherelloidea australomiocenica	0	2	2	0.40
Cytherelloidea intermedia	1	1	2	0.40
Loxocythere sp 1	1	1	2	0.40
Xestoleberis cf *cooki*	0	2	2	0.40
Alatahermanites septarca?	0	1	1	0.20
Bythocypris sp 1	0	1	1	0.20
Bythocypris subrectangula	0	1	1	0.20
Callistocythere sp 4	0	1	1	0.20
Copytus? sp	0	1	1	0.20
Cytherella sp	0	1	1	0.20
Deltaleberis rugosapytta	0	1	1	0.20
Maddocksella sp	0	1	1	0.20
Cytheropteron antipodum	1	0	1	0.20
Paijenborchella solitaria	0	1	1	0.20
Paracytheridea sp	0	1	1	0.20
Paradoxostoma sp 1	0	1	1	0.20
Pellucistoma sp	1	0	1	0.20
Platella parapunctata	1	0	1	0.20
?*Pontocyprella* sp	1	0	1	0.20
Propontocypris sp 1	0	1	1	0.20
Propontocypris sp 2	0	1	1	0.20
Pseudeucythere pseudosubovalis	0	1	1	0.20
Saida sp1 Warne 1987	0	1	1	0.20
Semicytherura sp 2	0	1	1	0.20

C17 cont'd				
Semicytherura sp 9	1	0	1	0.20
Indeterminate			5	1.00
			497	

C16	8.00m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Parakrithella sp 1	60	15	75	14.94
Callistocythere sp 'zigzag'	23	40	63	12.55
?*Actinocythereis* sp	21	15	36	7.17
Oculocytheropteron microfornix	7	19	26	5.18
Bradleya cf *kincaidiana*	15	6	21	4.18
Bradleya praemckenziei	5	13	18	3.59
Pellucistoma sp	15	2	17	3.39
?*Keijia* sp B Neil	12	4	16	3.19
Argilloecia argilloeciaformis	2	12	14	2.79
Neobuntonia batesfordiense	4	9	13	2.59
Neonesidea chapmani	1	11	12	2.39
Cletocythereis caudispinosa	5	6	11	2.19
Spinobradleya nodosa	0	11	11	2.19
Cytherelloidea intermedia	3	7	10	1.99
Oculocytheropteron parawellmani	4	5	9	1.79
?*Pontocyprella* sp	9	0	9	1.79
Cytherella sp	0	8	8	1.59
Loxoconcha cf *mcgowrani*	5	3	8	1.59
Argilloecia australomiocenica	2	5	7	1.39
Neonesidea australis	0	7	7	1.39
Callistocythere sp 3	3	3	6	1.20
Paradoxostoma sp 1	5	1	6	1.20
Alataleberis sp	1	4	5	1.00
Macromckenzia sp 1	1	4	5	1.00
Loxoconcha cf *mioaustralis*	2	2	4	0.80
Loxoconcha cf *punctabella*	2	2	4	0.80
Munseyella splendida	2	2	4	0.80
Argilloecia sp B	1	2	3	0.60
Bythocypris subrectangula	2	1	3	0.60
Bythocythere sp	2	1	3	0.60
Hermanites glyphica	0	3	3	0.60
Hermanites sp A	0	3	3	0.60
Neonesidea sp A	1	2	3	0.60
Trachyleberis sp 1	0	3	3	0.60
Xestoleberis cf *cooki*	2	1	3	0.60
Arculacythereis? sp	0	2	2	0.40
Bythoceratina sp Whatley & D.	2	0	2	0.40
Callistocythere sp 'nodosa'	2	0	2	0.40
Cytherelloidea australomiocenica	0	2	2	0.40
Deltaleberis rugosapytta	0	2	2	0.40
Hemicytherura cf *pentagona*	2	0	2	0.40
Propontocypris sp 1	1	1	2	0.40
Pseudeucythere parapubera	0	2	2	0.40
Pseudocythere micropuncta	2	0	2	0.40
Semicytherura sp 2	0	2	2	0.40
Arcacythere sp	1	0	1	0.20
Argilloecia sp A	0	1	1	0.20
Copytus? sp	1	0	1	0.20
Cytherelloidea sp A (specimen lost)	1	0	1	0.20

C16 cont'd				
Genus 3 sp	1	0	1	0.20
Hemicytherura cf *reekmani*	0	1	1	0.20
Kangarina macropus	1	0	1	0.20
Macrocyprina? sp	1	0	1	0.20
Cytheropteron antipodum	1	0	1	0.20
Paijenborchella solitaria ponticola	0	1	1	0.20
Phlyctobythocythere? sp 2 Whatley & D.	0	1	1	0.20
Platella parapunctata	1	0	1	0.20
Pseudeucythere pseudosubovalis	0	1	1	0.20
Quadracythere sp 1	0	1	1	0.20
Semicytherura sp 1	1	0	1	0.20
Indeterminate	0	0	5	1.00
			489	

C15	8.85m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Callistocythere sp 'zigzag'	53	39	92	18.66
Bradleya praemckenziei	7	31	38	7.71
Neonesidea australis	11	21	32	6.49
Parakrithella sp 1	17	4	21	4.26
Cletocythereis caudispinosa	7	13	20	4.06
Oculocytheropteron microfornix	8	10	18	3.65
Bradleya cf *kincaidiana*	4	12	16	3.25
Alataleberis sp	6	7	13	2.64
Neobuntonia batesfordiense	4	9	13	2.64
Oculocytheropteron parawellmani	8	4	12	2.43
?*Actinocythereis* sp	4	6	10	2.03
Quadracythere sp 2	3	6	9	1.83
Xestoleberis cf *cooki*	0	10	9	1.83
Argilloecia argilloeciaformis	2	4	6	1.22
Hemicytherura cf *reekmani*	0	6	6	1.22
Neonesidea chapmani	0	6	6	1.22
Deltaleberis rugosapytta	0	5	5	1.01
Foveoleberis ?*minutissima*	0	5	5	1.01
?*Keijia* sp B Neil	4	1	5	1.01
Loxoconcha cf *mioaustralis*	1	4	5	1.01
Macrocypridid sp. indet	3	2	5	1.01
Macromckenzia porcelanica	0	5	5	1.01
Cytherella sp	1	3	4	0.81
Cytheropteron antipodum	2	2	4	0.81
Pseudeucythere submytila	2	2	4	0.81
Trachyleberis sp 1	1	3	4	0.81
Arcacythere sp	2	1	3	0.61
Argilloecia australomiocenica	0	3	3	0.61
Bythocypris subrectangula	1	2	3	0.61
Callistocythere sp 4	0	3	3	0.61
Cytheralison pravacauda	1	2	3	0.61
Cytherelloidea intermedia	2	1	3	0.61
Hanaiceratina arenacea	1	2	3	0.61
Hemicytherura cf *pentagona*	3	0	3	0.61
Hermanites sp A	0	3	3	0.61
Kangarina macropus	2	1	3	0.61
Loxoconcha cf *punctabella*	0	3	3	0.61
Microxestoleberis sp 1	1	2	3	0.61
Morkhovenia sp	1	2	3	0.61
Munseyella splendida	1	2	3	0.61
Paradoxostoma sp 2	0	3	3	0.61
Polycope melbournensis	1	2	3	0.61
?*Pontocyprella* sp	1	2	3	0.61
Retibythere? sp	0	3	3	0.61
Semicytherura sp 1	3	0	3	0.61
Spinobradleya nodosa	1	2	3	0.61
Tenedocythere nuda	0	3	3	0.61
Argilloecia sp A	1	1	2	0.41
Bythoceratina sp C Neil 1992	2	0	2	0.41

C15 cont'd				
Chapmanella flexicostata	0	2	2	0.41
Cletocythereis rastromarglnata	0	2	2	0.41
Loxoconcha cf *mcgowrani*	1	1	2	0.41
Loxocythere sp 2	1	1	2	0.41
Maddocksella sp	0	2	2	0.41
Oculocytheropteron sp 1	0	2	2	0.41
Pellucistoma sp	2	0	2	0.41
Saida sp1 Warne 1987	0	2	2	0.41
Semicytherura sp 3	0	2	2	0.41
Arculacythereis? sp	0	1	1	0.20
Bythoceratina sp Whatley & D.	1	0	1	0.20
Bythocypris? sp 2	0	1	1	0.20
Callistocythere sp 'nodosa'	1	0	1	0.20
Copytus? sp	1	0	1	0.20
Hermanites glyphica	0	1	1	0.20
Hornibrookella sp	0	1	1	0.20
Loxocythere sp 1	1	0	1	0.20
Loxocythere sp 3	0	1	1	0.20
Mckenzieartia? sp	1	0	1	0.20
Neonesidea sp A Warne	1	0	1	0.20
Nunana? sp	1	0	1	0.20
Paijenborchella solitaria ponticola	1	0	1	0.20
Paradoxostoma sp 1	1	0	1	0.20
Platella parapunctata	1	0	1	0.20
Polycope sp 1	1	0	1	0.20
Polycope sp 2	1	0	1	0.20
Pseudeucythere parapubera	0	1	1	0.20
Pseudocythere micropuncta	1	0	1	0.20
Pterygocythereis? sp	0	1	1	0.20
Semicytherura sp 2	0	1	1	0.20
Semicytherura sp 8	1	0	1	0.20
Vandiemencythere sp 1	0	1	1	0.20
Xestoleberis? sp	0	1	1	0.20
Indeterminate			8	1.62
			484	

C14	9.25m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Oculocytheropteron microfornix	16	65	81	16.46
Callistocythere sp 'zigzag'	16	23	39	7.93
Bradleya praemckenziei	10	26	36	7.32
Loxoconcha cf *mioaustralis*	4	22	26	5.28
Neonesidea australis	6	10	16	3.25
Paijenborchella solitaria ponticola	8	8	16	3.25
Parakrithella sp 1	13	3	16	3.25
Argilloecia australomiocenica	2	13	15	3.05
Cletocythereis caudispinosa	3	11	14	2.85
Xestoleberis cf *cooki*	0	14	14	2.85
Krithe nitida	0	10	10	2.03
Pellucistoma sp	9	0	9	1.83
?*Actinocythereis* sp	1	7	8	1.63
Argilloecia argilloeciaformis	2	6	8	1.63
Oculocytheropteron parawellmani	6	2	8	1.63
Paradoxostoma sp 1	1	7	8	1.63
Macromckenzia sp 1	1	6	7	1.42
Semicytherura sp 2	1	6	7	1.42
Cytherella sp	1	5	6	1.22
Neobuntonia batesfordiense	3	3	6	1.22
Neonesidea chapmani	0	6	6	1.22
Arcacythere sp	4	1	5	1.02
Cytherelloidea intermedia	0	5	5	1.02
Hemicytherura cf *reekmani*	1	4	5	1.02
Hermanites glyphica	0	5	5	1.02
Oculocytheropteron sp 1	0	5	5	1.02
Saida sp1 Warne 1987	0	5	5	1.02
Argilloecia sp A	0	4	4	0.81
Bythocypris subrectangula	0	4	4	0.81
Foveoleberis ?*minutissima*	0	4	4	0.81
Hemicytherura cf *pentagona*	4	0	4	0.81
Kangarina macropus	2	2	4	0.81
Loxoconcha cf *punctabella*	0	4	4	0.81
Macroscapha sp	3	1	4	0.81
?*Pontocyprella* sp	3	1	4	0.81
Tenedocythere nuda	0	4	4	0.81
Bradleya cf *kincaidiana*	0	3	3	0.61
Callistocythere sp 4	0	3	3	0.61
Hermanites sp A	1	2	3	0.61
Maddocksella sp	0	3	3	0.61
Morkhovenia sp	0	3	3	0.61
Semicytherura sp 5	1	2	3	0.61
Alataleberis sp	2	0	2	0.41
Hornibrookella sp	0	2	2	0.41
Loxoconcha mcgowrani	0	2	2	0.41
Cytheropteron antipodum	2	0	2	0.41
Pseudeucythere parapubera	0	2	2	0.41
Pseudeucythere submytila	0	2	2	0.41
Quadracythere sp 2	1	1	2	0.41

C14 cont'd				
Retibythere ? sp	0	2	2	0.41
Semicytherura sp 3	0	2	2	0.41
Alatahermanites septarca?	0	1	1	0.20
Anchistrocheles sp	1	0	1	0.20
Arculacythereis cf *thomasi*	0	1	1	0.20
Arculacythereis sp	0	1	1	0.20
Bythocypris sp 1	0	1	1	0.20
Callistocythere sp 'nodosa'	1	0	1	0.20
Callistocythere sp 3	1	0	1	0.20
Genus 17 sp	0	1	1	0.20
Hanaiceratina arenacea	0	1	1	0.20
?*Keijia* sp B Neil	1	0	1	0.20
Loxocythere sp 2	0	1	1	0.20
Paracytheridea sp	0	1	1	0.20
Paradoxostoma sp 2	1	0	1	0.20
Pedicythere sp	0	1	1	0.20
Polycope sp 1	1	0	1	0.20
Polycope sp 2	1	0	1	0.20
Propontocypris sp 1	0	1	1	0.20
Propontocypris sp 2	0	1	1	0.20
Semicytherura sp 6	1	0	1	0.20
Semicytherura sp 7	0	1	1	0.20
Semicytherura sp A? Neil	0	1	1	0.20
Serratocythere? sp	0	1	1	0.20
Spinobradleya nodosa	0	1	1	0.20
Indeterminate			11	2.24
			492	

C13	9.65m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Bradleya praemckenziei	9	37	46	9.16
Callistocythere sp 'zigzag'	13	30	43	8.57
Neonesidea australis	9	29	38	7.57
Oculocytheropteron microfornix	4	32	36	7.17
Macromckenzia porcelanica	15	15	30	5.98
Loxoconcha cf *mioaustralis*	5	15	20	3.98
Xestoleberis cf *cooki*	0	15	15	2.99
Cytherella sp	4	9	13	2.59
Neonesidea chapmani	4	9	13	2.59
Macroscapha sp	7	5	12	2.39
Semicytherura sp 2	2	10	12	2.39
Argilloecia argilloeciaformis	5	6	11	2.19
?*Actinocythereis* sp	4	6	10	1.99
Cytherelloidea intermedia	4	6	10	1.99
Hornibrookella sp	0	9	9	1.79
Parakrithella sp 1	7	2	9	1.79
Argilloecia australomiocenica	2	6	8	1.59
Hemicytherura cf *reekmani*	6	2	8	1.59
Maddocksella sp	0	8	8	1.59
Callistocythere sp 4	0	6	6	1.20
Pellucistoma sp	5	1	6	1.20
Argilloecia sp A	3	2	5	1.00
Cletocythereis caudispinosa	1	4	5	1.00
Hanaiceratina arenacea	5	0	5	1.00
Neobuntonia batesfordiense	1	4	5	1.00
Oculocytheropteron parawellmani	1	4	5	1.00
Paijenborchella solitaria ponticola	4	1	5	1.00
Alataleberis sp	1	3	4	0.80
Deltaleberis rugosapytta	0	4	4	0.80
Hermanites sp A	0	4	4	0.80
Krithe nitida	2	2	4	0.80
?*Pontocyprella* sp	1	3	4	0.80
Pseudeucythere parapubera	1	3	4	0.80
Pseudocythere micropuncta	2	2	4	0.80
Kangarina sp	1	2	3	0.60
Macrocypridid sp. indet	2	1	3	0.60
Quadracythere sp 2	0	3	3	0.60
Retibythere? sp	0	3	3	0.60
Semicytherura sp 8	3	0	3	0.60
Trachyleberis sp 2	3	0	3	0.60
Vandiemencythere sp 1	0	3	3	0.60
Arcacythere sp	1	1	2	0.40
Bradleya cf *kincaidiana*	0	2	2	0.40
Cytheralison pravacauda	1	1	2	0.40
Foveoleberis ?*minutissima*	0	2	2	0.40
Loxoconcha cf *punctabella*	0	2	2	0.40
Oculocytheropteron sp 1	0	2	2	0.40
Paradoxostoma sp 1	1	1	2	0.40
Paradoxostoma sp 3	1	1	2	0.40

C13 cont'd				
Polycope melbournensis	1	1	2	0.40
Propontocypris sp 1	1	1	2	0.40
Saida sp 1 Warne 1987	2	0	2	0.40
Semicytherura sp 3	2	0	2	0.40
Semicytherura sp 5	0	2	2	0.40
Bythoceratina sp C Neil	1	0	1	0.20
Bythoceratina sp Whatley & D.	0	1	1	0.20
Bythocypris sp 1	1	0	1	0.20
Bythocythere sp	0	1	1	0.20
Cytheralison corrugata	0	1	1	0.20
Cytherelloidea australomiocenica	0	1	1	0.20
Dumontonia? sp	0	1	1	0.20
Eucytherura sp	1	0	1	0.20
Hemicytherura cf *pentagona*	1	0	1	0.20
Hemicytherura sp	1	0	1	0.20
Hermanites glyphica	0	1	1	0.20
Kangarina macropus	0	1	1	0.20
Loxoconcha cf *mcgowrani*	0	1	1	0.20
Macrocyprina? sp	0	1	1	0.20
Maddocksella tumefacta	1	0	1	0.20
Microxestoleberis sp 1	1	0	1	0.20
Morkhovenia sp	0	1	1	0.20
Munseyella splendida	1	0	1	0.20
Phlyctobythocythere? sp 2 Whatley & D.	0	1	1	0.20
Saida sp 1	0	1	1	0.20
Semicytherura sp 1	1	0	1	0.20
Semicytherura sp 4	0	1	1	0.20
Tenedocythere nuda	0	1	1	0.20
Indeterminate	0	0	9	1.79
			500	

C12	10.00m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Oculocytheropteron microfornix	27	70	97	19.76
Callistocythere sp 'zigzag'	16	45	61	12.42
Loxoconcha cf *mioaustralis*	16	27	43	8.76
Bradleya praemckenziei	3	22	25	5.09
Argilloecia argilloeciaformis	8	15	23	4.68
Neonesidea australis	2	13	15	3.05
Parakrithella sp 1	12	3	15	3.05
Maddocksella sp	1	12	13	2.65
Xestoleberis cf *cooki*	0	12	12	2.44
Paijenborchella solitaria ponticola	6	2	8	1.63
Hermanites sp A	0	7	7	1.43
Neonesidea chapmani	0	7	7	1.43
Semicytherura sp 2	3	4	7	1.43
Argilloecia australomiocenica	1	5	6	1.22
Argilloecia sp A	4	2	6	1.22
Deltaleberis rugosapytta	0	6	6	1.22
Hemicytherura sp	0	6	6	1.22
Kangarina macropus	2	4	6	1.22
Macroscapha sp	4	2	6	1.22
Oculocytheropteron parawellmani	4	2	6	1.22
Arcacythere sp	2	3	5	1.02
Cytherella sp	0	5	5	1.02
Macromckenzia porcelanica	2	3	5	1.02
Cletocythereis caudispinosa	0	4	4	0.81
Hemicytherura cf *reekmani*	4	0	4	0.81
Pellucistoma sp	4	0	4	0.81
Bradleya cf *kincaidiana*	1	2	3	0.61
?*Callistocythere* sp	1	2	3	0.61
Foveoleberis ?*minutissima*	0	3	3	0.61
Genus 17 sp	0	3	3	0.61
Hermanites glyphica	0	3	3	0.61
Kangarina sp	1	2	3	0.61
Macromckenzia sp 1	0	3	3	0.61
Pseudeucythere submytila	0	3	3	0.61
?*Actinocythereis* sp	0	2	2	0.41
Cytherelloidea intermedia	0	2	2	0.41
Hanaiceratina arenacea	1	1	2	0.41
Krithe nitida	1	1	2	0.41
Loxoconcha cf *punctabella*	0	2	2	0.41
Munseyella splendida	2	0	2	0.41
Cytheropteron antipodum	1	1	2	0.41
Platella parapunctata	0	2	2	0.41
?*Pontocyprella* sp	2	0	2	0.41
Pseudocythere micropuncta	1	1	2	0.41
Semicytherura sp 7	0	2	2	0.41
Tenedocythere nuda	0	2	2	0.41
Argilloecia sp B	0	1	1	0.20
Bythocypris sp 1	0	1	1	0.20
Bythocypris subrectangula	0	1	1	0.20

C12 cont'd				
Bythocythere sp	0	1	1	0.20
Dumontonia? sp	0	1	1	0.20
Hemicytherura cf *pentagona*	1	0	1	0.20
?*Keija* sp B Neil	1	0	1	0.20
Loxocythere sp 1	0	1	1	0.20
Loxocythere sp 2	0	1	1	0.20
Loxocythere sp 3	0	1	1	0.20
Microxestoleberis sp 1	0	1	1	0.20
Morkhovenia sp	0	1	1	0.20
Neobuntonia batesfordiense	0	1	1	0.20
Oculocytheropteron sp 1	0	1	1	0.20
Paradoxostoma sp 1	0	1	1	0.20
Polycope melbournensis	1	0	1	0.20
Polycopsis? sp	1	0	1	0.20
Propontocypris sp 1	0	1	1	0.20
Pseudocythere sp 1 Whatley & D.	1	0	1	0.20
Quadracythere sp 2	0	1	1	0.20
Saida sp1 Warne 1987	0	1	1	0.20
Semicytherura sp 3	0	1	1	0.20
Semicytherura sp 4	1	0	1	0.20
Semicytherura sp 8	1	0	1	0.20
Serratocythere? sp	0	1	1	0.20
Xestoleberis? sp	0	1	1	0.20
Indeterminate	0	0	14	2.85
			490	

C11	10.25m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Oculocytheropteron microfornix	12	49	61	12.30
Callistocythere sp 'zigzag'	16	28	44	8.87
Loxoconcha cf *mioaustralis*	16	24	40	8.06
Neonesidea australis	1	27	28	5.65
Bradleya praemckenziei	6	21	27	5.44
Neonesidea chapmani	0	15	15	3.02
Argilloecia argilloeciaformis	5	7	12	2.42
Loxoconcha cf *punctabella*	0	12	12	2.42
Oculocytheropteron parawellmani	7	5	12	2.42
Parakrithella sp 1	10	2	12	2.42
Semicytherura sp 4	1	9	10	2.02
Alataleberis sp	1	8	9	1.81
Macroscapha sp	6	3	9	1.81
Hermanites sp A	0	8	8	1.61
Macromckenzia porcelanica	4	4	8	1.61
Xestoleberis cf *cooki*	0	8	8	1.61
Deltaleberis rugosapytta	1	5	6	1.21
Hemicytherura cf *reekmani*	6	0	6	1.21
Maddocksella sp	0	6	6	1.21
Oculocytheropteron sp 1	0	6	6	1.21
Pterygocythereid gen. sp.	0	6	6	1.21
Arculacythereis? sp	0	5	5	1.01
Argilloecia australomiocenica	0	5	5	1.01
Bradleya cf *kincaidiana*	0	5	5	1.01
Cytherella sp	0	5	5	1.01
Loxocythere sp 2	0	5	5	1.01
Propontocypris sp 1	0	5	5	1.01
Pseudocythere cf *micropuncta*	3	2	5	1.01
Semicytherura sp 2	0	5	5	1.01
?*Actinocythereis* sp	1	3	4	0.81
Cytherelloidea intermedia	0	4	4	0.81
Hemicytherura cf *pentagona*	3	1	4	0.81
Hemicytherura sp	0	4	4	0.81
Kangarina macropus	0	4	4	0.81
Macromckenzia sp	0	4	4	0.81
Morkhovenia sp	0	4	4	0.81
Cytheropteron antipodum	0	4	4	0.81
Arcacythere sp	0	3	3	0.60
Hermanites glyphica	0	3	3	0.60
Hornibrookella sp	0	3	3	0.60
Krithe nitida	2	1	3	0.60
Loxocythere sp 1	2	1	3	0.60
Paijenborchella solitaria ponticola	3	0	3	0.60
Polycope melbournensis	2	1	3	0.60
Propontocypris sp 2	0	3	3	0.60
Argilloecia sp A	0	2	2	0.40
Bythoceratina sp C Neil 1992	1	1	2	0.40
Bythocypris sp 1	1	1	2	0.40
Bythocythere sp	0	2	2	0.40

C11 cont'd				
Foveoleberis ?minutissima	0	2	2	0.40
Macrocypridid sp. indet	0	2	2	0.40
Microxestoleberis sp 2	0	2	2	0.40
Neobuntonia batesfordiense	0	2	2	0.40
Retibythere? sp	0	2	2	0.40
Rhombonesidea sp A Neil 1992	0	2	2	0.40
Saida sp 1 Warne 1987	1	1	2	0.40
Semicytherura sp 8	0	2	2	0.40
Tenedocythee nuda	0	2	2	0.40
Alatahermanites septarca?	0	1	1	0.20
Arculacythereid ? gen indet	0	1	1	0.20
Bythoceratina cf *fragilis*	1	0	1	0.20
?*Callistocythere* sp	0	1	1	0.20
Cletocythereis caudispinosa	0	1	1	0.20
Cytheralison pravacauda	1	0	1	0.20
Dumontonia? sp	0	1	1	0.20
Genus 17 sp	0	1	1	0.20
Genus 8 sp	0	1	1	0.20
Hanaiceratina arenacea	1	0	1	0.20
?*Keija* sp B Neil	0	1	1	0.20
Loxoconcha cf *mcgowrani*	0	1	1	0.20
Loxoconcha sp	0	1	1	0.20
Maddocksella tumefacta	1	0	1	0.20
Microceratina sp 1	1	0	1	0.20
Munseyella splendida	1	0	1	0.20
Paradoxostoma sp 1	1	0	1	0.20
Paradoxostoma sp 2	1	0	1	0.20
Pellucistoma sp	1	0	1	0.20
Polycopsis? sp	0	1	1	0.20
?*Pontocyprella* sp	1	0	1	0.20
Pseudeucythere parapubera	0	1	1	0.20
Pseudeucythere pseudosubovalis	0	1	1	0.20
Pseudeucythere submytila	1	0	1	0.20
Saida sp 1	1	0	1	0.20
Semicytherura sp 1	0	1	1	0.20
Semicytherura sp 3	0	1	1	0.20
Semicytherura sp 7	0	1	1	0.20
Vandiemencythere sp 1	0	1	1	0.20
Indeterminate	0	0	2	0.40
			498	

C10	10.55m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Oculocytheropteron microfornix	10	67	77	15.52
Neonesidea australis	4	21	25	5.04
Bradleya praemckenziei	6	15	21	4.23
Argilloecia argilloeciaformis	8	11	19	3.83
Oculocytheropteron parawellmani	7	11	18	3.63
Arcacythere sp	5	11	16	3.23
Callistocythere sp 'zigzag'	2	14	16	3.23
Xestoleberis cf *cooki*	0	15	15	3.02
Argilloecia australomiocenica	5	8	13	2.62
Hemicytherura cf *reekmani*	4	8	12	2.42
Semicytherura sp 4	8	4	12	2.42
Hemicytherura cf *pentagona*	8	3	11	2.22
Alataleberis sp	1	7	8	1.61
Semicytherura sp 2	4	4	8	1.61
Deltaleberis rugosapytta	3	4	7	1.41
Hornibrookella sp	0	7	7	1.41
Macromckenzia porcelanica	4	3	7	1.41
Macroscapha sp	5	2	7	1.41
Maddocksella sp	1	6	7	1.41
Microxestoleberis sp 1	3	4	7	1.41
Argilloecia sp A	3	3	6	1.21
Hemicytherura sp	1	5	6	1.21
Hermanites glyphica	0	6	6	1.21
Hermanites sp A	0	6	6	1.21
Krithe nitida	3	3	6	1.21
Loxoconcha cf *mioaustralis*	2	4	6	1.21
Foveoleberis ?minutissima	0	5	5	1.01
Loxoconcha cf *punctabella*	1	4	5	1.01
Loxocythere sp 1	5	0	5	1.01
Oculocytheropteron sp 1	1	4	5	1.01
Propontocypris sp 2	0	5	5	1.01
Pseudocythere cf *micropuncta*	2	3	5	1.01
Alatahermanites septarca?	0	4	4	0.81
Bradleya cf *kincaidiana*	1	3	4	0.81
Cytherelloidea intermedia	0	4	4	0.81
Hanaiceratina arenacea	4	0	4	0.81
Morkhovenia sp	0	4	4	0.81
Neobuntonia batesfordiense	0	4	4	0.81
Paradoxostoma sp 1	1	3	4	0.81
Polycope melbournensis	3	1	4	0.81
Saida sp 2	2	2	4	0.81
Xestoleberis? sp	0	4	4	0.81
Arculacythereis? sp	0	3	3	0.60
Bythoceratina cf *fragilis*	3	0	3	0.60
Kangarina sp	1	2	3	0.60
Cytheropteron antipodum	3	0	3	0.60
Serratocythere? sp	2	1	3	0.60
Bythocypris sp 1	0	2	2	0.40
Bythocythere sp	1	1	2	0.40

C10 cont'd				
Cletocythereis caudispinosa	0	2	2	0.40
Genus 17 sp	1	1	2	0.40
Macromckenzia sp	1	1	2	0.40
Paijenborchella solitaria ponticola	1	1	2	0.40
Parakrithella sp 1	1	1	2	0.40
?*Pontocyprella* sp	1	1	2	0.40
Pseudeucythere submytila	0	2	2	0.40
Retibythere? sp	0	2	2	0.40
Rhombonesidea sp A Neil 1992	0	2	2	0.40
Semicytherura sp 1	2	0	2	0.40
Vandiemencythere sp 1	0	2	2	0.40
?*Actinocythereis* sp	0	1	1	0.20
Bythoceratina sp C Neil 1992	1	0	1	0.20
?*Callistocythere* sp	0	1	1	0.20
Cytheralison pravacauda	1	0	1	0.20
Cytherella sp	0	1	1	0.20
Dumontonia? sp	0	1	1	0.20
Eucythere? sp	0	1	1	0.20
Kangarina macropus	1	0	1	0.20
Loxocythere sp 3	0	1	1	0.20
Microceratina sp 1	1	0	1	0.20
Munseyella splendida	1	0	1	0.20
Neonesidea chapmani	0	1	1	0.20
Paradoxostoma sp 2	0	1	1	0.20
Pellucistoma sp	0	1	1	0.20
Platella parapunctata	0	1	1	0.20
Polycopsis? sp	0	1	1	0.20
Pterygocythereid gen. sp.	0	1	1	0.20
Quadracythere sp 2	0	1	1	0.20
Saida sp 1 Warne	1	0	1	0.20
Semicytherura sp 8	0	1	1	0.20
Tenedocythere nuda	0	1	1	0.20
Vandiemencythere sp 2	0	1	1	0.20
Indeterminate	0	0	6	1.21
			488	

C9	10.90m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Oculocytheropteron microfornix	13	86	99	19.80
Bradleya praemckenziei	11	34	45	9.00
Neonesidea australis	7	22	29	5.80
Loxoconcha cf *mioaustralis*	5	15	20	4.00
Argilloecia australomiocenica	6	10	16	3.20
Callistocythere sp 'zigzag'	3	13	16	3.20
Oculocytheropteron parawellmani	8	6	14	2.80
Arcacythere sp	2	11	13	2.60
Hemicytherura cf *pentagona*	11	1	12	2.40
Cytheropteron antipodum	3	9	12	2.40
Argilloecia argilloeciaformis	6	5	11	2.20
Alataleberis sp	0	9	9	1.80
Hermanites sp A	1	7	8	1.60
Hornibrookella sp	0	8	8	1.60
Maddocksella sp	0	8	8	1.60
Paijenborchella solitaria ponticola	4	3	7	1.40
Deltaleberis rugosapytta	2	4	6	1.20
Neonesidea chapmani	0	6	6	1.20
Semicytherura sp 2	0	6	6	1.20
Hemicytherura sp	4	1	5	1.00
Kangarina macropus	2	3	5	1.00
Loxoconcha cf *punctabella*	0	5	5	1.00
Macroscapha sp	3	2	5	1.00
Xestoleberis cf *cooki*	0	5	5	1.00
Bradleya cf *kincaidiana*	0	4	4	0.80
Cletocythereis caudispinosa	1	3	4	0.80
Hermanites glyphica	0	4	4	0.80
Kangarina sp	1	3	4	0.80
Macromckenzia porcelanica	3	1	4	0.80
Oculocytheropteron sp 1	1	3	4	0.80
Paracytheridea sp 2	1	3	4	0.80
Semicytherura sp 4	3	1	4	0.80
Argilloecia sp A	0	3	3	0.60
Callistocythere sp 1	2	1	3	0.60
Foveoleberis ?minutissima	0	3	3	0.60
Loxoconcha sp	2	1	3	0.60
Morkhovenia sp	0	3	3	0.60
Parakrithella sp 1	3	0	3	0.60
Propontocypris sp 1	0	3	3	0.60
Tenedocythere nuda	1	2	3	0.60
?*Actinocythereis* sp	0	2	2	0.40
Arculacythereis? sp	0	2	2	0.40
Bythoceratina cf *fragilis*	1	1	2	0.40
Bythoceratina sp C Neil 1992	2	0	2	0.40
Callistocythere sp 4	0	2	2	0.40
Cytheralison pravacauda	1	1	2	0.40
Dumontonia? sp	0	2	2	0.40
Loxocythere sp 3	1	1	2	0.40
Munseyella sp 1	1	1	2	0.40

C9 cont'd				
Paracytheridea sp 1	0	2	2	0.40
Saida sp 1 Warne 1987	1	1	2	0.40
Semicytherura sp 7	2	0	2	0.40
Serratocythere? sp	0	2	2	0.40
Spinobradleya nodosa	0	2	2	0.40
Vandiemencythere? sp 1	1	1	2	0.40
Bythocypris sp 1	0	1	1	0.20
Bythocythere sp	0	1	1	0.20
Cytherelloidea intermedia	0	1	1	0.20
Eucytherura sp	1	0	1	0.20
Genus 17 sp	0	1	1	0.20
Hanaiceratina arenacea	1	0	1	0.20
Krithe nitida	0	1	1	0.20
Loxocythere sp 1	1	0	1	0.20
Loxocythere sp 2	0	1	1	0.20
Microceratina sp 2	1	0	1	0.20
Munseyella sp 2	1	0	1	0.20
Munseyella splendida	1	0	1	0.20
Neobuntonia batesfordiense	0	1	1	0.20
Nunana? sp	1	0	1	0.20
Paradoxostoma sp 1	0	1	1	0.20
Pedicythere? sp 2	1	0	1	0.20
Pellucistoma sp	1	0	1	0.20
Polycope sp 2	1	0	1	0.20
Propontocypris sp 2	1	0	1	0.20
Pseudeucythere parapubera	1	0	1	0.20
Pseudeucythere pseudosubovalis	0	1	1	0.20
Pseudocythere cf *micropuncta*	1	0	1	0.20
Retibythere? sp	1	0	1	0.20
Saida sp 1	0	1	1	0.20
Semicytherura sp 1	1	0	1	0.20
Semicytherura sp 5	0	1	1	0.20
Semicytherura sp 8	1	0	1	0.20
Trachyleberis sp 1	0	1	1	0.20
Indeterminate	0	0	12	2.40
			496	

C8	11.05m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Oculocytheropteron microfornix	13	85	98	19.68
Bradleya praemckenziei	8	40	48	9.64
Loxoconcha cf *mioaustralis*	12	17	29	5.82
Callistocythere sp 'zigzag'	5	17	22	4.42
Hornibrookella sp	0	20	20	4.02
Arcacythere sp	3	16	19	3.82
Neonesidea australis	2	12	14	2.81
Argilloecia argilloeciaformis	2	9	11	2.21
Argilloecia australomiocenica	4	7	11	2.21
Hemicytherura sp	5	5	10	2.01
?*Actinocythereis* sp	1	8	9	1.81
Cytheropteron antipodum	3	5	8	1.61
Semicytherura sp 2	0	8	8	1.61
Semicytherura sp 4	7	1	8	1.61
Deltaleberis rugosapytta	2	5	7	1.41
Oculocytheropteron parawellmani	6	1	7	1.41
Alataleberis sp	0	6	6	1.20
Cletocythereis caudispinosa	0	6	6	1.20
Parakrithella sp 1	6	0	6	1.20
Semicytherura sp 5	5	1	6	1.20
Xestoleberis cf *cooki*	0	6	6	1.20
Hemicytherura cf *pentagona*	3	2	5	1.00
Loxoconcha cf *punctabella*	1	4	5	1.00
Macroscapha sp	1	4	5	1.00
Munseyella sp 2	3	2	5	1.00
Propontocypris sp 1	0	5	5	1.00
Cytheroma sp	1	3	4	0.80
Munseyella splendida	3	1	4	0.80
Neonesidea chapmani	0	4	4	0.80
Oculocytheropteron sp 1	0	4	4	0.80
Paijenborchella solitaria ponticola	1	3	4	0.80
Pellucistoma sp	4	0	4	0.80
Spinobradleya nodosa	0	4	4	0.80
Argilloecia sp B	0	3	3	0.60
Callistocythere sp 4	0	3	3	0.60
Chapmanella flexicostata	1	2	3	0.60
Cytherella sp	0	3	3	0.60
Hemicytherura cf *reekmani*	2	1	3	0.60
Hermanites glyphica	0	3	3	0.60
Kangarina sp	1	2	3	0.60
Loxocythere sp 2	1	2	3	0.60
Maddocksella sp	0	3	3	0.60
Microceratina sp 2	2	1	3	0.60
Microxestoleberis sp 1	1	2	3	0.60
Paracytheridea sp 1	2	1	3	0.60
Paracytheridea sp 2	2	1	3	0.60
Semicytherura sp 1	3	0	3	0.60
Semicytherura sp 8	3	0	3	0.60
Serratocythere? sp	0	3	3	0.60

C8 cont'd				
Bythocypris sp 1	2	0	2	0.40
Cytherelloidea intermedia	0	2	2	0.40
Dumontonia? sp	2	0	2	0.40
Kangarina macropus	2	0	2	0.40
Krithe nitida	1	1	2	0.40
Loxocythere sp 1	0	2	2	0.40
Platella parapunctata	0	2	2	0.40
Pseudeucythere parapubera	0	2	2	0.40
Pseudocythere cf *micropuncta*	1	1	2	0.40
Arculacythereis? sp	0	1	1	0.20
Argilloecia sp A	0	1	1	0.20
Bythoceratina sp	1	0	1	0.20
Bythocythere sp	0	1	1	0.20
Callistocythere sp 1	1	0	1	0.20
Cytherelloidea australomiocenica	0	1	1	0.20
Cytherelloidea sp C Neil 1992	0	1	1	0.20
Genus 17 sp	0	1	1	0.20
Hanaiceratina arenacea	1	0	1	0.20
Hermanites sp A	0	1	1	0.20
Retibythere? sp	1	0	1	0.20
Saida sp 1	1	0	1	0.20
Saida sp 1 Warne 1987	1	0	1	0.20
Xestoleberis? sp	0	1	1	0.20
Indeterminate	0	0	6	1.20
			498	

C7	11.45m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Oculocytheropteron microfornix	20	76	96	19.20
Callistocythere sp 'zigzag'	22	18	40	8.00
Loxoconcha cf *mioaustralis*	13	19	32	6.40
Bradleya praemckenziei	2	29	31	6.20
Foveoleberis ?minutissima	1	16	17	3.40
Hornibrookella sp	0	16	16	3.20
Xestoleberis cf *cooki*	2	14	16	3.20
Arcacythere sp	4	10	14	2.80
Oculocytheropteron parawellmani	10	3	13	2.60
Parakrithella sp 1	9	3	12	2.40
Argilloecia australomiocenica	3	8	11	2.20
Neonesidea australis	3	8	11	2.20
Alataleberis sp	1	9	10	2.00
Oculocytheropteron sp 1	1	7	8	1.60
Paijenborchella solitaria ponticola	3	5	8	1.60
Cytherella sp	0	7	7	1.40
Loxoconcha cf *punctabella*	0	7	7	1.40
Pellucistoma sp	7	0	7	1.40
Semicytherura sp 2	0	7	7	1.40
Hermanites glyphica	0	6	6	1.20
Kangarina macropus	5	1	6	1.20
Neonesidea chapmani	0	6	6	1.20
Cytheropteron antipodum	2	4	6	1.20
Cletocythereis caudispinosa	4	1	5	1.00
Deltaleberis rugosapytta	1	4	5	1.00
Hermanites sp A	1	4	5	1.00
Krithe nitida	1	4	5	1.00
Semicytherura sp 4	3	2	5	1.00
?Actinocythereis sp	1	3	4	0.80
Argilloecia argilloeciaformis	1	3	4	0.80
Callistocythere sp 4	3	1	4	0.80
Kangarina sp	1	3	4	0.80
Maddocksella sp	0	4	4	0.80
Semicytherura sp 8	3	1	4	0.80
Hemicytherura cf *pentagona*	3	0	3	0.60
Hemicytherura cf *reekmani*	1	2	3	0.60
Propontocypris sp 1	1	2	3	0.60
Dumontonia? sp	0	2	2	0.40
Genus 1 sp	1	1	2	0.40
Hemicytherura sp	0	2	2	0.40
Paracytheridea sp 1	0	2	2	0.40
Pseudocythere cf *micropuncta*	2	0	2	0.40
Quadracythere sp 2	0	2	2	0.40
Spinobradleya nodosa	0	2	2	0.40
Arculacythereis? sp	0	1	1	0.20
Bradleya cf *kincaidiana*	0	1	1	0.20
Bythoceratina sp C Neil 1992	1	0	1	0.20
Bythocypris sp 1	0	1	1	0.20
Bythocythere sp	0	1	1	0.20

C7 cont'd				
Callistocythere sp 'nodosa'	1	0	1	0.20
Chapmanella flexicostata	0	1	1	0.20
Cytheralison pravacauda	1	0	1	0.20
Cytherelloidea intermedia	0	1	1	0.20
Cytheroma sp	0	1	1	0.20
Eucythere? sp	1	0	1	0.20
Genus 17 sp	0	1	1	0.20
Loxocythere sp 2	1	0	1	0.20
Macromckenzia porcelanica	1	0	1	0.20
Macroscapha sp	1	0	1	0.20
Microceratina sp 1	0	1	1	0.20
Microceratina sp 2	0	1	1	0.20
Morkhovenia sp	0	1	1	0.20
Munseyella splendida	1	0	1	0.20
Neobuntonia batesfordiense	0	1	1	0.20
Paracypris sp	1	0	1	0.20
Paradoxostoma sp 1	0	1	1	0.20
Propontocypris sp 2	1	0	1	0.20
Pseudeucythere parapubera	1	0	1	0.20
Pseudeucythere submytila	1	0	1	0.20
Pterygocythereis? sp	0	1	1	0.20
Saida sp1 Warne 1987	1	0	1	0.20
Semicytherura sp 1	1	0	1	0.20
Semicytherura sp 5	1	0	1	0.20
Serratocythere? sp	0	1	1	0.20
Tenedocythere nuda	1	0	1	0.20
Trachyleberis sp 1	0	1	1	0.20
Indeterminate	0	0	5	1.00
			496	

C6	11.85m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Callistocythere sp 'zigzag'	54	14	68	13.68
Xestoleberis cf *cooki*	23	41	64	12.88
Bradleya praemckenziei	9	30	39	7.85
Parakrithella sp 1	34	1	35	7.04
Quadracythere sp 2	15	20	35	7.04
Foveoleberis ?minutissima	10	20	30	6.04
Loxoconcha cf *mioaustralis*	25	5	30	6.04
Cletocythereis caudispinosa	6	21	27	5.43
Callistocythere sp 'nodosa'	16	5	21	4.23
Neonesidea australis	7	14	21	4.23
Oculocytheropteron microfornix	6	11	17	3.42
?*Actinocythereis* sp	10	6	16	3.22
Alataleberis sp	6	2	8	1.61
Argilloecia argilloeciaformis	5	3	8	1.61
Paracypris sp	4	3	7	1.41
Macroscapha sp	3	3	6	1.21
Cytherella sp	3	1	4	0.80
Hornibrookella sp	0	4	4	0.80
Oculocytheropteron parawellmani	3	1	4	0.80
Callistocythere sp 4	0	3	3	0.60
Chapmanella flexicostata	1	2	3	0.60
Macromckenzia porcelanica	3	0	3	0.60
Semicytherura sp 2	0	3	3	0.60
Argilloecia australomiocenica	0	2	2	0.40
Bradleya cf *kincaidiana*	1	1	2	0.40
Bythocythere sp	0	2	2	0.40
Neonesidea chapmani	0	2	2	0.40
Paijenborchella solitaria ponticola	1	1	2	0.40
Pellucistoma sp	2	0	2	0.40
Platella parapunctata	2	0	2	0.40
Bythoceratina sp C Neil 1992	1	0	1	0.20
Cytherelloidea australomiocenica	0	1	1	0.20
Cytherelloidea intermedia	0	1	1	0.20
Deltaleberis rugosapytta	0	1	1	0.20
Genus 3 sp	1	0	1	0.20
Hemicytherura cf *pentagona*	1	0	1	0.20
?*Keijia* sp B Neil	0	1	1	0.20
Loxoconcha cf *mcgowrani*	0	1	1	0.20
Loxoconcha cf *punctabella*	0	1	1	0.20
Maddocksella sp	0	1	1	0.20
Microceratina sp 2	1	0	1	0.20
Munseyella splendida	1	0	1	0.20
Neobuntonia batesfordiense	0	1	1	0.20
Semicytherura sp 4	1	0	1	0.20
Spinobradleya nodosa	0	1	1	0.20
Trachyleberis sp 1	0	1	1	0.20
Indeterminate	0	0	3	0.60
			489	

C5	12.20m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Callistocythere sp 'zigzag'	57	15	72	14.49
Bradleya praemckenziei	11	39	50	10.06
Oculocytheropteron microfornix	11	28	39	7.85
Cletocythereis caudispinosa	9	25	34	6.84
Quadracythere sp 2	12	21	33	6.64
Xestoleberis cf *cooki*	5	20	25	5.03
Loxoconcha mioaustralis	13	9	22	4.43
Parakrithella sp 1	18	1	19	3.82
Callistocythere sp 'nodosa'	13	5	18	3.62
?*Actinocythereis* sp	9	7	16	3.22
Foveoleberis ?*minutissima*	1	13	14	2.82
Oculocytheropteron parawellmani	5	6	11	2.21
Argilloecia argilloeciaformis	5	4	9	1.81
Neonesidea australis	3	6	9	1.81
Paracypris sp	8	1	9	1.81
Cytherella sp	0	8	8	1.61
Paijenborchella solitaria ponticola	5	3	8	1.61
Deltaleberis rugosapytta	0	6	6	1.21
Hornibrookella sp	0	5	5	1.01
Semicytherura sp 4	4	1	5	1.01
Alataleberis sp	1	3	4	0.80
Argilloecia australomiocenica	1	3	4	0.80
Bradleya cf *kincaidiana*	1	3	4	0.80
Chapmanella flexicostata	0	4	4	0.80
Genus 17 sp	1	3	4	0.80
Macroscapha sp	2	2	4	0.80
Cytheropteron antipodum	3	0	3	0.60
Semicytherura sp 2	0	3	3	0.60
Arcacythere sp	1	1	2	0.40
Bythocythere sp	0	2	2	0.40
Callistocythere sp 4	0	2	2	0.40
Hermanites glyphica	0	2	2	0.40
Hermanites sp A	0	2	2	0.40
Kangarina macropus	2	0	2	0.40
Krithe nitida	0	2	2	0.40
Loxoconcha cf *punctabella*	0	2	2	0.40
Loxocythere sp 1	2	0	2	0.40
Maddocksella sp	0	2	2	0.40
Paradoxostoma sp 1	0	2	2	0.40
?*Pontocyprella* sp	2	0	2	0.40
Bythoceratina sp C Neil 1992	1	0	1	0.20
Callistocythere sp 2	0	1	1	0.20
Cytherelloidea sp C Neil 1992	0	1	1	0.20
Hemicytherura cf *pentagona*	1	0	1	0.20
Kangarina sp	0	1	1	0.20
Keijia sp A Neil	0	1	1	0.20
?*Keijia* sp B Neil	0	1	1	0.20
Loxoconcha cf *mcgowrani*	0	1	1	0.20
Munseyella splendida	1	0	1	0.20

C5 cont'd				
Oculocytheropteron sp 1	1	0	1	0.20
Pellucistoma sp	1	0	1	0.20
Platella parapunctata	0	1	1	0.20
Polycopsis? sp	0	1	1	0.20
Pseudocythere cf *micropuncta*	1	0	1	0.20
Retibythere? sp	1	0	1	0.20
Rhombonesidea sp A Neil 1992	0	1	1	0.20
Semicytherura sp 1	1	0	1	0.20
Semicytherura sp 8	0	1	1	0.20
Spinobradleya nodosa	0	1	1	0.20
Vandiemencythere sp 1	1	0	1	0.20
Indeterminate	0	0	10	2.01
			496	

C4	12.50m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Loxoconcha cf *mioaustralis*	49	27	76	15.29
Parakrithella sp 1	63	7	70	14.08
Callistocythere sp 'zigzag'	47	11	58	11.67
Xestoleberis cf *cooki*	8	32	40	8.05
Neonesidea australis	5	26	31	6.24
Cletocythereis caudispinosa	3	21	24	4.83
?*Actinocythereis* sp	4	17	21	4.23
Foveoleberis ?minutissima	7	12	19	3.82
Bradleya praemckenziei	4	14	18	3.62
Cytherella sp	9	9	18	3.62
Quadracythere sp 2	4	13	17	3.42
Oculocytheropteron microfornix	5	9	14	2.82
Alataleberis sp	3	5	8	1.61
Callistocythere sp 'nodosa'	6	0	6	1.21
Loxoconcha sp 2	3	3	6	1.21
Paracypris sp	2	4	6	1.21
Platella parapunctata	5	1	6	1.21
Oculocytheropteron parawellmani	3	1	4	0.80
Arcacythere sp	2	1	3	0.60
Bradleya cf *kincaidiana*	0	3	3	0.60
Maddocksella sp	0	3	3	0.60
Pellucistoma sp	3	0	3	0.60
Argilloecia argilloeciaformis	1	1	2	0.40
Cytheralison pravacauda	2	0	2	0.40
Deltaleberis rugosapytta	1	1	2	0.40
Hemicytherura cf *pentagona*	1	1	2	0.40
Keijia sp 4	0	2	2	0.40
Krithe nitida	0	2	2	0.40
Paijenborchella solitaria ponticola	1	1	2	0.40
Paradoxostoma sp 1	0	2	2	0.40
Pontocyprella sp	1	1	2	0.40
Argilloecia australomiocenica	0	1	1	0.20
Callistocythere sp 4	0	1	1	0.20
Chapmanella flexicostata	0	1	1	0.20
Hermanites glyphica	0	1	1	0.20
Hermanites sp A	0	1	1	0.20
Hornibrookella sp	0	1	1	0.20
Kangarina macropus	1	0	1	0.20
Loxocythere sp 2	1	0	1	0.20
Macroscapha sp	0	1	1	0.20
Morkhovenia sp	1	0	1	0.20
Neobuntonia batesfordiense	0	1	1	0.20
Neonesidea chapmani	1	0	1	0.20
Polycope sp 2	1	0	1	0.20
Polycopsis? sp	0	1	1	0.20
Rhombonesidea sp A Neil 1992	0	1	1	0.20
Trachyleberis sp 1	0	1	1	0.20
Indeterminate	0	0	5	1.01
			493	

C3	12.85m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Loxoconcha cf *mioaustralis*	49	16	65	13.03
Callistocythere sp 'zigzag'	43	7	50	10.02
Oculocytheropteron microfornix	12	19	31	6.21
Parakrithella sp 1	27	4	31	6.21
Bradleya praemckenziei	5	23	28	5.61
Cletocythereis caudispinosa	9	19	28	5.61
Xestoleberis cf *cooki*	7	16	23	4.61
Neonesidea australis	19	3	22	4.41
?*Actinocythereis* sp	8	10	18	3.61
Alataleberis sp	6	12	18	3.61
Quadracythere sp 2	4	9	13	2.61
Paijenborchella solitaria ponticola	6	5	11	2.20
Bradleya cf *kincaidiana*	1	8	9	1.80
Callistocythere sp 3	9	0	9	1.80
Hemicytherura cf *pentagona*	8	0	8	1.60
Oculocytheropteron sp 1	2	6	8	1.60
Morkhovenia sp	0	7	7	1.40
Cytherella sp	0	5	5	1.00
Foveoleberis ?minutissima	2	3	5	1.00
?*Keijia* sp B Neil	4	1	5	1.00
Paradoxostoma sp 1	0	5	5	1.00
Semicytherura sp 2	0	5	5	1.00
Bythoceratina posterocrassa	4	0	4	0.80
Callistocythere sp 'nodosa'	4	0	4	0.80
Cytheralison pravacauda	1	3	4	0.80
Loxoconcha sp 2	3	1	4	0.80
Oculocytheropteron parawellmani	1	3	4	0.80
Semicytherura sp 4	4	0	4	0.80
Deltaleberis rugosapytta	0	3	3	0.60
Genus 3 sp	1	2	3	0.60
Hornibrookella sp	0	3	3	0.60
Krithe nitida	1	2	3	0.60
Platella parapunctata	3	0	3	0.60
Serratocythere? sp	1	2	3	0.60
Callistocythere sp 2	1	1	2	0.40
Hemicytherura sp	2	0	2	0.40
Hermanites glyphica	0	2	2	0.40
Loxoconcha cf *punctabella*	0	2	2	0.40
Macroscapha sp	2	0	2	0.40
Neobuntonia batesfordiense	0	2	2	0.40
Polycope sp 2	1	1	2	0.40
Saida sp 1 Warne 1987	2	0	2	0.40
Semicytherura sp A ? Neil	1	1	2	0.40
Arculacythereis? sp	0	1	1	0.20
Argilloecia argilloeciaformis	0	1	1	0.20
Argilloecia australomiocenica	0	1	1	0.20
Callistocythere sp 1	0	1	1	0.20
Callistocythere sp 4	0	1	1	0.20
Cytherelloidea intermedia	0	1	1	0.20

C3 cont'd				
Cytherelloidea sp A Neil 1992	0	1	1	0.20
Hermanites sp A	0	1	1	0.20
Kangarina macropus	1	0	1	0.20
Kangarina sp	0	1	1	0.20
Loxoconcha cf *mcgowrani*	1	0	1	0.20
Munseyella splendida	1	0	1	0.20
Paracypris sp	1	0	1	0.20
Polycope sp A Warne	1	0	1	0.20
Propontocypris sp 1	1	0	1	0.20
Semicytherura sp 1	1	0	1	0.20
Semicytherura sp 7	1	0	1	0.20
Semicytherura sp 8	1	0	1	0.20
Spinobradleya nodosa	0	1	1	0.20
Tenedocythere nuda	0	1	1	0.20
Indeterminate	0	0	4	0.80
			488	

C2	13.25m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Xestoleberis cf *cooki*	9	27	36	14.40
Neonesidea australis	7	23	30	12.00
Parakrithella sp 1	27	1	28	11.20
Loxoconcha cf *mioaustralis*	14	6	20	8.00
?*Keijia* sp B Neil	9	3	12	4.80
Callistocythere sp 'zigzag'	2	9	11	4.40
Oculocytheropteron microfornix	7	1	8	3.20
Cytherella sp	1	6	7	2.80
Bradleya praemckenziei	2	4	6	2.40
Callistocythere sp 'nodosa'	6	0	6	2.40
Parakrithella sp 2	6	0	6	2.40
Cletocythereis caudispinosa	0	5	5	2.00
Hornibrookella sp	0	5	5	2.00
?*Actinocythereis* sp	0	4	4	1.60
Loxoconcha sp 2	3	1	4	1.60
Cytheralison pravacauda	1	2	3	1.20
Hemicytherura cf *pentagona*	3	0	3	1.20
Hemicytherura cf *reekmani*	3	0	3	1.20
Morkhovenia sp	2	1	3	1.20
Paradoxostoma sp 1	1	2	3	1.20
Propontocypris sp 1	1	2	3	1.20
Callistocythere sp 3	1	1	2	0.80
Keijia sp A Neil	2	0	2	0.80
Semicytherura sp 4	2	0	2	0.80
Arculacythereis? sp	0	1	1	0.40
Bradleya cf *kincaidiana*	0	1	1	0.40
Bythoceratina posterocrassa	1	0	1	0.40
Callistocythere sp 1	1	0	1	0.40
Cytheralison corrugata	0	1	1	0.40
Deltaleberis rugosapytta	0	1	1	0.40
Foveoleberis ?minutissima	0	1	1	0.40
Genus 3 sp	0	1	1	0.40
Hermanites glyphica	0	1	1	0.40
Hermanites sp A	1	0	1	0.40
Kangarina macropus	1	0	1	0.40
Krithe nitida	0	1	1	0.40
Macroscapha sp	0	1	1	0.40
Neobuntonia batesfordiense	0	1	1	0.40
Neonesidea chapmani	0	1	1	0.40
Cytheropteron antipodum	1	0	1	0.40
Pellucistoma sp	1	0	1	0.40
Platella parapunctata	1	0	1	0.40
Quadracythere sp 2	1	0	1	0.40
Semicytherura sp 1	1	0	1	0.40
Serratocythere? sp	1	0	1	0.40
Indeterminate	0	0	5	2.00
			238	

C1	13.45m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Parakrithella sp 1	59	1	60	12.02
Loxoconcha cf *mioaustralis*	36	12	48	9.62
Quadracythere willungaensis	24	19	43	8.62
Xestoleberis cf *cooki*	15	25	40	8.02
Callistocythere sp 'zigzag'	18	9	27	5.41
?*Actinocythereis* sp	9	14	23	4.61
Oculocytheropteron microfornix	12	11	23	4.61
Bradleya praemckenziei	3	18	21	4.21
Neonesidea australis	10	11	21	4.21
Foveoleberis ?minutissima	7	11	18	3.61
?*Keijia* sp B Neil	8	4	12	2.40
Cletocythereis caudispinosa	4	7	11	2.20
Paijenborchella solitaria ponticola	7	3	10	2.00
Callistocythere sp 'nodosa'	6	2	8	1.60
Hornibrookella sp	0	8	8	1.60
Loxoconcha cf *punctabella*	7	1	8	1.60
Hemicytherura cf *pentagona*	7	0	7	1.40
Bradleya cf *kincaidiana*	1	5	6	1.20
Morkhovenia sp	0	6	6	1.20
Parakrithella sp 2	6	0	6	1.20
Quadracythere sp 2	3	3	6	1.20
Alataleberis sp	1	3	4	0.80
Cytherella sp	0	4	4	0.80
Oculocytheropteron parawellmani	4	0	4	0.80
Bythoceratina posterocrassa	1	2	3	0.60
Cytheralison pravacauda	1	2	3	0.60
Hermanites sp A	2	1	3	0.60
Krithe nitida	3	0	3	0.60
Neonesidea chapmani	1	2	3	0.60
Alatahermanites septarca?	0	2	2	0.40
Arculacythereis? sp 2	0	2	2	0.40
Bythoceratina sp	0	2	2	0.40
Callistocythere sp 2	1	1	2	0.40
Callistocythere sp 4	1	1	2	0.40
Deltaleberis rugosapytta	0	2	2	0.40
Hermanites glyphica	0	2	2	0.40
Macroscapha sp	1	1	2	0.40
Paradoxostoma sp 1	1	1	2	0.40
Polycope sp 2	2	0	2	0.40
Polycopsis? sp	2	0	2	0.40
Semicytherura sp 1	2	0	2	0.40
Semicytherura sp 4	2	0	2	0.40
Spinobradleya nodosa	1	1	2	0.40
Arcacythere sp	1	0	1	0.20
Argilloecia argilloeciaformis	1	0	1	0.20
Argilloecia australomiocenica	1	0	1	0.20
Bythoceratina sp C Neil 1992	1	0	1	0.20
Bythocypris sp 1	0	1	1	0.20
Bythocythere sp	1	O	1	0.20

C1 cont'd				
Callistocythere sp 3	0	1	1	0.20
Cytherelloidea australomiocenica	0	1	1	0.20
Dumontonia? sp	1	0	1	0.20
Hemicytherura cf *reekmani*	1	0	1	0.20
Hemicytherura sp	1	0	1	0.20
Loxoconcha cf *mcgowrani*	0	1	1	0.20
Macrocyprina? sp	1	0	1	0.20
Maddocksella sp	1	0	1	0.20
Microceratina sp 1	1	0	1	0.20
Neobuntonia batesfordiense	0	1	1	0.20
Nunana? sp	1	0	1	0.20
Cytheropteron antipodum	1	0	1	0.20
Oculocytheropteron sp 1	0	1	1	0.20
Platella parapunctata	1	0	1	0.20
Polycope melbournensis	1	0	1	0.20
Retibythere? sp	1	0	1	0.20
Saida sp 1 Warne 1987	1	0	1	0.20
Tenedocythere nuda	0	1	1	0.20
Xestoleberis? sp	1	0	1	0.20
Indeterminate	0	0	1	0.20
			493	

M1	14.00m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Loxoconcha cf *mioaustralis*	75	20	95	18.96
Callistocythere sp 'zigzag'	55	32	87	17.37
Parakrithella sp 1	48	8	56	11.18
Foveoleberis ?minutissima	2	35	37	7.39
Parakrithella sp 2	32	0	32	6.39
Xestoleberis cf *cooki*	8	18	26	5.19
Quadracythere willungaensis	16	9	25	4.99
?Actinocythereis sp	12	8	20	3.99
Argilloecia australomiocenica	8	8	16	3.19
Hermanites glyphica	3	13	16	3.19
Bradleya praemckenziei	2	11	13	2.59
Neonesidea chapmani	5	8	13	2.59
Oculocytheropteron microfornix	1	7	8	1.60
Neonesidea australis	1	4	5	1.00
Loxoconcha sp 2	3	1	4	0.80
Paijenborchella solitaria ponticola	2	2	4	0.80
Quadracythere sp 2	1	3	4	0.80
Alataleberis sp	1	2	3	0.60
Paradoxostoma sp 1	0	3	3	0.60
Bythoceratina sp	1	1	2	0.40
Cletocythereis caudispinosa	0	2	2	0.40
?Keijia sp B Neil	2	0	2	0.40
Pellucistoma sp	2	0	2	0.40
Arcacythere sp	0	1	1	0.20
Bythoceratina cf *fragilis*	0	1	1	0.20
Bythoceratina posterocrassa	1	0	1	0.20
Bythoceratina sp C Neil 1992	1	0	1	0.20
Bythocypris sp 1	1	0	1	0.20
?Callistocythere sp	0	1	1	0.20
Cytherelloidea australomiocenica	0	1	1	0.20
Cytherelloidea intermedia	0	1	1	0.20
Hemicytherura cf *reekmani*	1	0	1	0.20
Kangarina sp A	0	1	1	0.20
Maddocksella sp	0	1	1	0.20
Cytheropteron antipodum	1	0	1	0.20
Oculocytheropteron parawellmani	1	0	1	0.20
Cytheropteron? mchenryi	0	1	1	0.20
Platella parapunctata	1	0	1	0.20
?Pontocyprella sp	1	0	1	0.20
Propontocypris sp 2	1	0	1	0.20
Semicytherura sp 8	1	0	1	0.20
Indeterminate	0	0	7	1.40
			500	

M2	14.45m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Oculocytheropteron microfornix	19	58	77	15.49
Callistocythere sp 'zigzag'	53	14	67	13.48
Loxoconcha cf *mioaustralis*	32	24	56	11.27
Bradleya praemckenziei	3	18	21	4.23
Cletocythereis caudispinosa	2	13	15	3.02
?*Actinocythereis* sp	6	7	13	2.62
Alataleberis sp	8	4	12	2.41
Cytheralison pravacauda	6	5	11	2.21
Oculocytheropteron sp 1	5	6	11	2.21
Arcacythere sp	7	3	10	2.01
Paijenborchella solitaria ponticola	6	4	10	2.01
Xestoleberis cf *cooki*	5	5	10	2.01
Bradleya cf *kincaidiana*	4	5	9	1.81
Hemicytherura cf *pentagona*	9	0	9	1.81
Deltaleberis rugosapytta	2	6	8	1.61
Keijia sp 3	1	6	7	1.41
Keijia sp A Neil	1	6	7	1.41
Oculocytheropteron parawellmani	5	2	7	1.41
Callistocythere sp 3	3	3	6	1.21
Hermanites glyphica	0	6	6	1.21
Morkhovenia sp	3	3	6	1.21
Parakrithella sp 1	2	4	6	1.21
Bythoceratina sp	4	1	5	1.01
Hornibrookella sp	0	5	5	1.01
Parakrithella sp 2	5	0	5	1.01
Semicytherura sp 4	4	1	5	1.01
Arculacythereis? sp	0	4	4	0.80
Callistocythere sp 'nodosa'	3	1	4	0.80
Hermanites sp A	1	3	4	0.80
Neobuntonia batesfordiense	0	4	4	0.80
Argilloecia argilloeciaformis	1	2	3	0.60
Chapmanella flexicostata	0	3	3	0.60
Kangarina macropus	2	1	3	0.60
Loxocythere sp 2	3	0	3	0.60
Neonesidea australis	2	1	3	0.60
Quadracythere sp 2	2	1	3	0.60
Vandiemencythere sp 1	1	2	3	0.60
Bythoceratina posterocrassa	1	1	2	0.40
Callistocythere sp	1	1	2	0.40
Dumontonia? sp	1	1	2	0.40
Keijia sp 4	1	1	2	0.40
Loxoconcha cf *punctabella*	2	0	2	0.40
Paradoxostoma sp 1	0	2	2	0.40
Quadracythere willungaensis	1	1	2	0.40
Retibythere? sp	2	0	2	0.40
Semicytherura sp 2	1	1	2	0.40
Bythoceratina sp C Neil 1992	1	0	1	0.20
Callistocythere sp 1	1	0	1	0.20
Callistocythere sp 2	0	1	1	0.20

M2 cont'd			
Cytherella sp	0	1	1	0.20
Cytherelloidea intermedia	0	1	1	0.20
Cytherelloidea sp C Neil 1992	0	1	1	0.20
Cytheropteron? mchenryi	0	1	1	0.20
Eucytherura sp	1	0	1	0.20
Genus 17 sp	0	1	1	0.20
Hemicytherura cf *reekmani*	1	0	1	0.20
Hemicytherura sp	0	1	1	0.20
Kangarina sp	0	1	1	0.20
Loxoconcha cf *mcgowrani*	0	1	1	0.20
Loxocythere sp 1	0	1	1	0.20
Maddocksella sp	0	1	1	0.20
Maddocksella sp 2	0	1	1	0.20
Munseyella splendida	0	1	1	0.20
Cytheropteron antipodum	0	1	1	0.20
Pellucistoma sp	1	0	1	0.20
Platella parapunctata	0	1	1	0.20
Pseudeucythere parapubera	1	0	1	0.20
Saida sp 1 Warne 1987	1	0	1	0.20
Saida sp 2	1	0	1	0.20
Semicytherura sp 8	1	0	1	0.20
Indeterminate	0	0	6	1.21
			489	

M3	15.20m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Callistocythere sp 'zigzag'	77	23	100	20.12
Oculocytheropteron microfornix	23	56	79	15.90
Loxoconcha cf *mioaustralis*	40	6	46	9.26
Bradleya praemckenziei	7	26	33	6.64
Keijia sp 3	19	12	31	6.24
Parakrithella sp 1	22	1	23	4.63
Paijenborchella solitaria ponticola	14	4	18	3.62
?*Actinocythereis* sp	12	2	14	2.82
Keijia sp 4	10	3	13	2.62
Quadracythere sp 2	9	2	11	2.21
Cletocythereis caudispinosa	2	5	7	1.41
Oculocytheropteron parawellmani	5	2	7	1.41
Callistocythere sp 3	4	2	6	1.21
Neonesidea australis	2	4	6	1.21
Hemicytherura cf *pentagona*	5	0	5	1.01
Kangarina macropus	5	0	5	1.01
Morkhovenia sp	2	3	5	1.01
Pellucistoma sp	5	0	5	1.01
Semicytherura sp 1	3	1	4	0.80
Alataleberis sp	2	1	3	0.60
Deltaleberis rugosapytta	0	3	3	0.60
Hornibrookella sp	0	3	3	0.60
Keijia sp 6	1	2	3	0.60
Keijia sp A Neil	1	2	3	0.60
Loxocythere sp 2	3	0	3	0.60
Cytheropteron antipodum	2	1	3	0.60
Platella parapunctata	3	0	3	0.60
Semicytherura sp 8	3	0	3	0.60
Argilloecia australomiocenica	0	2	2	0.40
Bradleya cf *kincaidiana*	2	0	2	0.40
?*Callistocythere* sp	1	1	2	0.40
Callistocythere sp 'nodosa'	2	0	2	0.40
Chapmanella flexicostata	0	2	2	0.40
Cytherelloidea sp C Neil 1992	1	1	2	0.40
Munseyella splendida	2	0	2	0.40
Oculocytheropteron sp 1	0	2	2	0.40
Parakrithella sp 2	2	0	2	0.40
Pseudeucythere submytila	1	1	2	0.40
Argilloecia argilloeciaformis	0	1	1	0.20
Bythoceratina posterocrassa	1	0	1	0.20
Callistocythere sp 4	0	1	1	0.20
Cytherelloidea intermedia	0	1	1	0.20
Dumontonia? sp	1	0	1	0.20
Eucytherura sp	0	1	1	0.20
Foveoleberis ?minutissima	0	1	1	0.20
Genus 10 sp	1	0	1	0.20
Genus 17 sp	0	1	1	0.20
Loxoconcha cf *mcgowrani*	0	1	1	0.20
Loxoconcha cf *punctabella*	1	0	1	0.20

M3 cont'd				
Microceratina sp 2	1	0	1	0.20
Neobuntonla batesfordiense	1	0	1	0.20
Neonesidea chapmani	1	0	1	0.20
Paracytheridea sp 1	0	1	1	0.20
Saida sp 1	0	1	1	0.20
Semicytherura sp 4	0	1	1	0.20
Vandiemencythere sp 1	1	0	1	0.20
Indeterminate	0	0	6	1.21
			483	

M4	15.75m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Callistocythere sp 'zigzag'	63	8	71	14.40
Keijia sp 4	46	12	58	11.76
Oculocytheropteron microfornix	6	29	35	7.10
Bradleya praemckenziei	8	20	28	5.68
Keijia sp 3	15	10	25	5.07
Bradleya cf *kincaidiana*	6	16	22	4.46
Arcacythere sp	7	14	21	4.26
?*Actinocythereis* sp	11	2	13	2.64
Callistocythere sp 2	7	6	13	2.64
Cletocythereis caudispinosa	7	5	12	2.43
Morkhovenia sp	9	3	12	2.43
Paracytheridea sp 1	6	6	12	2.43
Loxoconcha cf *mioaustralis*	10	1	11	2.23
Arculacythereis? sp	2	7	9	1.83
Deltaleberis rugosapytta	6	3	9	1.83
Cytheralison pravacauda	2	6	8	1.62
Cytherella sp	2	6	8	1.62
Oculocytheropteron parawellmani	5	3	8	1.62
Paijenborchella solitaria ponticola	5	2	7	1.42
Alataleberis sp	2	3	5	1.01
Semicytherura sp 4	4	1	5	1.01
?*Callistocythere* sp	1	3	4	0.81
Genus 5 sp	0	4	4	0.81
Neobuntonia batesfordiense	2	2	4	0.81
Paradoxostoma sp 1	2	2	4	0.81
Platella parapunctata	4	0	4	0.81
Werribeeleberis sp	2	2	4	0.81
Callistocythere sp 'nodosa'	3	0	3	0.61
Callistocythere sp 3	3	0	3	0.61
Hemicytherura cf *pentagona*	3	0	3	0.61
Kangarina macropus	2	1	3	0.61
Keijia sp A Neil	3	0	3	0.61
Pseudeucythere pseudosubovalis	2	1	3	0.61
Cytherelloidea sp A Neil 1992	0	2	2	0.41
Genus 10 sp	2	0	2	0.41
Hornibrookella sp	0	2	2	0.41
Loxocythere sp 1	2	0	2	0.41
Semicytherura sp 2	1	1	2	0.41
Semicytherura sp 7	0	2	2	0.41
Semicytherura sp 8	2	0	2	0.41
Xestoleberis cf *cooki*	2	0	2	0.41
Bythoceratina sp	0	1	1	0.20
Callistocythere sp 1	1	0	1	0.20
Chapmanella flexicostata	0	1	1	0.20
Cytherelloidea australomiocenica	0	1	1	0.20
Cytheropteron? *mchenryi*	1	0	1	0.20
Dumontonia? sp	1	0	1	0.20
Eucythere? sp	1	0	1	0.20
Genus 17 sp	1	0	1	0.20

M4 cont'd				
Genus 3 sp	1	0	1	0.20
Hemicytherura cf *reekmani*	1	0	1	0.20
Hermanites sp A	0	1	1	0.20
Keijia sp 5	1	0	1	0.20
Microceratina sp 1	1	0	1	0.20
Cytheropteron antipodum	1	0	1	0.20
Oculocytheropteron sp 1	0	1	1	0.20
Oculocytheropteron sp 2	0	1	1	0.20
Pseudeucythere submytila	1	0	1	0.20
Quadracythere sp 2	1	0	1	0.20
Quadracythere willungaensis	0	1	1	0.20
Vandiemencythere sp 1	1	0	1	0.20
Indeterminate	0	0	11	2.23
			481	

M5	16.35m			
SPECIES	ADULTS	JUVENILES	TOTAL	% OF FAUNA
Keijia sp 3	38	17	55	22.00
Arcacythere sp	16	25	41	16.40
Arculacythereis? sp	7	12	19	7.60
Morkhovenia sp	15	1	16	6.40
Callistocythere sp 'zigzag'	12	2	14	5.60
?*Callistocythere* sp	7	4	11	4.40
?*Actinocythereis* sp	6	2	8	3.20
Keijia sp 4	8	0	8	3.20
Keijia sp 5	7	0	7	2.80
Oculocytheropteron sp 2	0	6	6	2.40
Genus 17 sp	2	3	5	2.00
Genus 5 sp	0	4	4	1.60
Pseudeucythere parapubera	2	2	4	1.60
Pseudeucythere pseudosubovalis	2	2	4	1.60
Pseudeucythere submytila	4	0	4	1.60
Bradleya cf *kincaidiana*	1	2	3	1.20
Cytheralison pravacauda	0	3	3	1.20
Werribeeleberis sp	2	1	3	1.20
Callistocythere sp 'nodosa'	2	0	2	0.80
Callistocythere sp 2	1	1	2	0.80
Cytherella sp	1	1	2	0.80
Genus 10 sp	1	1	2	0.80
Hemicytherura cf *pentagona*	2	0	2	0.80
Loxocythere sp 1	2	0	2	0.80
Neobuntonia batesfordiense	0	2	2	0.80
Oculocytheropteron microfornix	1	1	2	0.80
Paracytheridea sp 1	1	1	2	0.80
Semicytherura sp 8	2	0	2	0.80
Arculacythereid gen. indet sp A Neil 1992	0	1	1	0.40
Bradleya praemckenziei	0	1	1	0.40
Cletocythereis caudispinosa	1	0	1	0.40
Cytherelloidea sp A Neil 1992	0	1	1	0.40
Kangarina macropus	1	0	1	0.40
Loxoconcha cf *mcgowrani*	0	1	1	0.40
Loxoconcha cf *mioaustralis*	0	1	1	0.40
Oculocytheropteron parawellmani	1	0	1	0.40
Quadracythere sp 2	1	0	1	0.40
Indeterminate	0	0	6	2.40
			250	

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